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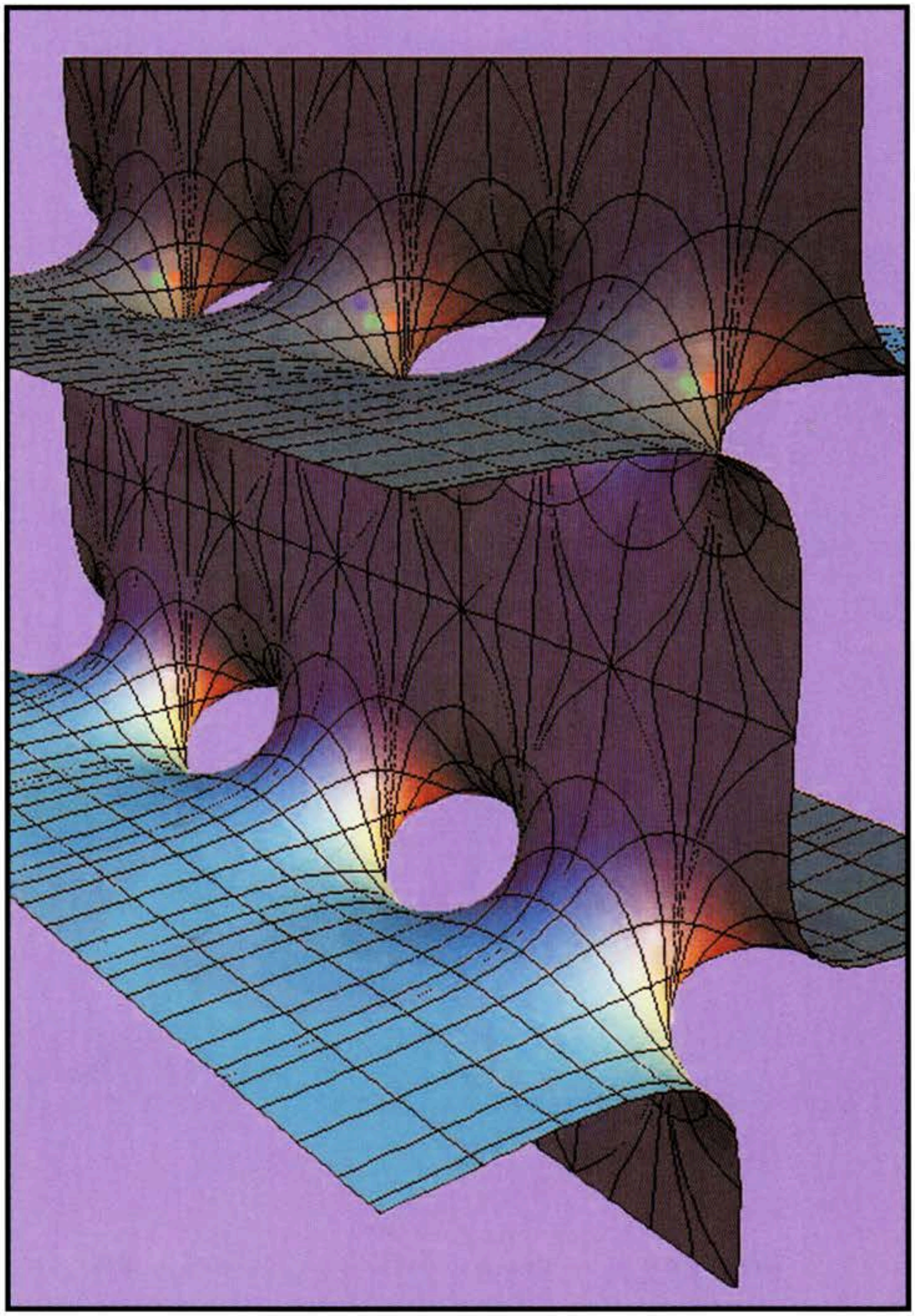
# Notices

## of the American Mathematical Society

June/July 1999

Volume 46, Number 6





*Karcher's JE Saddle Towers* *(See page 658)*

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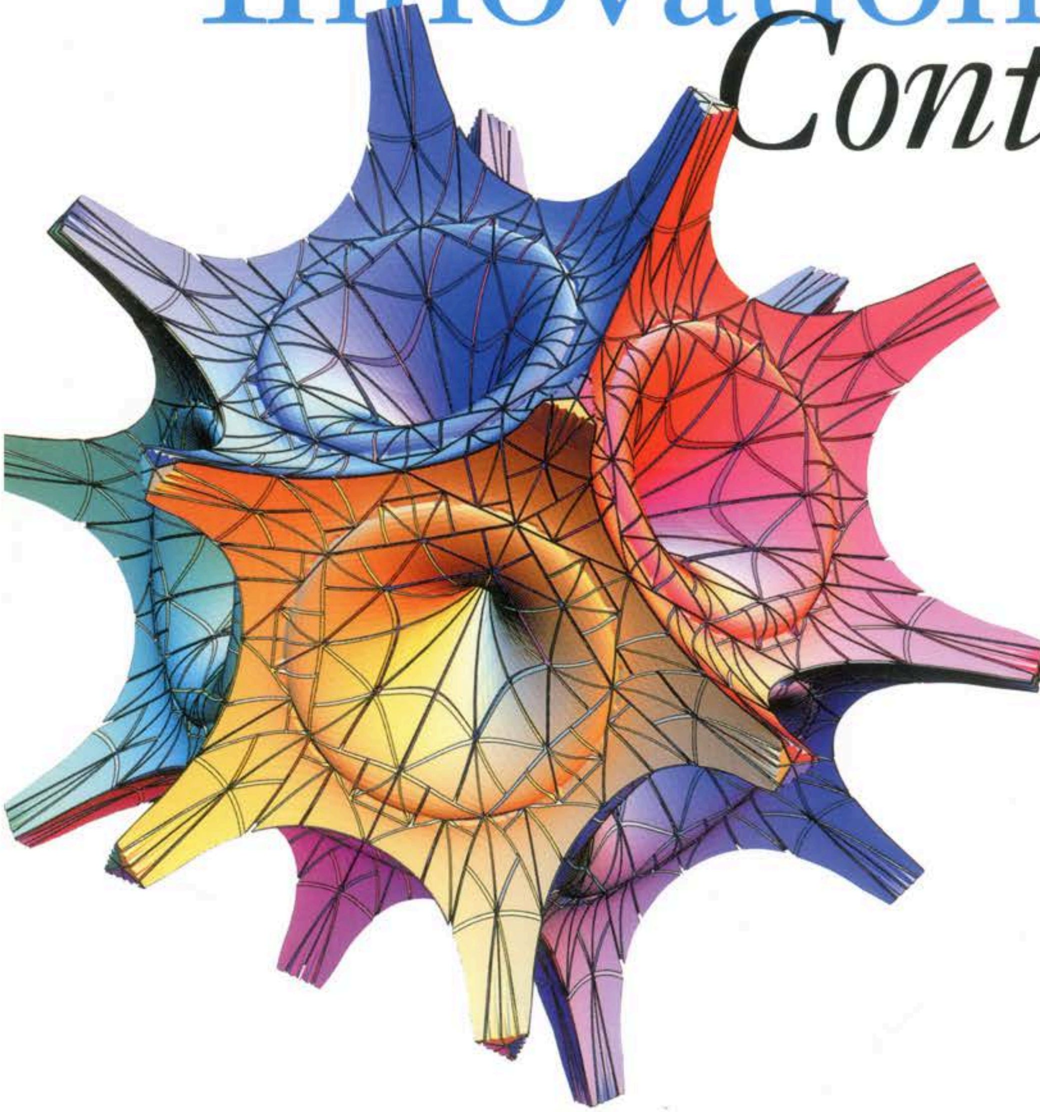

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# American Mathematical Society

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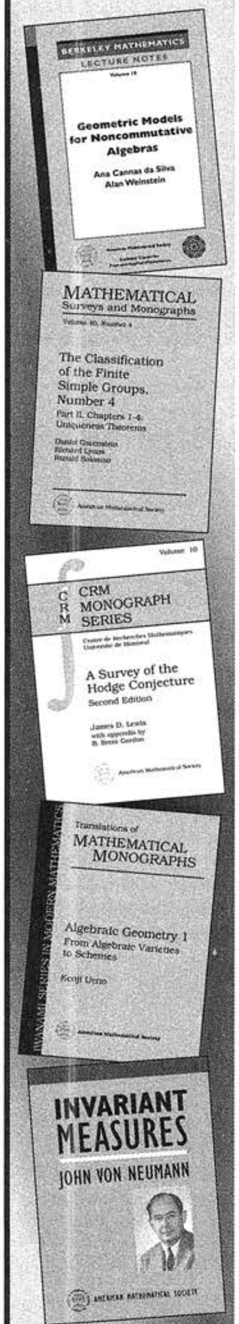


**Supplementary Reading**

## Geometric Models for Noncommutative Algebras

**Ana Cannas da Silva** and **Alan Weinstein**, *University of California, Berkeley*

The volume is based on a course, "Geometric Models for Noncommutative Algebras" taught by Professor Weinstein at Berkeley. Noncommutative geometry is the study of noncommutative algebras *as if* they were algebras of functions on spaces, for example, the commutative algebras associated to affine algebraic varieties, differentiable manifolds, topological spaces, and measure spaces. In this work, the authors discuss several types of geometric objects (in the usual sense of sets with structure) that are closely related to noncommutative algebras.

Central to the discussion are symplectic and Poisson manifolds, which arise when noncommutative algebras are obtained by deforming commutative algebras. The authors also give a detailed study of groupoids (whose role in noncommutative geometry has been stressed by Connes) as well as of Lie algebroids, the infinitesimal approximations to differentiable groupoids.

**Berkeley Mathematical Lecture Notes**, Volume 10; 1999; 184 pages; Softcover; ISBN 0-8218-0952-0; List $20; All AMS members $16; Order code BMLN/10NT96

## The Classification of the Finite Simple Groups, Number 4

### Part II, Chapters 1–4: Uniqueness Theorems

**Daniel Gorenstein** †, **Richard Lyons**, *Rutgers University, New Brunswick, NJ*, and **Ronald Solomon**, *Ohio State University, Columbus*

After three introductory volumes on the classification of the finite simple groups, (*Mathematical Surveys and Monographs*, Volumes 40.1, 40.2, and 40.3), the authors now start the proof of the classification theorem: They begin the analysis of a minimal counterexample $G$ to the theorem.

Two fundamental and powerful theorems in finite group theory are examined: the Bender-Suzuki theorem on strongly embedded subgroups (for which the non-character-theoretic part of the proof is provided) and Aschbacher's Component theorem. Included are new generalizations of Aschbacher's theorem which treat components of centralizers of involutions and $p$-components of centralizers of elements of order $p$ for arbitrary primes $p$.

This book, with background from sections of the previous volumes, presents in an approachable manner critical aspects of the classification of finite simple groups.

**Mathematical Surveys and Monographs**, Volume 40; 1999; 341 pages; Hardcover; ISBN 0-8218-1379-X; List $75; Individual member $45; Order code SURV/40.4NT96

**Independent Study**

## A Survey of the Hodge Conjecture

### Second Edition

**James D. Lewis**, *University of Alberta, Edmonton, Canada*

The book is a self-contained presentation, completely devoted to the Hodge conjecture and related topics. It includes many examples, and most results are completely proven or sketched. The motivation behind many of the results and background material is provided. This comprehensive approach to the book gives it a "user-friendly" style. Readers need not search elsewhere for various results. The book is suitable for use as a text for a topics course in algebraic geometry; includes an appendix by B. Brent Gordon.

**CRM Monograph Series**, Volume 10; 1999; 368 pages; Hardcover; ISBN 0-8218-0568-1; List $79; Individual member $47; Order code CRMM/10NT96

## Characters of Connected Lie Groups

**Lajos Pukanszky** †

This book adds to the great body of research that extends back to A. Weil and E. P. Wigner on the unitary representations of locally compact groups and their characters, i.e. the interplay between classical group theory and modern analysis. The groups studied here are the connected Lie groups of general type (not necessarily nilpotent or semisimple).

Final results reflect Kirillov's orbit method; in the case of groups that may be non-algebraic or non-type I, the method requires considerable sophistication. Methods used range from deep functional analysis (the theory of $C^*$-algebras, factors from F. J. Murray and J. von Neumann, and measure theory) to differential geometry (Lie groups and Hamiltonian actions).

**Mathematical Surveys and Monographs**; 1999; approximately 152 pages; Hardcover; ISBN 0-8218-1088-X; List $59; Individual member $35; Order code SURV-PUKANSZKYNT96

**Recommended Text**

## Algebraic Geometry I

### From Algebraic Varieties to Schemes

**Kenji Ueno**, *Kyoto University, Japan*

This is the first of three volumes on algebraic geometry.

The book begins with a description of the standard theory of algebraic varieties. Then, sheaves are introduced and studied, using as few prerequisites as possible. Once sheaf theory has been well understood, the next step is to see that an affine scheme can be defined in terms of a sheaf over the prime spectrum of a ring. By studying algebraic varieties over a field, Ueno demonstrates how the notion of schemes is necessary in algebraic geometry.

Ueno's book is a self-contained introduction to this important circle of ideas, assuming only a knowledge of basic notions from abstract algebra (such as prime ideals). It is suitable as a text for an introductory course on algebraic geometry.

**Translations of Mathematical Monographs** (*Iwanami Series in Modern Mathematics*); 1999; approximately 168 pages; Softcover; ISBN 0-8218-0862-1; List $25; All AMS members $20; Order code MMONO-UENO2NT96

**A Classic**

## Invariant Measures

**John von Neumann**

In 1940–1941 von Neumann lectured on invariant measures at the Institute for Advanced Study at Princeton. This book is essentially a written version of those lectures.

The lectures began with general measure theory and went on to Haar measure and some of its generalizations. Shizuo Kakutani was at the Institute that year, and he and von Neumann had many conversations on the subject. The conversations revealed facts and produced proofs. Quite a bit of the content of the course, especially toward the end, was discovered a few weeks before it appeared on the blackboard. The original version of these notes was prepared by Paul Halmos, von Neumann's assistant that year. Von Neumann read the handwritten version before it went to the typist and sometimes scribbled comments on the margins; he rewrote most of Chapter 6. This book is the first published version of the original notes.

1999; approximately 144 pages; Softcover; ISBN 0-8218-0912-1; List $39; All AMS members $31; Order code INMEASNT96

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**P. Falb,** Brown University, Providence, RI

This book gives, together with Part I, an introduction to the ideas of algebraic geometry in the motivated context of system theory, specifically written to serve the needs of researchers and students of systems, control, and applied mathematics. Part I contains a clear presentation, with an applied flavor, of the core ideas in the algebro-geometric treatment of scalar linear system theory, while Part II extends the theory to multivariable systems. Without sacrificing mathematical rigor, the author makes the basic ideas of algebraic geometry accessible to engineers and applied scientists, and he puts the emphasis on constructive methods and clarity rather than on abstraction. Familiarity with Part I is helpful, but not essential, since a considerable amount of relevant material is included here. Prerequisites are the basics of linear algebra, some simple topological notions, the elementary properties of groups, rings, and fields, and a basic course in linear systems. Exercises are an integral part of the text, and five appendices contain further supplementary material.

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1999 368 pp. Hardcover ISBN 0-8176-4113-0

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### Methods of Algebraic Geometry in Control Theory: Part I

*Scalar Linear Systems and Affine Algebraic Geometry*

**P. Falb,** Brown University, Providence, RI

Systems and Control: Foundations and Applications, Vol. 4

1990 202 pp. Hardcover ISBN 0-8176-3454-1

**$51.50**

### Analysis and Geometry in Several Complex Variables

**G. Komatsu,** Osaka University, Japan & **M. Kuranishi,** Columbia University, New York, NY (Eds.)

This volume is an outgrowth of the 40th Taniguchi Symposium "Analysis and Geometry in Several Complex Variables" held in Katata, Japan. Highlighted are the most recent developments in complex analysis related to PDE techniques and differential geometry such as the Bergman kernel/projection and the CR structure.

**Contributors:** D. Catlin, M. Eastwood, C.L. Fefferman, K. Hirachi, G. Komatsu, J.J. Kohn, M. Kuranishi, J. Michel, K. Miyajima, S. Nayatani, T. Ohsawa, M.-C. Shaw, H. Tsuji, S.M. Webster, K. Yamaguchi

Trends in Mathematics

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*Centro Stefano Franscini, Ascona, September 1996*

**R.C. Dalang,** EPF Lausanne, Switzerland, **M. Dozzi,** Université Henri Poincaré, Vandoeuvre-les-Nancy, France & **F. Russo,** Université Paris 13, Paris. France (Eds.)

Progress in Probability, Vol. 45

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*Euroconference in Essen (Germany), April 1-5, 1999*

**P. Dräxler,** Universität Bielefeld, **G.O. Michler,** Universität GH Essen & **C.M. Ringel,** Universität Bielefeld, all, Germany (Eds.)

An outgrowth of the Euroconference "Computational Methods for Representations of Groups and Algebras" held at Essen University, Germany, in 1997, the papers presented in this volume provide a survey of general theoretical and computational methods and recent advances in the representation theory of groups and algebras.

**Contributors:** M. Barot, J.F. Carlson, A.M. Choen, S. Cojacaru, G. Cooperman, W. Decker, P. Dowbor, P. Dräxler, F. du Cloux, P. Fleischmann, H. Gollan, E. Green, G.-M. Greuel, G. Havas, H. von Höhne, D. Holt, T. Hübner, T. de Jong, G. Kemper, W. Lempken, H. Lenzing, R. de Man, G.O. Michler, J. Müller, R. Nörenberg, S. Oviensko, J.A. de la Peña, G. Pfister, A. Podoplelov, J. Rosenboom, C. Sims, A. Steel, V. Ufnarovski, M. Weller, R.A Wilson

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*QMath7Conference, Prague, June 22-26, 1998*

**J. Dittrich, P. Exner & M. Tater,** all, Academy of Science, Rez near Prague, Czech Republic (Eds.)

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*June/July 1999*

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# Notices

of the American Mathematical Society

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## From the Executive Editor of MR

# The Evolution of *Mathematical Reviews*: Where Now?

Next January *Mathematical Reviews* (MR) will be celebrating its sixtieth anniversary. A glance through the library shelves containing the volumes of MR since 1940 would appear to indicate that not much has changed over the years. There is still the familiar matte orange cover, the 9" × 12" trim size, and inside the same review format. Although of course there have been changes—for example, in classification schemes, in typography, and, most conspicuously, in sheer size (the 1999 volume of MR will contain 25 times as many reviews as the 1940 volume)—the essential editorial policy has remained the same. But this is only half the story.

As we are all aware, there have been dramatic changes in scholarly publishing over the last decade or so. To enumerate just some of those changes: (1) More and more journals are becoming available to subscribers in both paper and electronic Web-based versions. (2) New journals are often available only electronically. (3) Authors now routinely submit articles in publishable format so that the time lag between acceptance of an article and (electronic) publication can be essentially zero. (4) Scholars who used to circulate a limited number of paper preprints to colleagues now make their preprints freely available on preprint servers. (5) Moreover, published material may include one or more new formats: CD-ROM, videocassette,….

MR has been among the first to take advantage of the new technologies. In the early 1980s MR was made available (as MathSci) through a number of online vendors, and since the late 1980s the data has been available in CD-ROM format as MathSci Disc. Finally, in 1996, MathSciNet was launched on the Web; it is now, for many users, the format of choice for access to MR data. Soon MathSciNet will contain the complete archive of reviews in MR, in TeX format, from 1940 to the present.

The ready availability of so much data on MathSciNet, together with tools for complex searching and multiple links both within MathSciNet (e.g., forward and backward citations, lists of all papers by a given author, tables of contents of journal issues) and to outside sites (e.g., original articles), has revolutionized the way MR data is used.

It is time now to step back and ask what if any editorial changes might be desirable in the new environment. What more might we provide editorially to the underlying database to take advantage of the Web tools and thus enhance its value? Are evaluative reviews even more important as the literature grows and it becomes increasingly difficult for an individual to look at all relevant original articles? Or, as more and more abstracts become freely available, is it more important to use our resources to expand the scope of the database and list more items? Should reviewers be encouraged to add more relevant references to reviews and/or should reference lists from the original articles be captured? Would the addition of survey articles to show how a field has developed or show how fields interconnect (in each case liberally sprinkled with references) greatly enhance the value of the MR database? We need your help to suggest and advise on ways we can improve the service MR provides, and so in 1999 we are conducting a survey of users to find out how they are accessing and using MR data and the directions in which they would like the editorial policy to move.

With crucial contributions from reviewers from around the world, the work of MR's own dedicated staff, and valuable input from users, MR expects to maintain and improve its database in the years to come. The goal, however, will remain unchanged: to provide a high-quality database that gives comprehensive coverage of mathematical research and serves as a focal point for all mathematicians as they navigate the mathematical literature.

—*Jane E. Kister*

# Commentary

## In My Opinion

# Ask and You Shall Receive …

The job market continues to be dreadful. But, like reformed evangelists, we are all whistling in the dark—hoping that the bogie man will go away.

There are some points of light. At the San Antonio meetings, 400 jobs were offered (up from 250 last year), and the number of applicants was down. A recent issue of the *Chronicle of Higher Education* reports "An Upturn in the Job Market". The article cautions against reckless optimism. Tenure-track positions to replace recent attrition will not recur every year. Some universities are benefiting from the current strong economy. The long-term prospects are unclear. My view is that the American attitude toward universities and their denizens has changed. The academic profession seems to be downsizing, and young people are feeling the ill effects.

In the 1980s we all believed optimistic predictions for the 1990s: (i) those hired in the Sputnik era would retire, (ii) the children of baby boomers would go to college, (iii) the growing technological sector would demand mathematically trained people.

What happened? The flow of fresh Ph.D.'s into the job market has been affected by an influx of expatriates from Eastern Europe and elsewhere. That influx has subsided, but its effects remain. Many decided not to retire. Many children of baby boomers are not going to college, at least not right away. The technological sector needs people with new skills, such as programming in Java and C++. These demands create good jobs for which mathematicians can qualify. They are not what those predicting prosperity had in mind. Indications are that the technological sector needs more people who can read and write proper English than people who can program.

In 1996 the AMS reported that there were 1,154 new Ph.D.'s. Of these, 122 found jobs in the Group I (top 50) institutions, 47 landed jobs in Group II, 28 in Group III, and 15 in Group IV. The total of jobs at Ph.D.-granting institutions was less than 20 percent of applicants. That figure includes all instructorships at all institutions.

And so we face a brave new world. By anecdotal evidence, Ph.D.'s from even the top math departments have had difficulty landing jobs: late in the season, less than 50 percent typically have found a position. One might ask: if people do not want to hire the top Ph.D.'s, then whom *do* they want to hire?

What can senior mathematicians do? We could tell our graduate students at the outset that there are not many jobs. Or we can just continue to grind out new Ph.D.'s and ignore the problem. Or we can try to effect some change. Good mathematics is not the sole province of the Group I math departments. Good, vibrant mathematics is going on in virtually every math department, both Ph.D.-granting and not. As we saw twenty years ago, a hard time for the top departments can be a time of growth for others. There lies opportunity for job seekers.

We can steer students toward curricula that will train them for other choices. Courses in statistics, operating systems, applied linear algebra, operations research, and applied PDE can often lead to gainful and rewarding employment.

Non-Ph.D.-granting institutions have the majority of teaching jobs. This year some such colleges have five tenure-track openings. There are worthwhile jobs at the National Security Agency, at Boeing and Texas Instruments, at consulting companies like Daniel Wagner, at software firms, at genetics labs, in medical schools, and at actuarial firms.

If students think that the only future is at a Group I university, then most will be disappointed. If students instead see that mathematics is a smorgasbord of activities, only some of them academic, then they will be better equipped. If graduate programs provide internships during training, then students will be part of the job market before they leave school.

Senior faculty *could* rethink the curriculum. We should not supplant the current, time-tested course of study; rather, we should enhance it. We should emphasize the importance of good teaching. I do not have the skills to train my students in Java or in operations research. I can, however, make myself aware of the market and teach students what opportunities are available.

Senior faculty have tenure so that they can plan the future of math departments. As they set the curriculum, hire new faculty, and mentor young people, they can also teach the tools to deal with the future: (i) they can show that there are many rewarding roads to being a successful mathematician, (ii) they can maintain a network with former students and have them counsel current students, (iii) they can foster in the profession and among students awareness of the opportunities that are available.

We have arguably been living in a fool's paradise. Each year we have returned from a lambent summer of travel and introspection with the words "I wonder how much hiring we will do this year?" on our lips. In ten years we may instead be saying, "I wonder what our teaching load will be this year?" If indeed the profession of academic mathematics is restructuring, then it will not only be young job seekers who are affected. Even tenured, senior people will feel the pain. If we want to control our future, then we had better learn to understand it.

*—Steven G. Krantz*
*Associate Editor*

# Letters to the Editor

## Buying the Bois-Marie Estate

In the article "The IHÉS at Forty" (*Notices,* March 1999), it is stated that in 1962 the IHÉS bought the Bois-Marie estate, where the Institute's scientific buildings have been located ever since, from the French state. This is erroneous. The domain was the property of the Comar family, and it was purchased from them for the sum of 1,500,000 FF, paid partly directly from the Institute's budget and partly thanks to a seventeen-year loan from the Caisse des Dépôts et Consignations, a major state bank in France specializing in real estate. The portion of the domain which the Institute had to give up in 1967 for the construction of a roundabout at one end of the park represents a little less than 10% of the whole area. The IHÉS was paid 70,000 FF by the state, i.e., approximately 1/20 of the total price paid five years earlier. This is said to rectify the false allegation that through this operation the state paid a compensation to the Institute that exceeded the purchase price.

*—Jean-Pierre Bourguignon*
*Director*
*Institut des Hautes Études Scientifiques*

(Received March 9, 1999)

## Browder's Comments on Graduate Education

Felix Browder's comments on graduate education in mathematics in the March 1999 issue bring me back to my own experiences of forty years ago. After a Ph.D. in differential geometry at Princeton, a postdoc year at Chicago, and three years as an instructor at Harvard, I joined a group of electrical engineers at Lincoln Laboratory of MIT and spent the next years in their world. The mathematics of mechanics and control theory was of most immediate relevance to the problems studied by that group; needless to say, I had received no explicit training in those areas, which were considered in the mathematical circles from which I came as dead, nineteenth-century stuff. However, I did find the geometric mathematics I had learned—or studied on my own—to be of extreme usefulness, which contributed much to the future evolution of those fields. This taste of freedom from the dogmas of the avante-garde research mathematics of that day has determined my own idiosyncratic career.

I am now a research affiliate in the Artificial Intelligence Lab of MIT, where I can see many interesting and important problems whose solution could use the attention of mathematicians trained to the level I was forty years ago. Again, needless to say, I don't see them appear! Part of the problem is that the funding agencies in Washington have no understanding or appreciation of what well-trained mathematicians might contribute. Another part is that, as Browder admits, the AMS (among others) has done very little to build up a constituency.

*—Robert Hermann*
*Brookline, MA*

(Received February 18, 1999)

## Comments on "Science Wars" Citations

In the science wars it appears from the letter of Theo Theocharis [*Notices,* February 1999] that we have yet to attain an *All Quiet on the Western Front.* The book *Impostures Intellectuelles* by Alan Sokal and Jean Bricmont, to which the letter refers, consolidates the territory swept by physicist Sokal in his (now famous) breathtaking one-man foray into enemy lines ["Transgressing the boundaries: Toward a transformative hermeneutics of quantum gravity", *Social Text* **46/47** (1996), 217–252]. (Sokal, apparently, was provoked beyond restraint by the dark forces of postmodernism—antiscientism/pseudoscientism/subscientism—and embarked on a sort of academic *Saving Private Ryan.*)

The current counterattack by Theocharis is a reprise of an earlier but recent salient by Mara Beller ["The Sokal hoax: at whom are we laughing?", *Physics Today* (September 1998), 29–34]. Beller offered quotations by some eminent physicists (Bohn, Pauli, Heisenberg, ...) from the early days of quantum theory. Some of these quotations are indeed peculiar and show that their authors apparently were so bedazzled by the successes of the weird theory which they were creating that they wanted to apply it beyond physics—to social and psychological constructs. Beller asks, What is so different about such wild ideas and the quack pronouncements of the postmodernists?

Now Theocharis takes up the refrain, offers quotations and the devil-made-me-do-it argument: the postmodernists derived their silly ideas under the influence of "philosophical utterances of earlier mathematicians and scientists (mostly quantum physicists)." And finally there is a rebuke to the proscientists for being silliness-critical—"Before any mathematicians and scientists (and especially quantum physicists) dare to accuse any others...of intellectual imposture, they ought first to put their own houses in order."

Beller targeted only physicists, but, curiously, Theocharis has added two mathematicians to the mix—G. H. Hardy and Bertrand Russell. His particular quotations from physicists don't have the apply-quantum-theory-to-social-science focus that Beller's selection has. Instead, most of them sound more like tongue-in-cheek aphorisms meant for an in-house audience and are anything but postmodernist impostures—they are candid declarations in varying degrees of irony and discouragement.

As for the mathematicians who are quoted by Theocharis, Hardy's blameless idealism (that beautiful mathematics is desirable and ugly mathematics is undesirable) is puzzlingly irrelevant. Russell's remark (that in mathematics we never know what we are talking about, nor whether what we are saying is true) deserves context. This was no mere Wildean quip: Russell himself had contributed a notable addition (the set of all sets which do not contain themselves) to the collection of self-referential paradoxes which beset the early foundations theory and, moreover, by pointing out that this paradox was derivable from the text, had undermined Frege's book on foundations. And, as if these were not enough to show that there can be an unsettling psychological insecurity in the pursuit of understanding, Russell himself [*The Autobiography of Bertrand Russell 1914–1944*, Little, Brown & Co., 1951] had been exposed to a withering critique from Wittgenstein: "Do you remember...I wrote about Theory of Knowledge, which Wittgenstein criticized with the greatest severity? His criticism...was an event of first-rate importance in my life, and affected everything I have done since. I saw he was right, and I saw that I could not hope ever again to do fundamental work in philosophy." No imposture here. Just simple candor.

*—Robert M. Baer*
*Mill Valley, CA*

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### Why the Sky Is Falling

This letter is inspired by the article "The Sky Is Falling" by Solomon Garfunkel and Gail Young (*Notices*, February 1998). Their piece was a siren call to the mathematics community that we are losing students in our discipline at an alarming rate; what follows is my opinion as to why in large measure this has occurred. Hopefully this will elicit responses from the *Notices* readership, who may be in possession of even more recent data that support this apparent emerging trend.

I teach at Washburn University in Topeka, Kansas, and our enrollment in mathematics courses has dropped off especially in upper-division courses in recent years. Some brief background on Washburn: We support B.A. and B.S. programs in pure mathematics, actuarial science, and mathematics for secondary teaching. Total enrollment at Washburn exceeds 6,000 students, including those in a few master's programs supported here along with the law school. Our "normal" number of majors is about 35 to 40. That has fallen off to the point where many of our upper-division courses have only been managing to attract 3 to 6 students. Of those majoring in pure mathematics, most are majoring in computer science with mathematics as their secondary major.

Let's focus on the period beginning in the mid-1980s to now. The biggest reason I can see for the drop-off in students in math courses, particularly at the upper-division level, is the boom in the computing industry. Just take a look at catalogs of course offerings in the area of computer science today—majors in CIS, MIS, Network Management, and so forth simply did not exist in 1985. Many of these degrees are business-oriented, so they require some course work in business and finance. Some of these computer information graduates need to take no more than college algebra or perhaps a business calculus course to fulfill their mathematics requirements.

It is quite possible for today's students to enroll in these major programs and compete successfully in their classes even if their problem-solving skills are less than stellar. These tracks are very attractive, since internship opportunities are seemingly boundless and employment prospects are all but guaranteed. And of course I do not need to point out that starting salaries for these graduates are most impressive indeed! Last spring, the "average" good computer science student graduating from Washburn landed a position starting at $40,000 to $42,000 in the Topeka and Kansas City areas. By "average" I mean a student with an overall GPA between 3.0 and 3.5 on a 4.0 scale (higher in their major courses) and relevant work experience. Not bad to be twenty-two years old and starting out $5,000 to $10,000 higher than what many of your former professors currently make! (For more about current salaries in the computing industry, see the February 1, 1999, issue of *Newsweek*, page 44.)

So the reason for the drop-off in enrollment in upper-division mathematics courses is not so surprising in light of this. Why should someone struggle mightily learning to prove theorems when future employment prospects in mathematics pale in comparison with those in computing? Why not go into some aspect of computer work, where the jobs exist in abundance and the pay is unbeatable? The most recent information we have at Washburn suggests that our actuarial science graduates start at $35,000 if they have passed two exams of the Society of Actuaries (SOA). While they do get positions readily, their starting pay is several thousand dollars per year less than many CIS graduates, plus they must endure the rigors of the SOA examination series.

Let us also address the issue of why precalculus enrollment has been on the upswing while enrollments in remedial courses are down. At Washburn (and at the two institutions where I previously taught full time), students have the option of "waiving" their way out of the recommended mathematics course to take the course they choose. I know this is only anecdotal evidence, but an ever-increasing number of students are waiving out of a noncredit developmental course in favor of a for-credit course such as college algebra to fulfill their college or university mathematics requirement. Further exacerbating this situation is advisors in other departments who encourage their advisees to enroll in for-credit mathematics courses to "get them out of the way."

It appears that the drop-off in calculus enrollment stems from two sources. First, in the mid-1980s the average "good" student came in to college prepared to take calculus. Arguably the average "good" student today is at best ready for a precalculus course in college algebra or trigonometry; the norm has become the exception, unfortunately. Second, I have noted that fewer students seem to want to challenge themselves by taking calculus courses these days. Many who have the talent and background to successfully complete at least one course in the calculus sequence will indicate that they do not require it for their majors and opt to take a precalculus course instead.

So what can we do, individually and collectively, to stem the tide of our students disappearing from our mathematics classes? At Washburn we have undertaken a recruiting effort to attract not just those we hope will go on to major in mathematics, but also those who could do well in calculus and beyond and obtain a minor in math. Eventually we expect to work closely with faculty in computer science to coax them into encouraging more of their students to take more math. We could easily abdicate this responsibility to our offices of admissions and say that recruiting is their job, not ours. To some extent I agree with this, but as Garfunkel and Young point out, the stakes are now far too high to ignore this situation any longer.

*—Kevin Charlwood*
*Washburn University*

(Received March 31, 1999)

## Editorial Efficiency Is an Ethical Issue

I am writing to express my concern at recent problems I and others have experienced with the timely refereeing and publishing of mathematical articles.

It appears that the publish-or-perish syndrome is more intense than ever throughout the Western world, and probably elsewhere, and there is ever-increasing pressure from our administrators to publish. That being the case, it is more damaging than ever to have the refereeing and publishing of one's articles held up, for whatever reason.

I believe that the following two examples are symptomatic of a widespread malaise:

1) Two articles I submitted to a journal in September 1996 were not evaluated until May 1998. A colleague who submitted to another journal in January 1997 was notified in February 1999 that his article was rejected. I have recently heard tell of other examples where several years were required to evaluate articles.

2) One of my papers accepted for publication in 1995 has still to be published. When the article was accepted, another author of the paper was told by the editor that it would appear in late 1996.

The first examples concern journals run by the American Mathematical Society, while the second involves a commercially-published journal. Thus, unlike the cost problem, this concerns all sorts of mathematics journals.

I recognise that such things happen sometimes and that sometimes they are hard to avoid. A famous paper in Banach space theory took many years to referee because of its difficulty. But the papers submitted to the AMS journal above are not impossible to understand. These delays appear to be in contrast with the Society's stated policy of promoting "quick refereeing and timely publication". Similarly, the commercially-published journal above is not alone in the length of its backlog.

There are a number of problems involved here. First of all, the same "quality" managers who push for greater output give no credit whatsoever for the refereeing of papers or for the administrative work involved in editing. Publishing constraints, such as the number of pages in an issue, often militate against the publication of longer papers. But surely there are some ways in which we could do better. In particular, there appear to be several journals where the whim of the managing editor is more important than time-since-submission when the decisions about what to put in the next issue are being made. I have seen a letter from an editor of a well-known journal which indicates clearly that his whim is also extremely important in the refereeing process.

I believe that the Society, as the preeminent international professional society of mathematicians, should take the lead and tackle this problem. I would like to propose a number of issues for discussion, and I hope that some of these lead to concrete action.

1) The Society's statement of ethical principles contains guidelines about editorial practice. These are vague: is a three-year period "timely refereeing" or not? I believe not, but am willing to be convinced otherwise by a cogent argument. In any case, more precise indicators are surely appropriate. Similarly, "timely publication" is too vague.

2) The Society might bring pressure to bear on its own editors to apply these principles. Equally, via a questionnaire, it might apply a little pressure on other editors; even requesting a clear statement of editorial policy might be helpful in some cases.

3) The Society might consider whether its members or its authors have any responsibilities. If one submits five papers for publication each year, should one be prepared to referee a similar number of papers in a similar period of time?

Finally, let me point out an alternative for other frustrated authors. The *Bulletin of the Australian Mathematical Society*, of which I am editor, offers rapid publication. It is extremely unusual for the time between submission and refereeing to exceed six months, or for the time between submission and publication to exceed one year. Since we work fast, we sometimes get it wrong—but we never damage our aspiring authors by holding their manuscripts for two years and then rejecting them. Nor do we publish a large number of false proofs. At least some of the delays we authors experience are due to arguably excessive care being taken by editors who are told to seek several reports and only accept very high-quality work. I would argue that most other journals should aim to beat the *Bulletin*'s ethical standards as well as our *Science Citation Index* Impact Factor.

*—Michael Cowling*
*University of New South Wales*

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**Editor's Note:** The *Notices* annually publishes a list "Backlog of Mathematics Research Journals". The 1998 edition of this list appeared in September 1998, and the 1999 edition is planned for the September 1999 issue.

# André Weil: Memories of a Long Friendship

*Henri Cartan*

**Editor's Note:** André Weil died in August 1998. This is one of a short series of articles about Weil or his mathematics. The first articles in the series appeared in the April 1999 issue.

I met André Weil for the first time when I entered the École Normale in November 1923. He was then "carré",[1] having entered one year earlier at the age of sixteen (the director of the École, Gustave Lanson, reproached him then for wearing short pants). In the entering class with André Weil figured notably Jean Delsarte, who was to become dean of the Faculté des Sciences at Nancy and was to create there one of the best mathematics centers in France, and who was also to play an important role at the core of the Bourbaki group. There was also Yves Rocard, who after the war was to create and develop the physics department at the École Normale. Delsarte and Rocard were among those with whom André Weil associated. I knew that Weil was considered as a rather exceptional being, but I did not know that during his first year he had read Riemann and finished all his examinations. Finishing the École one year before me in 1925, he was too young to do his military service and obtained a grant to spend a year in Rome, where Vito Volterra was his advisor. He spent the following year in Germany, with a Rockefeller grant that Volterra had obtained for him, and became friends with the great mathematicians of the time, despite his being younger than they.

Upon his return to Paris, he wrote his thesis in algebraic geometry; in his *Souvenirs d'Apprentissage*[2] he tells how he found someone to write the report for this thesis, whose subject was then foreign to the interests of French mathematicians. He defended it in 1928. For my part I had prepared a thesis on normal families under the direction of Paul Montel; I defended it in December 1928. At the time I had been teaching mathematics in the Lycée de Caen since the month of October 1928. In this period positions in university teaching were few in number, and appointments were made at any time of the year. Thus it was that a position of "chargé de cours" was announced for the month of April 1929 at the Faculté des Sciences in Strasbourg, and Weil and I each had the idea of being a candidate. We were thus in competition; I had a priori an advantage, not because of personal merit, but because Georges Valiron, professor at Strasbourg, was interested more in functions of one complex variable than in the works of André Weil.

*Thus was born the Bourbaki group...*

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[1]*In the language of the École Normale, a "carré" is a second-year student.*

[2]*A. Weil,* Souvenirs d'Apprentissage, *Birkhäuser, Basel, 1991; English translation by Jennifer Gage,* The Apprenticeship of a Mathematician, *Birkhäuser, Basel, 1992.*

Photograph courtesy of Sylvie Weil.

**Formal photo of André Weil at the Institute for Advanced Study, about 1986.**

That is what happened. Weil did not mind, and thought then of going off to India (he had learned Sanskrit starting at the time of his *taupe* class[3]; and Sylvain Levi was encouraging him to accept a post there). In fact, it was in 1930 that he left for Aligarh, where he undertook the responsibility of reforming from top to bottom the teaching of mathematics. Rough task, which he brought to life for me in his letters.

When he returned to France in 1932, it was to accept a position as chargé de cours in Marseille. As for me, after a break for two years at the Faculté des Sciences in Lille, I had returned to Strasbourg at the end of 1931; I had pleasant memories of some weeks that I had spent there in 1929, and I encouraged Weil to come join me there. It is what he did upon his return in 1933, and as a result I stopped being the youngest member of the faculty. Here we were, both teaching in the large building in the university quadrangle behind the statue of Pasteur. But that lasted only two months, because at the beginning of January I was admitted to the hospital on the Boulevard Clemenceau with typhoid fever, whose complications kept me from teaching until the end of the school year. But I will not forget the comforting visits that he made to me in the hospital.

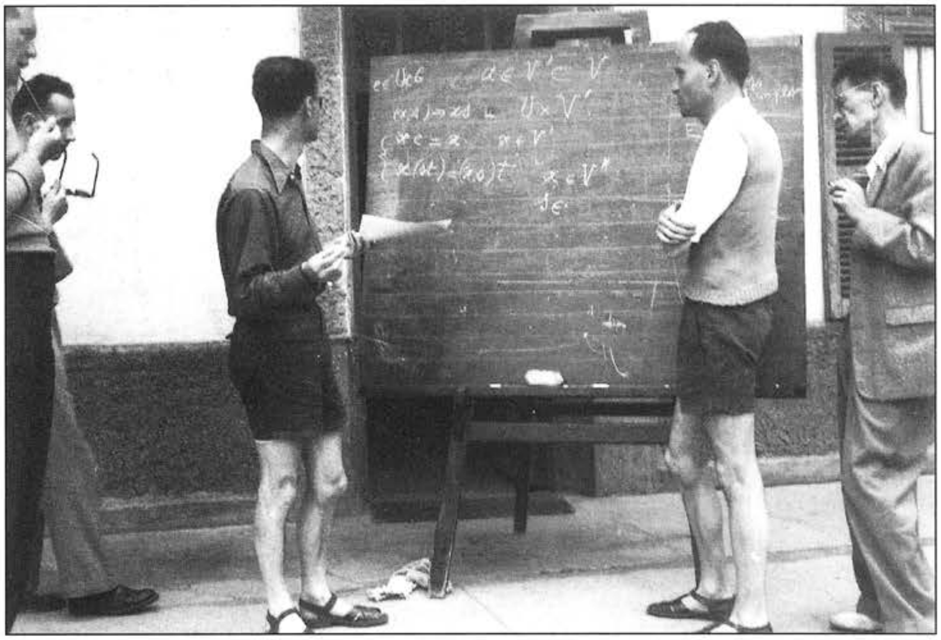
I resumed my teaching at the beginning of 1934. I was in charge of the course Differential and Integral Calculus, and I posed many questions to myself about the way to present certain chapters of the course, not finding in the classical treatise of Goursat an exposition that satisfied me. As we met often, Weil and I, at the mathematics department, I questioned him and asked for his opinions. One fine day he said to me, "Now that's enough: let's meet with some other people to discuss these questions. Let's finalize the answers, and then we will not have to speak of them again." Thus was born the Bourbaki group, which of course did not yet bear this name. Weil decided that eight or nine of us, all Normaliens in the entering classes of 1922 to 1926, would meet every two weeks in Paris to build the plan of a "Treatise on Analysis". I have the good fortune to own the accounts of these meetings carefully kept by Delsarte. In effect, we were all Normaliens, with the exception of Szolem Mandelbrojt, a little older than we, and well assimilated since his arrival in France. The role played by Weil in the Bourbaki enterprise was continually decisive. It is he who decided that everyone should be capable of editing any subject and that anonymity should be respected. It is he who imposed retirement from the group at age fifty in order that new generations could feel responsible in their turn. And that lasted until the war.

In the meantime, Weil was married in October 1937, and his friends were able to see how this union had transformed his life. He himself wrote that his life had effectively ended at "the death on May 24, 1986, of my wife and companion, Eveline".

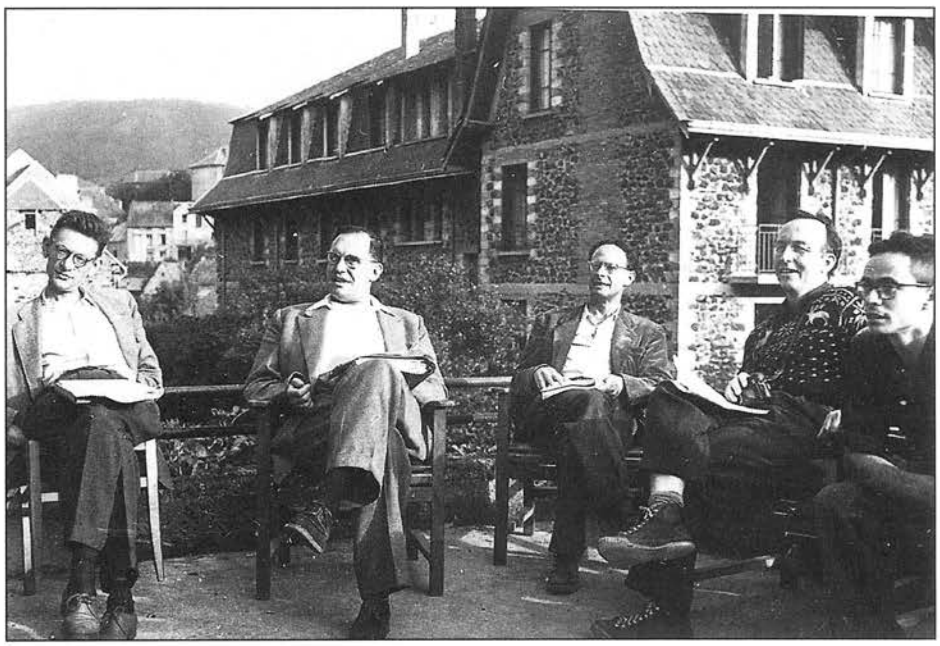
During these last years before the war, I sometimes had occasion to make the train trip with André Weil between Paris and Strasbourg. And, of course, we discussed mathematics. In general, it is I who made him part of my preoccupations of the moment and often he claimed that I was on the wrong track. He explained to me one day that he acted that way in order to challenge me to go more deeply into the problems. A little earlier, toward 1930, it is he who had oriented me toward the study of analytic functions of *several* variables by pointing out to me the work of Carathéodory on circled domains. One cannot overestimate what I owe to André Weil.

Came the summer of 1939. In his *Souvenirs d'Apprentissage* Weil explains the reasons that had led him to decide that in case of war he would leave France. He was, like all the former Normaliens

[3] *A preparatory class for the entrance examinations at the École Polytechnique and the scientific section of the École Normale.*



**Bourbaki congress at Pelvoux, June/July 1951. Left to right: Jean Dieudonné, Jacques Dixmier, André Weil, Laurent Schwartz, and Roger Godement.**



**Bourbaki congress at Murol (sometimes spelled Murols) just south of Clermont-Ferrand, August 1954. Left to right: Roger Godement, Jean Dieudonné, André Weil, Saunders Mac Lane, and Jean-Pierre Serre.**

Photographs this page courtesy of Henri Cartan.

through the entering class of 1922, a reserve officer. I have recently found the letters that he wrote to me in the course of the year 1939. He had left with his wife for a trip in North Europe: Cambridge in England, Oslo, Copenhagen, Sweden, and up to Lapland. His first letter from Finland is dated September 12; he and his wife were invited to stay with their friends the Ahlfors in the suburbs of Helsinki. He signed his name "Ahlfors" because of French censorship. Letters at that time took two weeks to be delivered. He asked insistently for news of "all our friends who have been mobilized." In the month of October he wrote to me at Beaumont, a close suburb of Clermont-Ferrand, where the Université de Strasbourg had withdrawn. In this period his wife returned to France. On November 21 he wrote to me at length; he still signed his name "Ahlfors", for Finland was at war with the Soviet Union, and Finnish censorship had begun in earnest. He was preoccupied with the works of Bourbaki and elaborated at length on this subject.

Then there was silence. He had been arrested at the end of November. One knows about his odyssey through Haparanda in northern Finland, then Norway and on to Sweden, Norway again, Scotland and London, to land finally at Le Havre, where he was immediately taken to military prison before being transferred to the prison at Rouen, toward mid-February 1940. From the end of January I had been kept up to date by two letters from his sister, Simone. Weil wrote me on February 22 a long handwritten letter (he no longer had his typewriter). Between February 29 and May 2, he wrote me fifteen letters, most of them several pages long. It is also at the time of his stay at the Rouen prison that he wrote for Bourbaki a long report on the theory of integration. It is, I believe, the only mathematical text of André Weil that is handwritten; it is today in the archives of the Académie des Sciences (Paris).

His trial took place May 3; my father went to Rouen to testify in his favor. Following his sentencing, Weil left prison to be inducted into the army as a private. But France was soon invaded, and the Weil family (his parents and his sister, Simone) took refuge in Vichy, then in Toulouse, although he himself began a long journey through England and North Africa to end October 9, 1940, in Marseille, where he was demobilized and found his parents again. All this time, I had served as intermediary between Weil and his family. On October 10 he arrived at the station in Clermont-Ferrand, where I awaited him.

Weil reunited only later with his wife, Eveline, who remained in the occupied zone. They left together for the United States with Alain, Eveline's son. At the end of 1944 we could again correspond; he left the United States for Brazil, having been named to a professorship at the Universidade de São Paulo. I saw André again in July 1945 when he was sent on a mission to take part in the first Bourbaki Congress after the war. We saw each other in that way each summer until 1955, Weil retiring from Bourbaki when he reached the age of fifty.

In January 1948 I was invited by Weil to the University of Chicago, where he had been teaching since 1947; it was Marshall Stone, in charge of reorganizing the mathematics department, who had appointed Weil there. It was my first trip to the United States, and I had much to learn, not merely the language. Weil was then a great help.

A tradition was established between us: each year, toward the end of the month of May, the same evening that he arrived in France, Weil called me on the telephone to tell me: "Je suis là" ("I am here"). We would meet, and he would come spend the entire afternoon at my home. We would go out to take some air in the gardens of the Cité Universitaire, which was quite close, and we did not lack subjects for conversation. Returning to my home, we would rejoin our spouses; then we would dine together, and the evening would go on until the Weils returned to their apartment on the Rue Auguste Comte. After the death of Eveline in 1986, André continued the tradition of his visits. It is in 1987, I believe, that a little at loose ends by his solitude during the French summer, he came to spend two weeks at Die, in the Drôme, where my family was vacationing in our summer house. He loved then to walk and to become acquainted with this beautiful countryside, which was new to him. The following years, he continued to come to spend an afternoon at my home in Paris, but he no longer wished to walk; he complained about his sight, his hearing, and his legs. The last time he came was in 1996; he seemed at the end of his strength, but he had kept all of his intellectual acuity. He no longer came to Paris, and the rare news of him that I could obtain was given to me by Armand Borel or by his daughters, Sylvie and Nicolette.

Courtesy of Sylvie Weil and reprinted from the work *Apprenticeship of a Mathematician* with permission from Birkhauser.

**André Weil and his sister Simone, Paris, 1911.**

Photograph courtesy of Sylvie Weil.

**André and Eveline Weil with their cat Catsou, Princeton, October 1960.**

It is not possible to evoke the memory of André Weil without that of his sister, Simone, the dedicated philosopher. Certainly they were very different from each other and did not have the same aspirations. But their thoughts came together sometimes, and they felt deep down a great affection for each other. André told of his despair when a telegram informed him in New York that his sister had just died of exhaustion at Asherford in England on August 24, 1943. He later occupied himself actively in the publication of the *Oeuvres Complètes* of Simone Weil. Each of them in turn has contributed to the enrichment of the heritage of mankind.

# How the Alternating Sign Matrix Conjecture Was Solved

*David Bressoud and James Propp*

## Introduction

Perusing the four volumes of Muir's *The Theory of Determinants in the Historical Order of Development*, one might be tempted to conclude that the theory of determinants was well and truly beaten to death in the nineteenth century. In fact, the field is thriving, and it has continued to yield challenging problems of deceptive elegance and simplicity. The Alternating Sign Matrix Conjecture was one of the most notorious of these problems. For fifteen years it defied assaults by some of the world's best mathematicians; then in 1995 three distinct proofs appeared. The first, by Doron Zeilberger, drew on results and techniques from partition theory, symmetric functions, and constant term identities, with a pivotal role played by the partial difference operator philosophy and by computer algebra. Greg Kuperberg found the second proof, which relied on the machinery of statistical mechanics and in particular on the Yang-Baxter equation for the 6-vertex lattice model. The third proof, again by Zeilberger, expanded Kuperberg's approach to prove a more general result. It combined the Yang-Baxter equation with the $q$-calculus and its associated orthogonal polynomials, and it relied on the WZ-method of Herbert Wilf and Zeilberger. Wilf and Zeilberger would later receive the Steele Prize for this algorithmic approach to discovering and proving series identities (*Notices*, April 1998).

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These tools did not come from outside determinant theory; rather, the classical theory of determinants grew into nineteenth-century invariant theory, a field whose twentieth-century progeny include partition theory and the $q$-calculus, representation theory and symmetric functions, and statistical mechanics. The proofs of the Alternating Sign Matrix Theorem have served to strengthen ties between these fields and to suggest new avenues of research.

An **alternating sign matrix** (ASM) is a matrix of 0's, 1's, and $-1$'s in which the entries in each row or column sum to 1 and the nonzero entries in each row or column alternate in sign. An example is

$$\begin{pmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & -1 & 1 \\ 1 & -1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix}.$$

This generalization of the notion of permutation matrices was discovered by David Robbins and Howard Rumsey in the early 1980s, but to tell our story properly, we should begin with Charles Lutwidge Dodgson (better known as Lewis Carroll).

Dodgson devised a method of evaluating determinants called **condensation** that is eminently suited to hand-calculations. Recall that the determinant of an $n$-by-$n$ matrix $(a_{i,j})$ is defined as

$$|a_{i,j}| = \sum_{\pi} (-1)^{I(\pi)} \prod_{i=1}^{n} a_{i,\pi(i)},$$

1
1 1
2 3 2
7 14 14 7
42 105 135 105 42
429 1287 2002 2002 1287 429
7436 26026 47320 56784 47320 26026 7436

**Figure 1. The counts of $n$-by-$n$ ASMs with a 1 at the top of column $k$.**

2/2
2/3 3/2
2/4 5/5 4/2
2/5 7/9 9/7 5/2
2/6 9/14 16/16 14/9 6/2
2/7 11/20 25/30 30/25 20/11 7/2

**Figure 2. The ratios of adjacent terms from Figure 1.**

where $\pi$ ranges over all permutations of $\{1, 2, \ldots, n\}$ and $\mathcal{I}(\pi)$ is the inversion number of $\pi$, i.e., the minimal number of transpositions of adjacent columns needed to turn the matrix representing $\pi$ into the identity matrix. This formula is practical for 3-by-3 and perhaps 4-by-4 matrices, but for large matrices it is inefficient. Most mathematicians are familiar with Gaussian elimination as a more practical method of evaluating determinants by hand, but condensation is also useful and deserves to be better known. One starts with an $n$-by-$n$ matrix and then successively computes an $(n-1)$-by-$(n-1)$ matrix, an $(n-2)$-by-$(n-2)$ matrix, etc., until one arrives at a 1-by-1 matrix whose sole entry is the determinant of the original $n$-by-$n$ matrix. The rule for computing the $k$-by-$k$ matrix $(n-1 \geq k \geq 1)$ is to take the $k^2$ 2-by-2 connected subdeterminants of the $(k+1)$-by-$(k+1)$ matrix and divide them by the corresponding $k^2$ central entries of the $(k+2)$-by-$(k+2)$ matrix. (In the case $k = n-1$, no divisions are performed.) Although the use of division may seem like a liability, it actually provides a useful form of error checking for hand calculations with integer matrices: when the algorithm is performed properly (with extra provisos for avoiding division by 0), all the entries of all the intervening matrices are integers, so that when a division fails to come out evenly, one can be sure that a mistake has been made somewhere. The method is also useful for computer calculations, especially since it can be executed in parallel by many processors. The $k$-by-$k$ matrix that one computes by this procedure has a natural interpretation: it is the matrix of determinants of the $k^2$ $(n-k+1)$-by-$(n-k+1)$ connected submatrices of the original matrix. The proof of this assertion makes use of one of Jacobi's matrix identities.

If one applies Dodgson condensation to the 3-by-3 matrix

$$\begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix},$$

one first obtains the 2-by-2 matrix

$$\begin{pmatrix} ae-bd & bf-ce \\ dh-eg & ei-fh \end{pmatrix},$$

and from this one finds the 1-by-1 matrix whose sole entry is

$$((ae^2i - aefh - bdei + bdfh) - (bdfh - befg - cdeh + ce^2g))/e$$

or, upon collection of terms,

$$(1)aei + (-1)afh + (-1)bdi + (0)bde^{-1}fh + (1)bfg + (1)cdh + (-1)ceg.$$

Six of these terms correspond to the six permutation matrices. For example, $(-1)afh$ is associated with the matrix with 1 in the same positions as occupied by $a$, $f$, and $h$ above, with 0's elsewhere. In addition, there is an extra (vanishing) term $(0)bde^{-1}fh$ that can be associated with the matrix with 1's in the positions of $b$, $d$, $f$, and $h$ and $-1$ in the position of $e$:

$$\begin{pmatrix} 0 & 1 & 0 \\ 1 & -1 & 1 \\ 0 & 1 & 0 \end{pmatrix}.$$

If one does the same thing for the general 4-by-4 matrix, one finds that, in addition to the 24 monomials that make nonzero contributions to the determinant, there are also 18 monomials with vanishing coefficient. Each of these 42 monomials is associated with a 4-by-4 matrix of 0's, 1's, and $-1$'s. In general, when Dodgson condensation is applied to an $n$-by-$n$ matrix and all like monomials are gathered together, the terms in the final expression (taking the vanishing terms along with the nonvanishing ones) are associated with the $n$-by-$n$ matrices of 0's, 1's, and $-1$'s in which the nonzero entries in each row and column alternate in sign, beginning and ending with a +1. These are the alternating sign matrices (or ASMs) of order $n$, invented by Robbins and Rumsey in their study of Dodgson condensation.

It was simple curiosity that led Robbins and Rumsey, now joined by William Mills, to investigate the number of ASMs. Letting $\mathcal{A}_n$ denote the set of $n$-by-$n$ ASMs and $A_n$ the cardinality of $\mathcal{A}_n$, the three investigators found by computer calculation that the sequence $A_n$ went

$$1, 2, 7, 42, 429, 7436, 218348,$$
$$10850216, 911835460, \ldots.$$

This was not a sequence any of them had seen before. The growth rate of the sequence and the absence of large prime divisors (e.g., $911835460 = 2^2 \cdot 5 \cdot 17^2 \cdot 19^3 \cdot 23$) suggested to Mills, Robbins, and Rumsey that there was a formula for $A_n$ as a ratio of products of factorials. To find this formula, they divided the set of $n$-by-$n$ ASMs into classes according to the position of the 1 in the first row. Their tallies yielded a triangular array in which the $k$th entry of the $n$th row is the number of $n$-by-$n$ ASMs with a 1 in row 1, column $k$, as shown in Figure 1.

Clearly the sum of the entries in each row is $A_n$, and it is not difficult to see as well that the first entry in each row must equal $A_{n-1}$. When Mills, Robbins, and Rumsey looked at ratios of horizontally adjacent entries, they discovered the remarkable pattern shown in Figure 2.

The $n$th row starts with $2/(n+1)$ and ends with $(n+1)/2$. The striking observation is that each ratio appears to arise from the two ratios diagonally above by adding numerators and adding denominators. Soon verified through $n = 20$, this became known as the **Refined ASM Conjecture**.

Using the fact that the first entry in each row is the sum of entries in the previous row, one can show that one consequence of the Refined ASM Conjecture is the formula

$$A_n = \prod_{j=0}^{n-1} \frac{(3j+1)!}{(n+j)!}.$$

This is the **ASM Conjecture**. It remained unproved until 1995 when an army of referees—88 people and one computer—pronounced as correct the latest version of the proof that Zeilberger had first proposed in 1992. The same year, Kuperberg produced a considerably simpler proof that relies on the Yang–Baxter equation for the 6-vertex model. By the end of that year, Zeilberger had adapted Kuperberg's proof to verify the Refined ASM Conjecture.

## Descending Plane Partitions

When Mills, Robbins, and Rumsey told Richard Stanley about their conjecture, they were astonished to hear that the sequence $1, 2, 7, 42, 429, 7436, \ldots$ had recently arisen in research done by George Andrews on a seemingly unrelated problem in the theory of plane partitions.

To explain plane partitions, we jump back to the nineteenth century and describe Percival Alexander MacMahon's work, which generalized the notion of number-partitions whose study had been initiated by Euler and continued by Sylvester, Frobenius, and others. Euler had shown that the number of ways of representing the positive integer $n$ as a sum of positive integers (without regard to order) equals the coefficient of $q^n$ in the power-series expansion of the infinite product

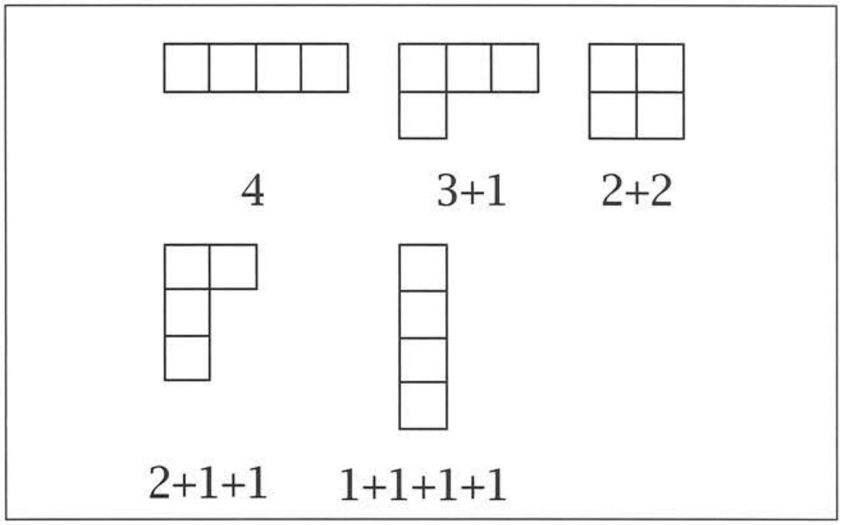



**Figure 3. Young diagrams corresponding to partitions of 4.**

$$\prod_{k=1}^{\infty} \frac{1}{1-q^k} = 1 + q + 2q^2 + 3q^3$$
$$+ 5q^4 + 7q^5 + 11q^6 + 15q^7 + \cdots.$$

In any partition of a number, it is customary to list the "parts", or summands, in nonincreasing order; thus, the five partitions of 4 are written as 4, 3 + 1, 2 + 2, 2 + 1 + 1, and 1 + 1 + 1 + 1. Partitions are frequently represented by means of Young diagrams; the Young diagrams of these five partitions are shown in Figure 3.

Each part in the partition is represented by a row of unit squares. These rows of squares are left-justified, and the lengths are weakly decreasing as one moves down. Figure 4 shows all the Young diagrams (including the empty partition of 0 at the upper left) that fit inside a 2-by-2 square. There is a unique lattice-path from the upper-right corner of the square to the lower-left corner that traces the lower-right outline of the Young diagram. In general, the partitions of integers less than or equal to $mn$ in which there are at most $n$ parts, and in which no part is larger than $m$, correspond to Young diagrams that fit inside an $m$-by-$n$ rectangle, which in turn correspond to lattice paths that go from the upper-right corner of the rectangle to the lower-left corner by means of leftward and downward steps. Each such path corresponds to a way of interspersing $m$ downward steps with $n$ leftward steps, and elementary combinatorics tells us that the number of such paths is the binomial coefficient $(m+n)!/m!n!$.

MacMahon realized that these diagrammatic representations could be extended to three dimensions in a very natural way. Specifically, one can define 3-dimensional Young diagrams as as-

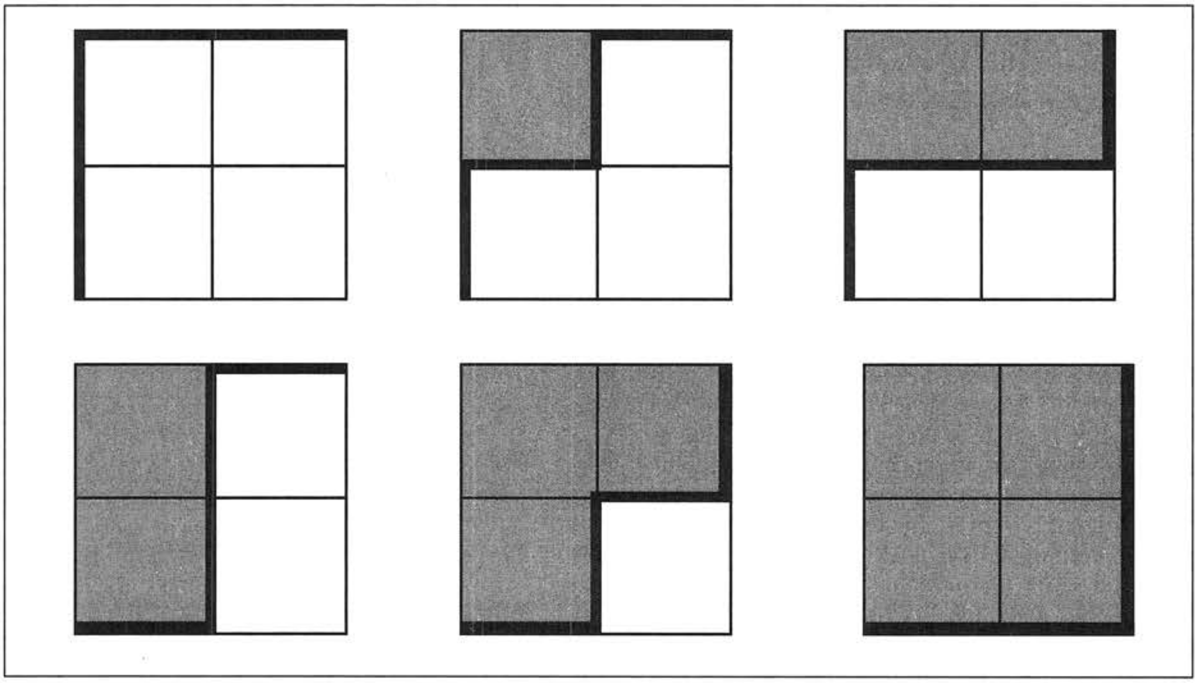


**Figure 4. Young diagrams and lattice paths.**

semblages of cubes inside an octant (as in Figure 5) such that every cube is "supported" on the three sides toward the bounding planes of the octant; to be supported on a particular side, a cube must be supported either by another cube that shares that face with it or by a bounding plane. These assemblages correspond to partitions of a number into parts arranged 2-dimensionally in a quadrant, as in the figure. Each vertical stack of cubes in part (a) of the figure is marked on its top face so that when we look straight down, we can read the number of cubes in that stack. When the assemblage of cubes is viewed from above, these numbers form the **plane partition** in part (b) of the figure.

MacMahon showed that the number of plane partitions of the number $n$ is given by the coefficient of $q^n$ in the power-series expansion of the infinite product

$$\prod_{k=1}^{\infty} \frac{1}{(1-q^k)^k} = 1 + q + 3q^2 + 6q^3 + 13q^4 + \cdots . \tag{1}$$

He also found a formula for the number of plane partitions whose Young diagrams fit inside an $a$-by-$b$-by-$c$ box; his formula was fairly complicated, but it is equivalent to the triple product

$$\prod_{i=1}^{a}\prod_{j=1}^{b}\prod_{k=1}^{c} \frac{i+j+k-1}{i+j+k-2}. \tag{2}$$

It should be mentioned that $d$-dimensional Young diagrams can be defined for larger integers $d$, but that the obvious generalizations of formulas (1) and (2) are wrong for every value of $d$ larger than 3.

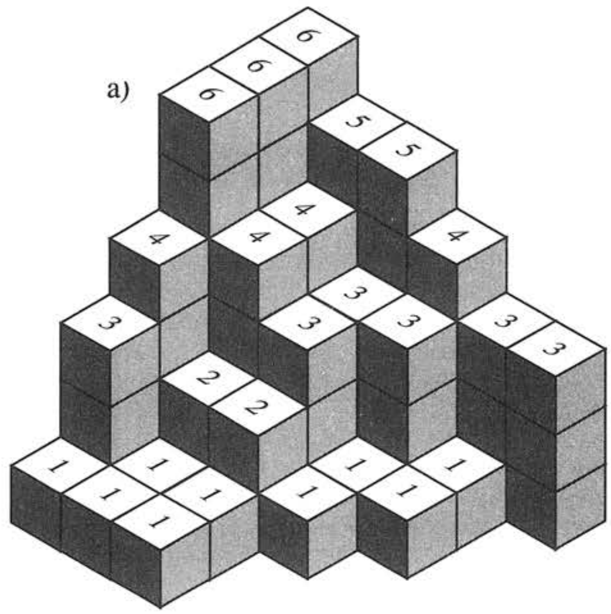
Earlier researchers had enumerated ordinary partitions whose Young diagrams are invariant under reflection in the diagonal axis, so it was natural for MacMahon to undertake an analysis of plane partitions with an analogous symmetry in their 3-dimensional representations. He did indeed discover a formula enumerating plane partitions with a single reflective symmetry; however, he did not give a proof, nor did he consider other sorts of symmetry. Starting in the 1960s, various researchers (notably Basil Gordon, Donald Knuth, Ian Macdonald, George Andrews, and Richard Stanley) sought to fill this gap by considering this and other symmetry classes of plane partitions. One class that proved challenging was the class of plane partitions whose solid Young diagrams are invariant under the rotation that cyclically permutes the $x$, $y$, and $z$ axes. In 1979 Macdonald had formulated a conjecture for the number of cyclically symmetric plane partitions of a given integer (CSPPs for short) in an $a$-by-$a$-by-$a$ box; specifically, he had proposed a product representation for the power series for which the coefficient of $q^n$ is the number of CSPPs of $n$, but he had not been able to find a proof. In that same year, Andrews proved the $q = 1$ version of Macdonald's conjecture, that is, a formula for the total number of CSPPs that fit inside an $a$-by-$a$-by-$a$ box.

One byproduct of Andrews's proof was a formula counting descending plane partitions. A **descending plane partition** (DPP) of order $n$ is a 2-dimensional array of positive integers less than or equal to $n$ such that the left-hand edges are successively indented, there is weak decrease across rows and strict decrease down columns, and the number of entries in each row is strictly less than the largest entry in that row. An example of order 7 (or greater) is

| | | | | | |
|---|---|---|---|---|---|
| 7 | 7 | 6 | 6 | 3 | 1 |
| | 6 | 5 | 4 | 2 | |
| | | 3 | 3 | | |
| | | | 2 | | |

There are seven DPPs of order 3. One of these is the empty DPP. Five of them consist of a single row: 2, 3, 31, 32, or 33. There is one with two rows: 33 above 2. Andrews had found a formula for the number of DPPs of order $n$, which he computed for small values of $n$, yielding the sequence $1, 2, 7, 42, 429, 7436, \ldots$. Thus it was natural that when Stanley heard about the work of Mills, Robbins, and Rumsey, he would recognize the sequence they had encountered. Stanley quickly verified that their conjectured formula for counting ASMs was essentially identical to Andrews's proved formula for DPPs. In this fashion, two lines of research—Dodgson's condensation algorithm and MacMahon's plane partitions—came together.

a)



b)

| | | | | | |
|---|---|---|---|---|---|
| 6 | 5 | 5 | 4 | 3 | 3 |
| 6 | 4 | 3 | 3 | 1 | |
| 6 | 4 | 3 | 1 | 1 | |
| 4 | 2 | 2 | 1 | | |
| 3 | 1 | 1 | | | |
| 1 | 1 | 1 | | | |

**Figure 5. The planar representation of a plane partition.**

Mills, Robbins, and Rumsey tried to prove the ASM Conjecture by establishing a 1-to-1 correspondence between ASMs and descending plane partitions. ASMs have a natural parameter that marks the position of the 1 in the first row. What is the corresponding parameter for descending plane partitions? They conjectured that it is the number of times the integer $n$ appears in the descending plane partition of order $n$.

Something unexpected happened. They discovered that this additional parameter was the key to a simple inductive proof of Andrews's formula for the number of descending plane partitions of order $n$. They translated this parameter to the problem of counting cyclically symmetric plane partitions. It simplified that proof and showed them how to prove Macdonald's original conjecture for the number of cyclically symmetric plane partitions of any integer inside any box. They had proved a significant outstanding conjecture, but not the one they had set out to prove. The ties between ASMs and plane partitions were now firmly established. They were about to be strengthened even more.

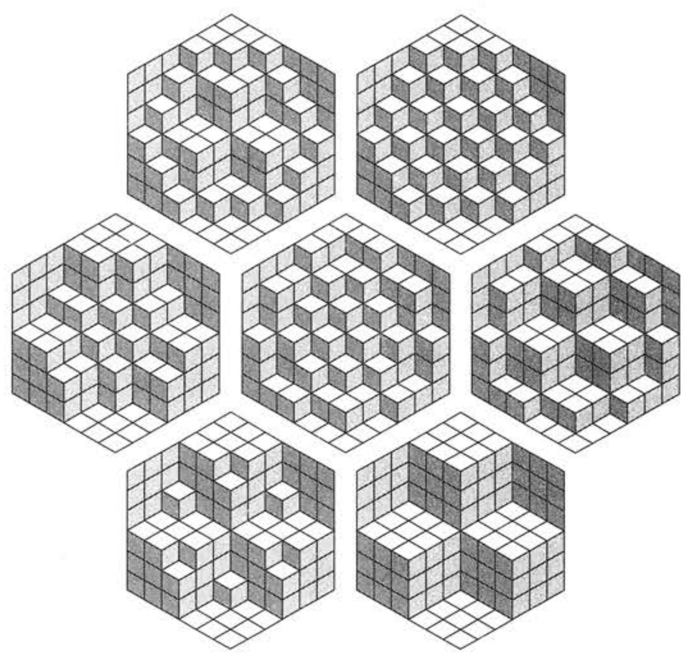


**Figure 6. The seven TSSCPPs in a 6 x 6 x 6 box.**

## Symmetries of Plane Partitions

One of the first problems that Mills, Robbins, and Rumsey ran into in trying to elucidate the connection between ASMs and DPPs was that the group of symmetries of the square acts in a natural way on the set of ASMs, whereas there is no obvious nontrivial group action on the set of DPPs. The three researchers began to search for symmetries of DPPs that would mirror the symmetries of ASMs. Soon they discovered an involution on the set of descending plane partitions of order $n$ that appeared to mimic vertical reflection of an ASM. Later they modified this involution so that it applied to the set of all cyclically symmetric plane partitions in an $n$-by-$n$-by-$n$ box. If the solid Young diagram of a plane partition fits inside a box of given size, one can take the collection of cubes that are in the box but do *not* belong to the solid Young diagram. These determine another plane partition called the **complement**. If a plane partition in an $n$-by-$n$-by-$n$ box is cyclically symmetric, so is its complement. The complement is in general different from the original plane partition but can in some cases be the same, in which case the plane partition is said to be **self-complementary**. Robbins looked at plane partitions whose Young diagrams fit inside an $n$-by-$n$-by-$n$ box and that, in addition to being totally symmetric (that is, invariant under arbitrary permutations of the three axes), were also self-complementary. Figure 6 shows the solid Young diagrams associated with the seven totally symmetric self-complementary plane partitions (called TSSCPPs for short) whose solid Young diagrams fit inside a 6-by-6-by-6 box. When $n$ is odd, there can be no TSSCPPs, since the number of cubes in a solid Young diagram and the number of cubes in its complement will necessarily have opposite parity. For $n$ even, Robbins found that the number of TSSCPPs goes like $1, 2, 7, 42, 429, 7436, \ldots$. The sequence associated with ASMs had now appeared three times, each time arising from a combinatorial question that seemed unrelated to the others.

Mills, Robbins, and Rumsey noticed that one way to make the conjectural connection between ASMs and TSSCPPs appear more natural is to represent both sorts of objects in the form of triangular arrays. A monotone triangle of order $n$ is a triangular array of numbers ($n$ numbers on each side) with entries between 1 and $n$, with strict increase across rows and weak increase as one moves diagonally up or down to the right. There is a simple bijection between ASMs of order $n$ and monotone triangles of order $n$. An example is given in Figure 7. In the triangle, the entries of row $j$, counted from the top, record the positions of the 1's in the vector formed by adding the top $j$ rows of the matrix. Monotone triangles are also sometimes referred to as strict Gelfand patterns, and Zeilberger would later dub them "gog triangles".

$$\begin{pmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & -1 & 1 \\ 1 & -1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix} \longleftrightarrow \begin{matrix} & & & & 4 & & & & \\ & & & 2 & & 5 & & & \\ & & 1 & & 4 & & 5 & & \\ & 1 & & 3 & & 4 & & 5 & \\ 1 & & 2 & & 3 & & 4 & & 5. \end{matrix}$$

$$(0,0,0,1,0) + (0,1,0,-1,1) + (1,-1,0,1,0) = (1,0,0,1,1) \longleftrightarrow 1 \quad 4 \quad 5.$$

**Figure 7. The correspondence between ASMs and monotone triangles.**

In a slightly more involved fashion, the TSSCPPs in a $2n$-by-$2n$-by-$2n$ box are in 1-to-1 correspondence with order-$n$ triangular arrays with entries 1 through $n$ that increase weakly across rows and down columns and such that all entries in column $j$ are less than or equal to $j$. An example for $n = 5$ is

$$\begin{matrix} 1 & & & & \\ 1 & 1 & & & \\ 1 & 1 & 1 & & \\ 1 & 1 & 1 & 3 & \\ 1 & 1 & 2 & 4 & 5. \end{matrix}$$

Zeilberger would later dub these "magog triangles".

The bottom row of a magog triangle is a weakly increasing sequence of the integers 1 through $n$, with the $i$th entry less than or equal to $i$. The northwest edge of a monotone or gog triangle is also a weakly increasing sequence of the integers 1 through $n$, with the $i$th entry less than or equal to $i$. Mills, Robbins, and Rumsey conjectured that the number of possible configurations for the bottom $k$ rows of a magog triangle of order $n$ (call this $M(n,k)$) is equal to the number of possible configurations for the first $k$ diagonals of a gog triangle (call this $G(n,k)$). The case $k = n$ would imply that the number of ASMs of order $n$ is equal to the number of TSSCPPs of order $n$.

The researchers proved the formula $G(n,k) = M(n,k)$ for $k = 2$ (the case $k = 1$ is the remark made at the beginning of the preceding paragraph), but their methods offered very little hope of yielding a proof for greater values of $k$. Zeilberger, hearing of the proof for $k = 2$, thought that a proof for general $k$ might be within reach, but the amount of work that he foresaw was daunting. Furthermore, the reward for such efforts would not be a proof of the ASM Conjecture, but only a proof that the ASM Conjecture was equivalent to the TSSCPP conjecture. Therefore he did not pursue the problem.

Throughout the mid to late 1980s, articles appeared with conjectured formulas for plane partitions or ASMs that satisfied certain symmetry conditions. The best-known of these articles was Stanley's paper "A baker's dozen of conjectures concerning plane partitions". Some of the conjectures were subsequently proved, but many were not. In 1991 Robbins sought a broader audience for these problems with his *Mathematical Intelligencer* article "The story of 1, 2, 7, 42, 429, 7436, ...", in which he exclaimed,

> These conjectures are of such compelling simplicity that it is hard to understand how any mathematician can bear the pain

of living without understanding why they are true.

## The First Proof of the ASM Conjecture

By the time Robbins published his *Intelligencer* article, the succession of insights that would lead to the proof of the ASM Conjecture was well under way. The first contribution to the solution of the TSSCPP problem came from William Doran, then an undergraduate, who succeeded in translating an arbitrary TSSCPP into a set of lattice paths. Ira Gessel and Xavier Viennot had shown how to use determinants to count sets of lattice paths, but Doran's paths did not quite fit the Gessel-Viennot paradigm.

Soichi Okada had run into a similar problem a few years earlier when trying to count all totally symmetric plane partitions (plane partitions invariant under all permutations of the axes). He had realized that instead of trying to transform the problem directly into the evaluation of a determinant, the key was to translate it into the evaluation of a Pfaffian, an analogue of the determinant that applies to triangular arrays of numbers and that is a signed sum indexed by set partitions of $\{1, \dots, n\}$ into pairs of elements. This is an approach to the enumeration of plane partitions that goes back to Basil Gordon in 1971.

John Stembridge realized that this would work for Doran's paths. The fact that the Pfaffian is the square root of the determinant of the corresponding skew symmetric matrix meant that the number of TSSCPPs could ultimately be expressed as a determinant. The matrix that emerged was skew symmetric with entries

$$H(i, j) = \sum_{2i-j<r\leq 2j-i} \binom{i+j}{r}$$

with $\quad 0 \leq i < j \leq n-1 \quad$ for $n$ even,

$\qquad 1 \leq i < j \leq n-1 \quad$ for $n$ odd.

Andrews then evaluated this determinant and confirmed the conjectured formula for the number of TSSCPPs in a box. Some highly unusual hypergeometric series appear in this problem, and Andrews relied on the WZ-method to prove the summation formulas that arose.

Emboldened by Andrews's solution of the TSSCPP problem, Zeilberger now tackled the problem of proving the formula $G(n, k) = M(n, k)$ by induction on $n$ and $k$. A proof of this formula, combined with Andrews's proof of the formula for $M(n, n)$ conjectured by Robbins, would yield a proof of the formula for $G(n, n)$ and thus prove the ASM Conjecture.

Zeilberger began by expressing each of the quantities to be counted as the constant term of a Laurent series in $k$ variables, $x_1, \dots, x_k$. Using a technique he had learned from Stembridge and Dennis Stanton, Zeilberger divided each of these series by $x_1 \cdots x_k$, shifted his attention to the residues at $x_1 = \cdots = x_k = 0$, and showed that these residues are left unchanged by the operator $g_{\sigma,S}$ that acts by first replacing each $x_i$ for which $i \in S$ by $\overline{x}_i = 1 - x_i$ and then replacing each $x_i$ by $x_{\sigma(i)}$. He then summed the images of these functions over all pairs $(\sigma, S)$ where $\sigma$ is a permutation and $S$ is a subset of $\{1, \dots, n\}$. Zeilberger needed to prove that the resulting rational functions had the same residues. In fact, he was able to prove that these rational functions were identical.

Zeilberger's proof was announced in 1992. Though essentially sound, it went through several revisions before it was finally accepted in 1995. The details of this proof are intricate. Zeilberger arranged them in a tree of lemmas, sublemmas, subsublemmas, through "sub$^7$lemmas". Many of these state that certain functions satisfy particular partial difference equations or boundary conditions. Some of them claim the invariance under $g_{\sigma,S}$ of various pieces of the final functions. All of this builds to the principal result that the sums over $(\sigma, S)$ of $g_{\sigma,S}$ of each Laurent series are identical. Zeilberger recruited his eighty-nine referees, who were each given one sub$^i$lemma and asked to verify that it did, indeed, follow from the corresponding sub$^j$lemmas, $j > i$. The names of the referees were listed in the article, along with a brief biographical sketch of each. Many of the people who have already been mentioned here were among the referees; the article thus gives a snapshot of the principal players in the study of ASMs in the 1990s. It is likely that Zeilberger's approach could have been extended to prove the Refined ASM Conjecture, but no one had the courage to begin this daunting task. Fortunately, within a few months Greg Kuperberg had found a much simpler route to the proof of the ASM Conjecture, using the machinery of statistical mechanics.

## Proofs via Statistical Mechanics

Kuperberg's work on the ASM Conjecture began around 1990 as an outgrowth of his work on enumeration of tilings in collaboration with Noam Elkies, Michael Larsen, and James Propp. On the one hand, the problem of counting domino tilings of certain plane regions known as Aztec diamonds had turned out to have connections with the theory of ASMs; on the other hand, the counting problem can be recast as a problem of counting "dimer configurations" and solved with the methods of statistical mechanics. Having become aware of such methods, Kuperberg proceeded to apply them to the problem of enumerating symmetry classes of plane partitions. We can view the TSSCPPs in Figure 6 as 2-dimensional hexagons filled with congruent parallelograms. Any plane partition inside a box translates visually into a 2-dimensional tiling problem. TSSCPPs are those tilings of a regular hexagon that are invariant under all symmetries

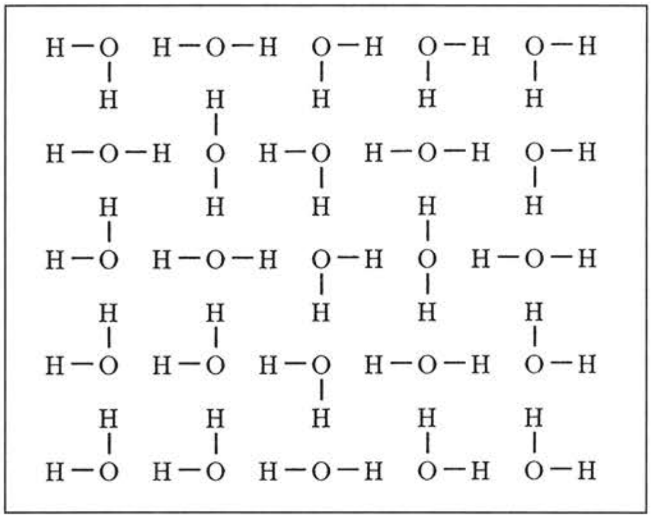


Figure 8. A patch of "square ice".

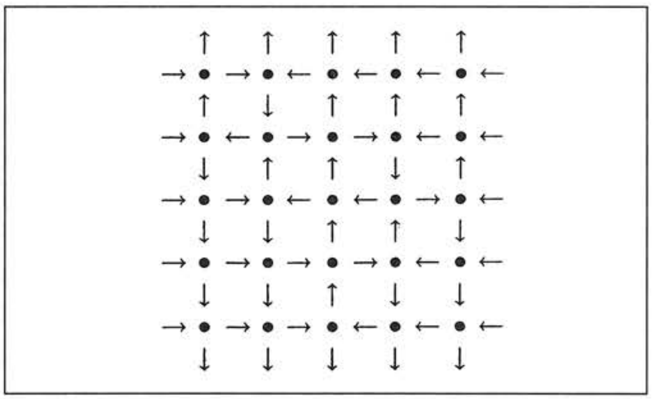


Figure 9. Figure 8 converted into a directed graph on a square lattice.

of the hexagon. Tilings of this kind can be viewed as states of 2-dimensional "dimer models". In his solution to the CSSCPP problem (enumerating cyclically symmetric, self-complementary plane partitions), Kuperberg made use of matrix methods developed by the statistical mechanician Pieter Willem Kasteleyn. It was natural for Kuperberg to turn next to the ASM problem to see whether statistical mechanics had anything to offer. He learned that physicists had independently been studying ASMs in another guise in connection with the study of the structure of ice.

The water molecules in actual ice crystals are arranged in a 3-dimensional lattice, but physicists substituted a 2-dimensional lattice (the square grid) to make the model more tractable. Figure 8 shows a patch of what is called "square ice". It corresponds to the ASM

$$\begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & -1 & 0 & 1 & 0 \\ 0 & 1 & 0 & -1 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix}.$$

Horizontal molecules correspond to +1, vertical molecules to $-1$, and angled molecules to 0.

Physicists often represent such a square ice state as a directed graph on a square lattice in which each vertex has in-degree and out-degree two, as in Figure 9. The oxygen atoms are at the vertices, and the directed edges correspond to hydrogen atoms, directed toward the atom to which they are bonded. The fact that there are six possible configurations at each vertex gives this model its name, the **6-vertex model**.

Note that along the boundary of Figure 9 the arrows point inward along the left and right and outward along the top and bottom. This boundary condition is called the domain wall boundary condition for the 6-vertex model. States satisfying this boundary condition were studied by Vladimir Korepin in the early 1980s; they are the square-ice states that are equivalent to ASMs.

Physicists are interested in weighted sums taken over all possible configurations of given size and satisfying given boundary conditions. Few such state-sums can be expressed in closed form, but Anatoli Izergin (building on the earlier work of Korepin) found such a formula for the 6-vertex model with domain wall boundary conditions. That formula is equivalent to the following determinant evaluation:

$$\begin{aligned} \det\left(\frac{1}{(x_i+y_j)(ax_i+y_j)}\right) & \\ \times \frac{\prod_{i,j=1}^{n}(x_i+y_j)(ax_i+y_j)}{\prod_{1\le i<j\le n}(x_i-x_j)(y_i-y_j)} & \\ = \sum_{A\in\mathcal{A}_n} \Big((-1)^{N(A)} & \\ \times a^{(n^2-n)/2-\mathcal{I}(A)}(1-a)^{2N(A)} & \\ \times \prod_{i=1}^{n} x_i^{N_i(A)} y_i^{N^i(A)} \prod_{\substack{1\le i,j\le n \\ a_{ij}=0}} (\alpha_{ij}x_i+y_j)\Big), & \end{aligned}$$

a sum over ASMs where $N(A)$ (respectively $N_i(A)$, $N^i(A)$) is the number of $-1$'s in $A$ (respectively row $i$ of $A$, column $i$ of $A$), $\mathcal{I}(A)$ is the inversion number of $A$ which is equal to $N(A)$ plus the number of southwest molecules (molecules with bonds to the hydrogen atoms to the left and below) in the corresponding patch of square ice, and $\alpha_{ij}$ is $a$ if the corresponding molecule is southwest or northeast and is 1 otherwise. The key to proving this identity is knowing that the right side is a symmetric function in the $x_i$'s and in the $y_i$'s. This fact follows from the Yang-Baxter equation for the 6-vertex model. Kuperberg had learned from Vaughan Jones of the power of the Yang-Baxter equation, and this had led him to Korepin's work on the 6-vertex model.

Kuperberg's initial attempt to exploit this formula was stymied by the unavailability of a full write-up; although Izergin's article was in print, the book by Korepin, Nikolai Bogoliubov, and Izergin that gave a fuller account would not be published until 1993, and the two draft chapters that Kuperberg had were difficult to understand out of the context of the full book. Kuperberg therefore put the problem aside and returned to it only in 1995, after Zeilberger's proof had been fully validated.

In reexamining the Korepin–Izergin determinant formula, Kuperberg realized that with $x_j = e^{-\pi i/3}$, $y_j = 1$, and $a = e^{2\pi i/3}$, the right side of this equation becomes $(-3)^{(n^2-n)/2}$ times the number of $n$-by-$n$ alternating sign matrices. Unfortunately, under this specialization, the left side behaves badly: both the determinant and the product in the denominator vanish. Kuperberg therefore needed to use some finesse on the left side. By approaching the desired specialization along an appropriate trajectory, he was able to show that the left side does indeed approach the desired value as the $x_j$'s approach $e^{-\pi i/3}$ and the $y_j$'s approach 1.

Kuperberg announced his proof and released a preprint in the summer of 1995. It is interesting to note that one of the techniques used in his article is Dodgson condensation, the very procedure whose study had led Mills, Robbins, and Rumsey to invent alternating sign matrices in the first place.

Philosophically, Kuperberg's proof is quite different from Zeilberger's: Kuperberg's proof is multiplicative, whereas Zeilberger's is additive. To explain this distinction with an analogy, we point out two different ways of obtaining an entry in Pascal's triangle. Under the additive approach, one obtains $\binom{n}{k}$ by adding $\binom{n-1}{k-1}$ and $\binom{n-1}{k}$ (the two entries in the row above). Under the multiplicative approach, one obtains $\binom{n}{k}$ by multiplying $\binom{n}{k-1}$ (the preceding entry in its row) by $(n-k)/k$. It seems fair to say that additive methods are more general and robust and give algebraically arduous proofs with very little combinatorial flavor; multiplicative methods are more fragile and specialized, but where they can be made to apply, they often give more elegant proofs.

After reading and absorbing Kuperberg's paper, Zeilberger proved the Refined ASM Conjecture by evaluating the limit of the left side with $x_1$ remaining indeterminate. His matrix evaluation uses the moments of the $q$-Legendre polynomials together with the fact that each monic polynomial in a family of orthogonal polynomials can be expressed as a ratio of determinants involving the moments. The Refined ASM Conjecture ultimately reduces to a cubic transformation formula for hypergeometric series. Zeilberger verified it using his WZ-method.

## Conclusion

The study of ASMs has gone hand in hand with the study of symmetry classes of plane partitions, and ideas have traveled in both directions between the two sorts of problems. However, the connection is still somewhat mysterious; for instance, no natural bijection between ASMs of order $n$ and TSSCPPs of order $n$ is yet known. Results discovered in the study of ASMs and symmetrical plane partitions are finding applications in representation theory. Many of the formulas for counting plane partitions with various symmetries were special cases of character formulas for irreducible representations of the symmetric group. Results discovered in the pursuit of the ASM Conjecture have led to analogues for the other Weyl groups, and these insights are generating new problems and conjectures.

Although the ASM formula has now been proved, many intriguing problems remain. Some of the most tantalizing involve symmetry classes of ASMs. Just as one can enumerate the rhombus-tilings of a hexagon that are invariant under some symmetry-group that maps the hexagon to itself, so too can one enumerate the $n$-by-$n$ ASMs that are invariant under some subgroup of the symmetry-group of the $n$-by-$n$ square. Robbins has proposed some exact formulas for enumerating certain symmetry classes of ASMs, but, aside from the case in which the symmetry group is trivial (coinciding with the unconstrained case), none of these conjectures has been proved. Intriguingly, one of these symmetry-class enumerations gives rise to integers that are (empirically) intimately connected to the way certain polynomial analogues of the numbers $A_n$ factor. Define the weight of an ASM as $x$ to the power of the number of $-1$'s in the matrix, and let $A_n(x)$ be the sum of the weights of all the ASMs of order $n$. $A_n(1)$ simply counts the number of alternating-sign matrices; Mills, Robbins, and Rumsey proved that $A_n(2) = 2^{n(n-1)/2}$; and Kuperberg proved a formula for $A_n(3)$ as a rational product of factorials. It does not appear that there exist similar nice formulas for $A_n(m)$ for larger values of $m$, since the resulting numbers have large prime factors. However, it appears that there exist polynomials $p_n(x)$ such that the polynomial $A_n(x)$ always factors as either $p_n(x)p_{n+1}(x)$ or $2p_n(x)p_{n+1}(x)$, according to whether $n$ is odd or even. Furthermore, the coefficients of $p_n(x)$ appear always to be nonnegative integers. When $n$ is odd, there is a conjectured interpretation of $p_n(x)$ as an enumeration of ASMs with a horizontal (or, equivalently, vertical) axis of bilateral symmetry; no such interpretation is known for when $n$ is even.

The ASM Conjecture has served to cross-fertilize the various modern offspring of classical invariant theory, drawing attention to connections no one had recognized. The study of alternating-sign matrices should continue to bear fruit for


many years to come—and to tantalize us with fruit that is just beyond our reach.

## Bibliography


[1] George E. Andrews, *The Theory of Partitions*, Reprint of the 1976 original, Cambridge Univ. Press, Cambridge, 1998.

[2] David M. Bressoud, *Proofs and Confirmations: The Story of the Alternating Sign Matrix Conjecture*, Cambridge Univ. Press, Cambridge, 1999.

[3] V. E. Korepin, N. M. Bogoliubov, and A. G. Izergin, *Quantum Inverse Scattering Method and Correlation Functions*, Cambridge Univ. Press, New York, 1993.

[4] Greg Kuperberg, Another proof of the alternating-sign matrix conjecture, *Internat. Math. Res. Notes* (1996), 139–150.

[5] ——, Another proof of the alternating-sign matrix conjecture, LANL e-print Archive, math.CO/9712207, 1997; `http://xxx.lanl.gov`. This reference and the previous one refer to the same article.

[6] Ian G. Macdonald, *Symmetric Functions and Hall Polynomials*, 2d ed, Oxford Univ. Press, Oxford, 1995.

[7] David P. Robbins, The story of 1, 2, 7, 42, 429, 7436, ..., *The Math. Intelligencer* **13** (1991), 12–19.

[8] Richard Stanley, A baker's dozen of conjectures concerning plane partitions, *Combinatoire Énumérative* (G. Labelle and P. Leroux, eds.), Lecture Notes in Math., vol. 1234, Springer-Verlag, New York, 1986, pp. 285–293.

[9] Doron Zeilberger, Proof of the alternating sign matrix conjecture, *Electron. J. Comb.* **3** (2) (1996), Research Paper 13; `http://www.combinatorics.org/`.

[10] ——, Proof of the refined alternating sign matrix conjecture, *New York J. Math.* **2** (1996), 59–68; `http://nyjm.albany.edu:8000/nyjm.html`.

# The Visualization of Mathematics: Towards a Mathematical Exploratorium

*Richard S. Palais*

*Let us help one another to see things better.*— CLAUDE MONET

## Introduction

Mathematicians have always used their "mind's eye" to visualize the abstract objects and processes that arise in all branches of mathematical research. But it is only in recent years that remarkable improvements in computer technology have made it easy to externalize these vague and subjective pictures that we "see" in our heads, replacing them with precise and objective visualizations that can be shared with others. This marriage of mathematics and computer science will be my topic in what follows, and I will refer to it as *mathematical visualization.*

The subject is of such recent vintage and in such a state of flux that it would be difficult to write a detailed account of its development or of the current state of the art. But there are two important threads of research that established the reputation of computer-generated visualizations as a serious tool in mathematical research. These are the explicit constructions of eversions of the sphere and of embedded, complete minimal surfaces of higher genus. The history of both of these is well documented, and I will retell some of it later in this article.

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*This article is dedicated to the memory of Alfred Gray.*

*Because some illustrated figures become clearer or more impressive when viewed in color or when animated, the author has made available a Web version of the article with links to such enhanced graphics. It is to be found at:* http://rsp.math.brandeis.edu/VisualizationOfMath.html.

However, my main reason for writing this article is not to dwell on past successes of mathematical visualization; rather, it is to consider the question, Where do we go from here? I have been working on a mathematical visualization program[1] for more than five years now. In the course of developing that program I have had some insights and made some observations that I believe may be of interest to a general audience, and I will try to explain some of them in this article. In particular, working on my program has forced me to think seriously about possibilities for interesting new applications of mathematical visualization, and I would like to mention one in particular that I hope others will find as exciting a prospect as I do: the creation of an online, interactive gallery of mathematical visualization and art that I call the "Mathematical Exploratorium".

Let me begin by reviewing some of the familiar applications of mathematical visualization techniques. One obvious use is as an educational tool to augment those carefully crafted plaster models of mathematical surfaces that inhabit display cases in many mathematics centers [Fi] and the line drawings of textbooks and in such wonderful classics as *Geometry and the Imagination* [HC]. The advantage of supplementing these and other such classic representations of mathematical objects by computer-generated images is not only that a computer allows one to produce such static displays quickly and easily, but in addition it then becomes straightforward to create rotation and mor-

[1] *The program is called 3D-Filmstrip, but I will refer to it simply as "my program" in this article. Later in the article I will explain how to obtain a copy for personal use.*

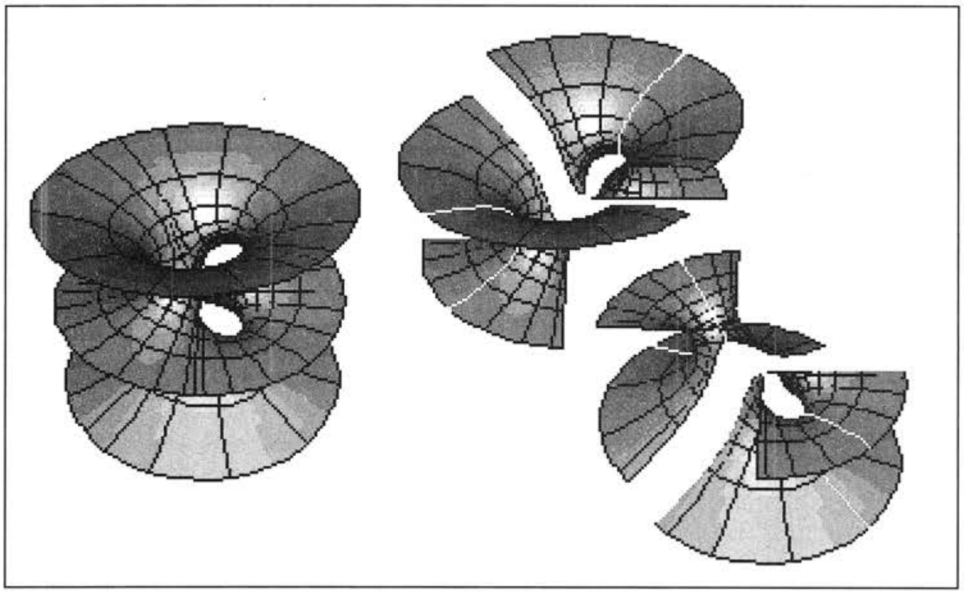


**Figure 1. Symmetries of the Costa surface. The Costa surface (left) is cut by the three coordinate planes into eight congruent tiles, fundamental domains for the symmetry group. The horizontal plane cuts the Costa surface along two straight lines; the upper and the lower half are moved apart so that they do not overlap. The vertical planes are planes of reflectional symmetry and the symmetry lines are emphasized as gaps in the top and bottom part. The eight fundamental domains, one per octant, can each be represented as a graph, and Hoffman-Meek's theorem that the Costa surface is embedded follows easily from this fact.**

phing animations that can bring the known mathematical landscape to life in unprecedented ways.

Even more exciting for the research mathematician are the possibilities that now exist to use mathematical visualization software to obtain fresh insights concerning complex and poorly understood mathematical objects. For example, giving an abstract mathematical object a geometric representation and then displaying it visually can sometimes reveal a new symmetry that was not apparent from the theoretical description. Just such a hidden symmetry, disclosed by visualization, played a key role in the Hoffman-Meeks proof of the embeddedness of the Costa minimal surface [H]. (See Figure 1.) Similarly, a morphing animation in which a particular visual feature of a family of objects remains fixed when certain parameters are changed can suggest the existence of a nonobvious invariant. The helicoid-catenoid morph that we discuss later is an example of this kind. (See Figure 2.)

Applied mathematicians find that the highly interactive nature of the images produced by recent mathematical visualization software allows them to do mathematical experiments with an ease never before possible. Since very few of the systems they deal with admit explicit, closed form solutions, this ability to investigate solutions visually has become an essential tool in many fields. For example, in studying fluid flow close to the onset of turbulence, the description of a velocity field in a small 3-dimensional region over a period of only a few seconds can generate trillions of floating point numbers. While there are statistical techniques for making sense of such huge data sets, displaying the velocity field visually is essential to get an insight into what is going on.

Also, scientists who need and use mathematics but are not completely at ease with abstract mathematical notations and formulas can often better understand the mathematical concepts they have to deal with if these concepts can be given a visual embodiment. Finally, there is no denying that mathematical visualization has a strong aesthetic appeal, even to the lay public—witness the remarkable success of coffee table picture books of fractal images!

## Mathematical Visualization $\not\subseteq$ Computer Graphics

One important lesson I have learned from my own experience is that mathematical visualization programming should not be approached as just a special case of 3-dimensional (3D) graphics programming. While the two share concepts and algorithms, their goals and methods are quite distinct. Indeed, there are peculiarities inherent in displaying mathematical objects and processes that if properly taken into account can greatly simplify programming tasks and lead to algorithms more efficient than the standard techniques of 3D graphics programming. Conversely, if one ignores these special features and, for example, displays a mathematical surface with software techniques designed for showing the boundary of a real-world solid object, many essential features of the surface that a mathematician is interested in observing will end up hidden. The mathematician's fine categorization of surfaces into parametric, implicit, algebraic, pseudo-spherical, minimal, constant mean curvature, Riemann surfaces, etc., becomes blurred by the computer graphics notion of surface, and one quickly learns that not only are off-the-shelf computer graphics methods inadequate for creating and displaying all of these various types of surfaces but also that a special method designed to optimize the display of one type of mathematical surface may not be appropriate for others. One corollary of this is that it is not a good strategy to base mathematical visualization on some small fixed number of predefined, high-level graphics routines and expect that one will be able to shoehorn in all varieties of mathematical objects. Of course, one needs a number of low-level graphics primitives to get going, but instead of the Pro-

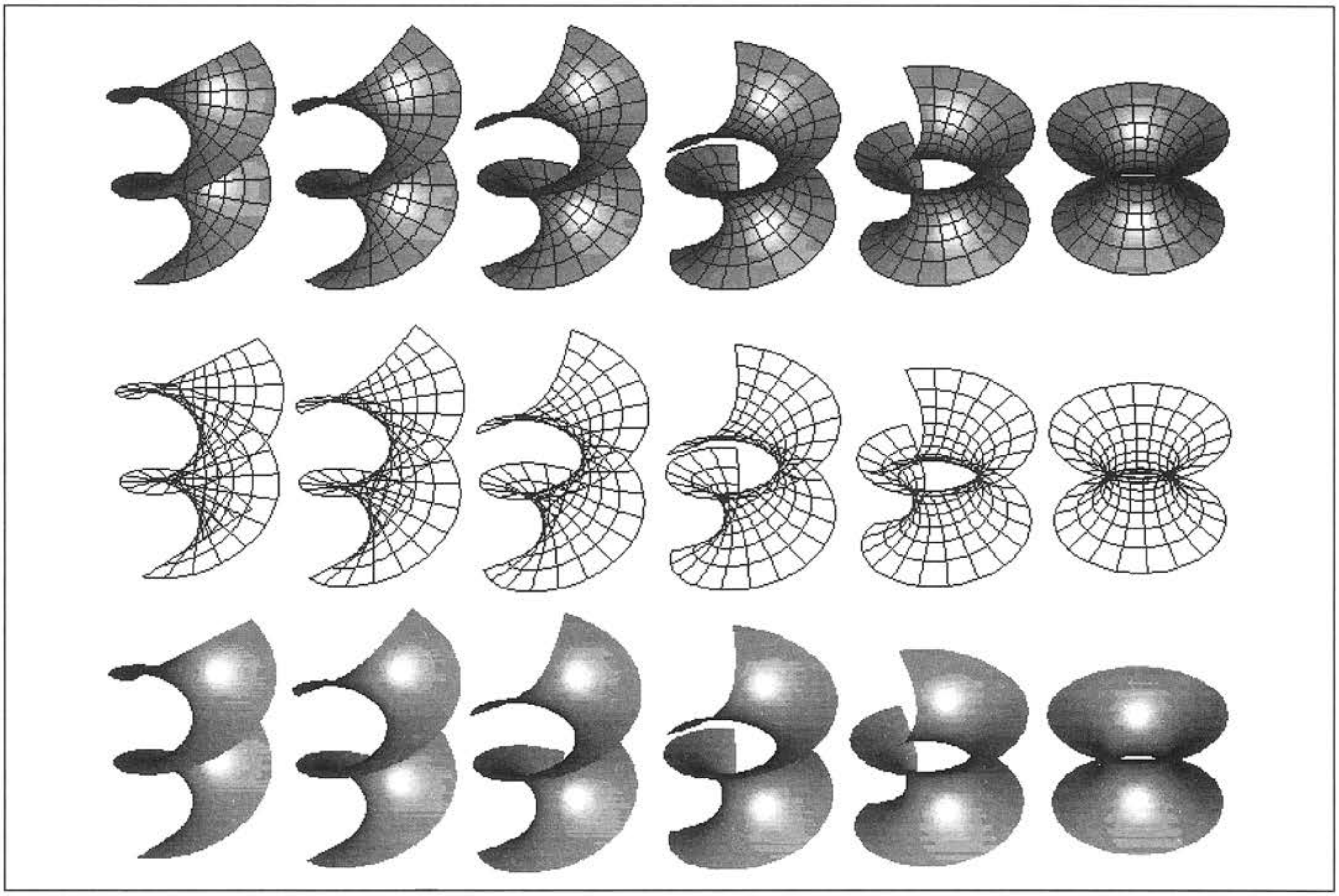


**Figure 2. Helicoid-Catenoid Morph. Shown here (using three rendering methods) are six frames of the associate family morph joining the helicoid and catenoid minimal surfaces. Patch rendering (top) and wireframe rendering (middle) expose the isometric quality of the deformation, while ceramic rendering conceals it. Note how the automatic hidden lines feature of the painter's algorithm makes the patch version visually superior to the wireframe one.**

crustean approach, attempting to fit each mathematical object to one of a few high-level display methods, it is better to use the low-level routines to design optimal display algorithms for each special kind of mathematical situation. This entails more effort for the programmer, but the superior results warrant the extra effort. A second corollary is that one or more mathematicians must play a central and ongoing role in the planning and development of any serious mathematical visualization software project. I consider myself fairly knowledgeable in differential geometry, and for much of the basic programming of the curves and surfaces parts of my program I played both the role of programmer and of mathematical consultant. But I found that it was absolutely essential for me to work closely with experts (Hermann Karcher and Chuu-Lian Terng respectively) to do a professional job in programming the creation and display of minimal surfaces and pseudospherical surfaces.

In what follows I will, as above, often illustrate some point by referring to the visualization of geometric objects like curves, surfaces, and polyhedra. I choose such examples mainly because they are highly intuitive and so require less explanation. But it is important to realize that almost all of the same points could be made in relation to the display of conformal mappings, solutions of ordinary and partial differential equations, or visualizations associated to almost any other category of mathematical object.

**Multiobject vs. Single-Object Graphics Worlds**

I claimed above that mathematical visualization has features that set it apart from general computer graphics and that requires some special techniques and algorithms. In this and the next section I will give two simple examples that illustrate this point.

If one examines a typical visual created by a 3D graphics program, say the lead-in to a nightly TV news program, one sees many different objects moving in disparate ways. A globe representing the earth spins around a vertical axis, while a logo zooms in as it simultaneously rotates about a horizontal axis, etc. This is an example of what I will refer to as a multiobject graphics world. The normal method for animating such a world is to create each 3D object in a "fiducial" location and orientation and then associate to the object a $4 \times 4$ "update matrix" that, for each frame of the animation, will have the values needed to translate and rotate the object from its original position to the position appropriate for that frame. To create one frame of such an animation requires that each point of each object in this multiobject world be transformed by the matrix appropriate to its object. To create a real-time animation for a scene of any complexity using this method, one needs a very powerful computer—usually one with specialized graphics hardware.

On the other hand, if one examines a typical mathematical visualization, one sees that it consists of a single object (curve, surface, polyhedron, etc.) that is usually centered on the screen, and a rotation animation is almost always about the screen center. Let me refer to such a graphics setup as a single-object graphics world. Now, of course, one could treat such a setup as just a special case of an $n$ object world, ignoring the fact that $n = 1$. But 1 is a rather special integer, and in fact there is a more efficient way to rotate a single-object world about an axis than applying the associated rotation matrix $M$ to each of the points defining the object—namely, apply the matrix inverse of $M$ to the viewing camera location and the three vectors defining its orientation. Visually this will have the same effect, but in general it will be considerably more efficient, and it can make it possible to do real-time rotation on simple desktop computers without special graphics hardware.

**Offscreen vs. Onscreen Drawing**

A standard rendering technique for displaying a surface on a computer monitor is the "painter's algorithm". The surface is represented as the union of "facets" (colored polygons, often triangles or rectangles). These facets are sorted by their distance from the viewing camera; then they are "painted" on the screen from back to front. This has the obvious advantage of automatically hiding those facets that are behind other facets.

Computer graphics experts nearly always couple the painter's algorithm with a second technique called "double-buffering" or "offscreen drawing". That is, they first draw the entire surface in a so-called "offscreen buffer", a block of computer memory that duplicates the video display memory. Only when the surface is complete is this buffer copied back to the video display. The result is that the completed surface suddenly appears on the monitor. The reason for double-buffering is that, in most situations, the user is not supposed to see the ugly sight of a partially painted surface.

But in certain situations, using offscreen drawing to display a mathematical surface is a programming offense that approaches a felony! Most interesting surfaces are highly complex and often immersed rather than imbedded. Viewed from any location, there will be several "sheets", and important details on far sheets will be obscured by the nearer sheets. Watching such a surface gradually being built up by the painter's algorithm can be a remarkably revealing experience, playing the role for a geometer akin to dissection for an anatomist.

Nevertheless, I receive occasional well-meaning e-mail messages from nonmathematicians with a knowledge of 3D computer graphics who have somehow come across my program. The message is always the same: my program is very nice, but I should really get hold of an elementary text on computer graphics and learn about double-buffering so that I can get rid of those silly partially drawn surfaces! (I usually respond that I do use double-buffering: after the surface is completely drawn on-screen, I copy the video RAM to an offscreen buffer that I use for screen updating. I suspect this completely backwards way of doing things convinces them I am hopeless, since the exchange usually ends there.)

## Processes

### It Is Important to Visualize Processes As Well As Objects

When I started developing my program, I felt that the main task of a mathematical visualization program was to display various mathematical objects. But as time has passed I have come to realize that this is only part of the story and perhaps much more important is the display of mathematical *processes*. I would be hard put to give a precise mathematical definition of what I mean here by "process"—one that would cover all the important cases that might arise—but, roughly speaking, I mean an animation that shows a related family of mathematical objects or else an object that arises by some procedure naturally associated to another object. Perhaps it is best to explain with a few examples.

**Morphing**

Morphing is one of the most important processes, so let me explain it first. Most mathematical objects occur in natural families that are described by certain parameters—also called moduli if we first divide out an appropriate group of automorphisms. For example, an ellipse can be described by five parameters, the coefficients of its implicit equation, and, if we divide out by the rigid motions of the plane, by two moduli, namely, the lengths of the two semi-axes. One initial goal for a mathematical theory of some new kind of object is usually a "classification theorem"—roughly speaking, discovering the space of moduli. The next step is a detailed investigation of the moduli space to see how various properties of the object depend on the moduli and to see what values of the moduli give rise to objects with special, interesting properties. For example, when its two semi-axes are equal, an ellipse is a circle and has a continuous group of symmetries, while the generic ellipse has only a finite symmetry group.

If we can devise a good way of displaying an object graphically, including its dependence on moduli, then we can move along a curve in the moduli space and draw frames consisting of the graphical representation of the object at various points along the curve. If we then play these frames back in rapid succession, we get a movie of how the object changes as we change the moduli along the curve, and this is what I call a *morph*. Clearly this can be a powerful tool in investigating the moduli space. Often, even when the moduli space is infinite dimensional, it will contain special curves that provide interesting morphs.

For example, minimal surfaces come in one-parameter families (so-called *associate families*), all of whose members are isometric, though usually not congruent. Using the associated family parameter as a morphing parameter provides a particularly beautiful animation, one that in principle can be modeled in sheet metal. The helicoid and the catenoid belong to an associate family, and differential geometry books often show several frames of a morph between them. (See Figure 2.)

Similarly, the space of moduli for pseudospherical surfaces can be identified with the space of solutions of the Sine-Gordon partial differential equation. The latter contains certain $n$-parameter families (the pure $n$-soliton solutions) that correspond to particularly interesting surfaces. The 1-solitons correspond to the well-known Dini family, which contains the pseudosphere, and it was Chuu-Lian Terng's desire to see how properties of the corresponding surfaces changed as one morphed within the 2-soliton family that provided the original motivation for starting work on my program. (See Figure 3.)

The morphing process is such a powerful and revealing tool that whenever I add a new category of mathematical objects to the repertory of my program, I spend a lot of time thinking about and experimenting with creative ways to use morphs that are particularly adapted to that category. For example, I found that in displaying conformal maps, morphing along a carefully chosen path between a given map and the identity map is a particularly good way to reveal the structure of the map. And morphing is the obvious method for displaying the bifurcations of solutions of ordinary differential equations or for watching the onset of chaos as some key parameter is varied. A typical case of the latter is the well-known Lorenz equation that provided one of the motivations for early work on chaos. In fact, Lorenz used the primitive computer techniques available to him at that time to vary the Reynolds number and watch as an attracting fixed point turned into the "Lorenz Attractor".

**More Processes**

Let me quickly mention just a few other "processes" to illustrate further the scope of that term.

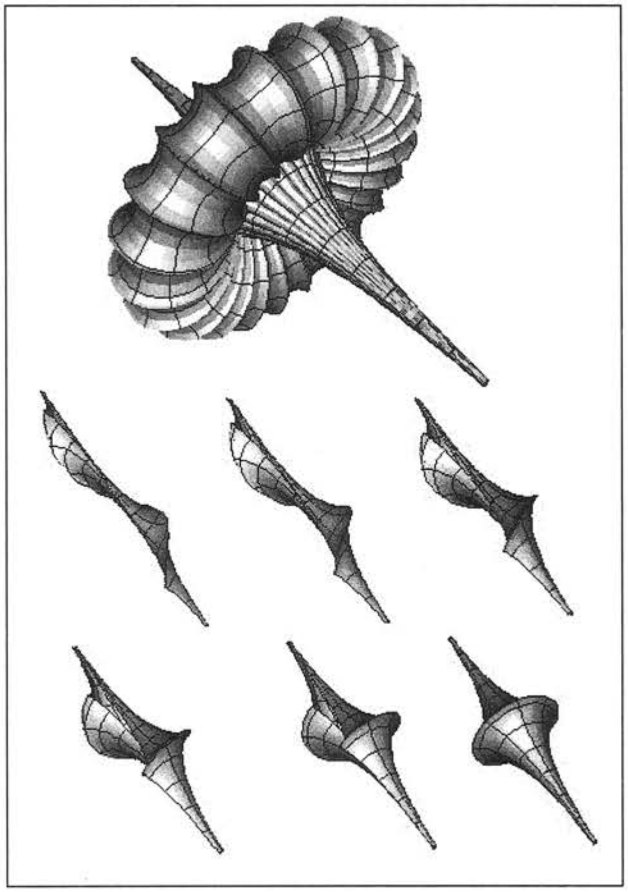


**Figure 3. Pseudospherical Surfaces. Solutions of the Sine-Gordon Equation (SGE), $u_{tt} - u_{xx} = \sin(u)$, correspond one-to-one with surfaces in $R^3$ that model Lobachevsky's hyperbolic geometry. SGE is a soliton equation, and at top we see the surface corresponding to a time-periodic solution with soliton number 2 called The Breather. Below that is a six frame morph through the Dini family of surfaces, corresponding to the 1-parameter family of SGE 1-solitons.**

If a plane curve is given, it is revealing to show an animation in which the "osculating circles" are drawn at a point that moves along the curve, the centers of curvature tracing out the evolute of the curve as the animation proceeds. In fact, there are many such classical processes that associate other curves with a given curve (pedals, strophoids, epicycloids, parallel curves, etc.), most of which become much easier to understand and illustrate with a computer.

For a space curve, an interesting process is the construction of a "tube" about the curve. This construction involves choosing a framing for the normal bundle to the curve, usually the "Frenet frame", and the tube serves to reveal the important (but usually invisible) framing. One's first impulse is to choose a tube with a round cross-section on aesthetic grounds, but to see the framing clearly, one should use a tube with a square cross-section. Once they see the point, mathematicians will almost

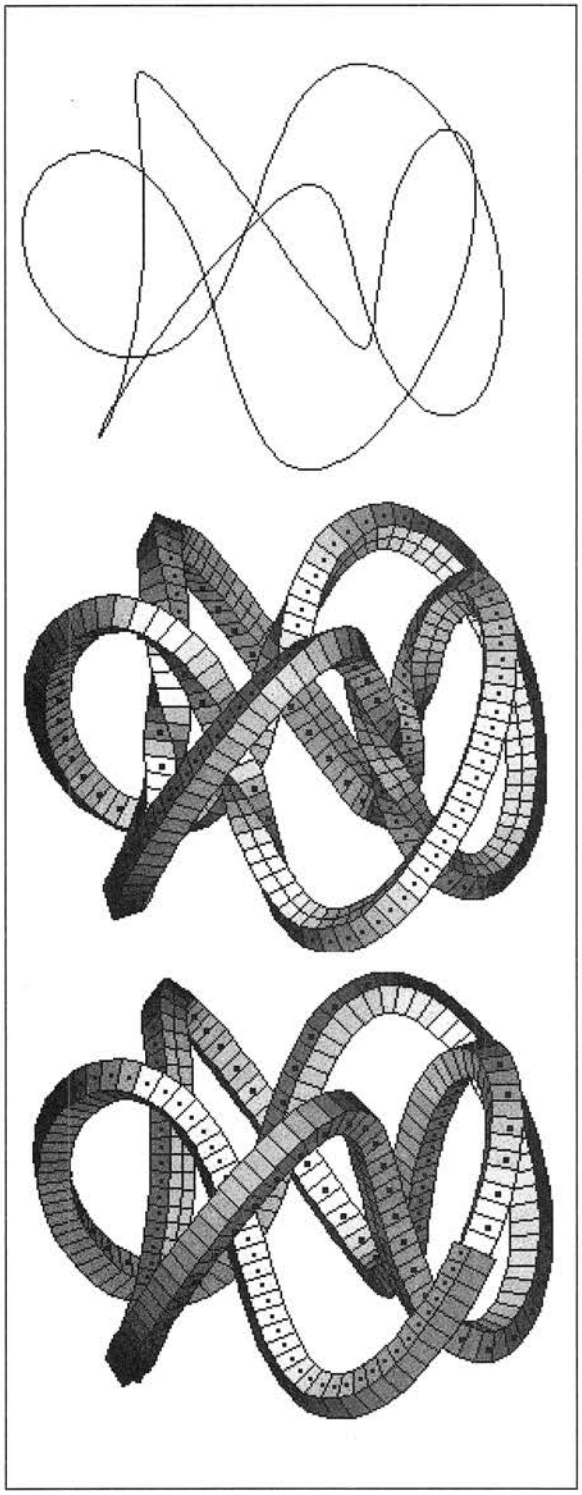


**Figure 4. Tubes about a Torus Knot. A projection of the 2, 5-torus knot, and of two tubes about it with square cross-section. The upper tube uses the Frenet framing of the normal bundle; the other uses parallel framing. Notice how the tubes expose the 3-dimensional nature of the knot. One can see the Frenet frame twist more rapidly in the inside of the torus, and the eye also detects the nontrivial holonomy of the parallel framing, shown by the tube not matching up in the lower right.**

always prefer the latter. Most people are usually very surprised to see how fast the Frenet frame may twist where the curvature is small. It is also interesting to switch from the Frenet frame to a parallel framing of the normal bundle. In this case there is no twisting, and the framing indeed looks parallel. But now the holonomy becomes strikingly visible: in going around a closed curve, the frame does not usually return to its starting value. (See Figure 4.)

For a surface, important processes are the construction of its focal sets and parallel surfaces.

For a polyhedron, two interesting processes are the constructions of its stellation and its truncation (the latter is what converts a regular icosahedron into a buckyball), and I find it instructive to morph between the untruncated and truncated forms.

## Mathematics vs. Art

One should not confuse mathematical visualization with mathematical art. By the latter I am referring to the work of talented graphic artists and sculptors whose principal subject matter originates in the world of mathematics. Everyone has seen the fascinating and beautiful mathematical drawings of M. C. Escher [Sc], the famous Dutch graphic artist of the first half of this century. More recently, the Russian mathematician and artist Anatoliĭ Fomenko has enriched our mathematical heritage with spectacular images of surreal vistas, drawn from the depths of his own inspired imagination, that illustrate and illuminate complex mathematical concepts [Fo]. Currently a new generation of artists is finding inspiration from the platonic world of mathematics. Prominent among these are the sculptors Helaman Ferguson, Charles Perry, and Brent Collins. All of them use mathematical visualization software to create the objects that underlie their sculpture, but like Escher before them, they then impress their own artistic vision on the mathematical raw material from which they start.

One seeming distinction between a mathematical visualization graphic and a piece of mathematical art is the apparent difference in time and difficulty it takes to produce them. The former is usually generated completely automatically, often in only a few moments of computer time, while the latter often takes days or even weeks of skilled handwork by the artist, perhaps preceded by an even longer period of thoughtful planning. But this way of seeing things distorts a deeper reality. The serious work of planning and creating a mathematical visualization graphic really takes place when the algorithms are developed and coded, and for complicated objects this can be a long and arduous piece of research. It is the programmer, not the computer, that creates a mathematical visualization.

The real difference between the two lies in their ultimate goals. In the creation of mathematical art, mathematics is a starting point, but art controls—"artistic license" is granted the artist to deviate from perfect fidelity to the mathematics and to use other aesthetic principles to emphasize aspects of reality that the artist is trying to show us.

But in the creation of a mathematical visualization, the controlling principle should always be to show as clearly as possible the underlying mathematical qualities and properties of the objects being visualized. The temptation to "pretty up" a visualization should be resisted, particularly if mathematical information gets lost in the process. One example of this principle was mentioned above, namely, using square rather than circular cross-sections for tubes around space-curves in order to make visible the framing of the normal bundle.

Here is another example, this time from surface theory. Examination of a great many computer-generated surface visualizations will show that they almost all fall into one of three main types that I will refer to as wire-frame, patch, and ceramic. The term "wire-frame surface" is self-explanatory. In a patch rendering, one still displays the wire-frame skeleton but in addition fills in each of the rectangular patches with a color that mimics the way white paint on the surface would reflect light from several light sources with different positions and colors. If these positions and colors are chosen with care, a patch mode rendering will give a realistic 3-dimensional appearance to the surface. In a ceramic rendering of a surface, the wire-frame is removed and only the colored patches are displayed. If the patches are small enough, the color of the surface will appear to vary smoothly, and the resulting rendering is again realistic.

Now, a nonmathematician may feel that the wire-frame skeleton is extraneous and that the ceramic version looks more beautiful. But beauty, it is said, is in the eye of the beholder, and to the eye of a geometer it is the wire-frame[2] or patch version that frequently looks more beautiful, since it conveys extra mathematical information that is discarded along with the wire-frame mesh. In fact, if chosen with care, the mesh will be an orthogonal net that displays the conformal structure or even the Riemannian metric induced from the immersion of the surface into $R^3$. A dramatic way to illustrate this is to watch in succession three versions of the helicoid-catenoid morph, using first wire-frame, then patch, then ceramic rendering. The crucial fact that one wants to illustrate, namely, that an associate family deformation is isometric, fairly jumps out of the screen in the first two versions but is completely hidden with a ceramic rendering (Figure 2). My point is not that a patch rendering is necessarily always better than a ceramic one, but rather that when using software to create a mathematical visualization, the ideal should be to carefully tailor all available options to display best the mathematical features that need emphasizing in a particular situation, and aesthetics should not be permitted to override mathematical considerations.

### The Mathematical Exploratorium

It is no secret that the incredible quantity of information on the World Wide Web is as yet poorly organized and is not easily classified as to relevance and quality. Trying to separate nuggets of serious value from all the dross can be a frustrating experience. Asking any of the various Web search engines to provide a list of Web sites that contain references to almost any imaginable topic will result in bushels of possibly relevant Web addresses (i.e., URLs), but sifting through them to find the few that are of serious interest is usually an arduous and time-consuming task.

*I think of my drawings as if they were photographs of a strange but real world.*
*—Anatoliĭ Fomenko*

Over the past year I have been diligently searching the Internet for sources of mathematical visualizations,[3] both as preparation for writing this article and for use in another project in which I am involved. It was a pleasant surprise to see how many things one can find already, and this corpus is growing rapidly. Of course it is not of uniform quality—some is amateurish and slapdash—but there is also much of professional quality. As I gradually arranged this material for my own immediate purposes, I began to realize what a useful resource could be created by carefully organizing all the best-quality visualizations and animations of mathematical objects and processes, cataloging and documenting them to form an online virtual museum of mathematics that I refer to as The Mathematical Exploratorium. Let

[2] *To be sure, wire-frame rendering lacks 3-dimensionality, but that defect can be easily overcome by using various stereo vision techniques. The name of my program, 3D-Filmstrip, was chosen because it emphasizes stereo rendering of 3D objects using the* anaglyph *method (i.e., using red/green glasses).*

[3] *I have created a gallery of 3D-Filmstrip visualizations and animations and placed it on the Web. The main catalog is at the Web address* `http://rsp.math.brandeis.edu/3D-Filmstrip_html/Galleries/Catalogs/MainCatalog.html`*, and that catalog also contains links to many of the best examples of mathematical visualization that I know of on the Web.*

me explain what I have in mind in a little more detail.

The Mathematical Exploratorium would be divided into "wings". There would be a Surface Wing, a Polyhedron Wing, a Fractal Wing, a Tiling Wing, an Ordinary Differential Equation Wing, etc. There would also be a wing devoted to a Museum School, where there would be software packages for the creation of visualizations as well as documentation and tutorials explaining their use. Each wing would be divided into galleries: for example, the Surface Wing would have a Pseudospherical Surface Gallery, a Minimal Surface Gallery, and so on, and some galleries would be further divided into alcoves.

There would be a main catalog that would list in an abbreviated format all the "holdings" of the Exploratorium, and each wing and gallery would have its own more detailed catalog, with thumbnail previews of all the objects it contains. Of course, these catalogs would be written in html (the "hypertext markup language"), and clicking on the name of an object or an animation would bring it up on the computer screen.

Each visualization would be accompanied by a short label giving its identity, its creator, and other items of a bibliographic nature. In addition, the label would contain a link to detailed mathematical documentation of the object being visualized—discoverer, special properties, mathematical theorems it illustrates, relations to other objects, interesting ways to morph it, etc. Similarly, each wing and gallery would have documentation that gives a quick overview of the mathematical area it covers and references to one or more monographs that cover the subject in detail.

## A Little History

Two problems in mathematics have helped push the state of the art in mathematical visualization—namely, the problems of everting the 2-sphere and of constructing new, embedded, complete minimal surfaces, especially higher-genus examples. In the case of eversion, the goal was to illuminate a process so complex that very few people, even experts, could picture the full details mentally. In the case of minimal surfaces, the visualizations actually helped point the way to rigorous mathematical proofs.

### Everting the Sphere

Let $f : S^n \to R^{n+1}$ be a smooth map of the $n$-sphere into Euclidean space of dimension $n+1$. We recall that $f$ is called an *immersion* if it is locally a nonsingular embedding or, equivalently (by the Implicit Function Theorem), if at each point $p$ of the sphere the differential, $Df_p$, is injective. In this case, we can associate to $f$ a self-mapping $G_f$ of $S^n$ (called the *Gauss map* of $f$) as follows. The (oriented) tangent space of $S^n$ at $p$ is mapped by $Df_p$ onto an oriented $n$-dimensional subspace $V$ of $R^{n+1}$, and $G_f(p)$ is that one of the two unit normals to $V$ that extends the orientation of $V$ to the standard orientation of $R^{n+1}$. We call the degree of $G_f$ the *turning number* of $f$.

A homotopy $f_t$ of $f = f_0$ is called a *regular* homotopy if each stage is an immersion and if, in addition, $f_t(x)$ is jointly smooth in $t$ and $x$. In that case, $Df_t$ is a homotopy and is easily seen to induce a homotopy $G_{f_t}$ of Gauss maps so that the turning numbers of $f_0$ and $f_1$ will be equal. It is a simple exercise to compute that the turning number of the identity map is 1 while that of the antipodal map is $(-1)^n$.

An *eversion* of the $n$-sphere is by definition a regular homotopy between the identity map and the antipodal map—in effect it turns the $n$-sphere inside out without creasing it along the way. By what we have just seen, there can be no eversion of a circle (or any odd-dimensional sphere). But how about the 2-sphere? The turning number is not an obstruction, but can we really turn it inside out? For most differential topologists in the mid-1950s it seemed that the answer must be no, so there was considerable surprise—and even some disbelief—when Stephen Smale in his thesis [Sm] proved a general result having as a corollary that *any* two immersions of the 2-sphere in $R^3$ were regularly homotopic. Smale's proof was in principle constructive, but it was so complicated that it did not really provide an effective method for giving an explicit eversion. The first explicit eversion was apparently discovered by Arnold Shapiro in 1961. Shapiro never published it, but it was described (with illustrations) by Anthony Phillips in a 1966 *Scientific American* article [Ph] that first brought the sphere eversion problem to public attention.

All proposed explicit eversions have been so complicated that most people are able to understand how they work only by watching an animated visualization played many times over. The first reasonably simple eversion was discovered by Bernard Morin in 1967, and a number of stages of Morin's eversion were rendered into chicken-wire models by Charles Pugh. Nelson Max [MC] digitized the grid points of these models by making careful hand measurements of their locations and then using a computer to interpolate the resulting 3-dimensional grids, creating in this way a morphing animation in the form of a movie (*Turning a Sphere Inside Out*) that provided the final "seeing is believing" argument to convince any remaining doubters that the 2-sphere could indeed be everted. In two further films (*Regular Homotopies in the Plane, Parts I and II*) Max used visualization techniques to explain the statement and proof of the so-called Whitney-Graustein Theorem—the fact that equality of turning numbers is not only necessary but also sufficient for two smooth immersions of the circle in the plane to be regularly homotopic.

Many more computer-generated visualizations of eversions have been proposed since that first one. One, suggested by William Thurston, has been made into a beautiful video called *Outside In* [L]. It is available, accompanied by a highly readable brochure called *Making Waves*, written by Silvio Levy. The latter documents the making of the video and the mathematics behind it and also gives further details concerning the history of sphere eversions through 1995. A recent and very interesting sphere eversion that uses Brakke's Surface Evolver software is described in [Sc] and [FSKB].

**Constructing Embedded Minimal Surfaces**

The theory of minimal surfaces is a fascinating mixture of complex function theory, partial differential equations, and differential geometry, and for well over a century it has attracted the creative energies of successive generations of mathematicians. Recent activity has centered on the study of embedded, complete minimal surfaces of "finite topology" (i.e., conformal to a compact Riemann surface with a finite number of points removed). Two decades ago the only known examples of such minimal surfaces were the plane, the catenoid, and the helicoid, all of which were already known to the geometer J. Meusnier at the time of the American Revolution. The fact that no more had been discovered over such a long period led to the obvious conjecture that there were in fact no others. About thirty years ago Robert Osserman started investigating a somewhat more restrictive class of complete minimal surfaces, namely, those for which the total curvature (i.e., the integral of the Gaussian curvature) was finite. Osserman's investigations eventually led to very tight constraints for any possible new embedded example of such a surface. Another decade passed before Celsoe Costa, in his thesis, discovered an example of a finite-curvature minimal immersion of the square torus with three punctures that fit all the known constraints for it to be embedded. But the equations were so complicated that there seemed no way to approach the problem of providing the analytic details required for a rigorous demonstration that Costa's surface had no self-intersections.

David Hoffman heard about the Costa example in a telephone conversation with Osserman and quickly decided to use computer graphics techniques to attempt to visualize Costa's surface well enough to check whether it at least appeared to be embedded and, if so, then perhaps also to see some visual clues that might help prove embeddedness rigorously. Hoffman discussed his ideas with William Meeks, who also became excited about the possibility of using computers in such an innovative way. Working together with James Hoffman, an expert in computer graphics programming, they were able to carry out this program over the course of several weeks, during which they alternated between staring at computer-generated images and finding rigorous proofs for the surprising conjectures those pictures suggested. (See Figure 1.) David Hoffman's well-written article [H] describing this project makes wonderful reading. I can do no better than quote a little from his telling of the story:

> ... we were able to create pictures of the surface. They were imperfect ... [H]owever, Jim Hoffman and I could see after one long night of staring at orthogonal projections of the surface from a variety of viewpoints that it was free of self-intersections. Also, it was highly symmetric. This turned out to be the key to getting a proof of embeddedness. Within a week, the way to prove embeddedness was worked out. During that time we used computer graphics as a guide to "verify" certain conjectures about the geometry of the surface. We were able to go back and forth between the equations and the images. The pictures were extremely useful as a guide to the analysis.

The article ends with these words:

> The computer-created model is not restricted to the role of illustrating the end product of mathematical understanding, as the plaster models are. They can be part of the process of doing mathematics.

## Software for Mathematical Visualization

My program, 3D-Filmstrip, is a mathematical visualization tool for Macintosh computers that is written in Object Pascal. The principal goal that has guided me in its development has been to make available a wide variety of interesting mathematical visualizations from many areas of mathematics, using an interface that is easily accessible, even to new users and nonprogrammers. One simply chooses an object from a pull-down menu (or describes a "user object" by entering a few algebraic formulas) and then immediately sees a default view of that object. There are several menus for customizing the view in various ways and another for creating animations. For a more complete description, including full documentation in hypertext (HTML) format, visit the 3D-Filmstrip home page on the Web {3dfs}.[4] The home page also has a link to a gallery of visualizations and QuickTime animations produced using the program. Macintosh users can obtain a copy for their personal use by

[4] *References in curly brackets refer to Universal Resource Locators (URLs) that will be found in the references at the end of the article.*

**Online Mathematics Visualization Software**

{3dfs} 3D-Filmstrip Home Page, http://rsp.math.brandeis.edu/public_html

{Evol} Ken Brakke's Surface Evolver Home Page, http://www.susqu.edu/facstaff/b/brakke/evolver/evolver.html

{Geom} Geomview Home Page, http://www.geom.umn.edu/software/download/geomview.html

{Grp} Grape Home Page, http://www-sfb288.math.tu-berlin.de/~konrad/grape/grape.html

{Oor} Oorange Home Page, http://www-sfb288.math.tu-berlin.de/oorange

{Snap} SnapPea Home Page, http://www.geom.umn.edu/software/download/snappea.html

{Sup} Superficies FTP Site, ftp://topologia.geomet.uv.es/pub/montesin/Superficies_Folder/

{Surf} Surf Home Page, http://www.mathematik.uni-mainz.de/AlgebraischeGeometrie/surf/surf.shtml

{MLb} Mathworks (Matlab) Home Page, http://www.mathworks.com/products/matlab/

{Mpl} Maple Home Page, http://www.maplesoft.on.ca/

{Wri} Wolfram Research (Mathematica) Home Page, http://www.wri.com/

downloading it from a link on the home page or using an ftp client aimed at:

ftp://rsp.math.brandeis.edu/pub/

As a developer of a particular mathematical visualization software package, I think it would be inappropriate in an article such as this for me to review other "competing" packages, so I will restrict myself to listing some of the better-known ones, with a few descriptive remarks about each.

There are a number of commercial software packages with mathematical visualization capabilities. Of these, perhaps the best known are The Three M's: Matlab {MLb}, Maple {Mpl}, and Mathematica {Wri}. The standard licenses for these programs are expensive, but there are also inexpensive student versions available, and many universities have site licenses. These are not primarily mathematical visualization programs. Maple and Mathematica are symbolic manipulation programs, and Matlab is a numerical analysis program, but all three have very good graphic backends for displaying the results of their computations, making them excellent platforms for mathematical visualization. One minor drawback is that each of these programs has its own programming language that a user must learn in order to do anything nontrivial with them. But these are very high-level interpreted languages, and they are considerably easier to learn and to use than the standard compiled languages. An important point in their favor is that there are versions of each for Macintosh, Wintel, and various flavors of UNIX, and software developed for any of these platforms is readily transportable to the others.

Geomview {Geom} is not really a mathematical visualization program in itself, but rather, as its name suggests, a viewing program. To use it, the user must create a 2D or 3D object in a prescribed format, either by writing a program to do so or by using some program (such as Surface Evolver; see below) that has a Geomview interface built in. Grape {Grp} and Oorange {Oor} are similar to GeomView, but they provide more tightly integrated facilities for the creation of the mathematical content to be displayed. Competent C programmers used to working on a UNIX workstation will probably find that using one of these programs provides the easiest approach to creating sophisticated mathematical visualizations on their own. But Mac or Wintel users and those without programming experience using a compiled language will probably be more comfortable working with one of the commercial programs mentioned above.

I should also mention some special-purpose mathematical visualization programs. There are many programs for displaying solutions of ordinary differential equations and analyzing them for various dynamical systems-related properties (closed orbits, limit cycles, etc.). Indeed, the use of such programs is rapidly becoming an essential component in the teaching of this subject. Some of these programs are stand-alone, while others are written to be used in conjunction with Matlab, Maple, or Mathematica.

Creating visualizations of implicitly defined curves and surfaces leads to many interesting problems, both for the mathematician and for the programmer. The need to solve the equations involved numerically is one major difficulty. Constructing reliable and efficient algorithms for finding all the solutions when there are no restrictions on permitted singularities is not a completely solved problem. This is so even for the important special case of interest to algebraic geometers, namely, when the objects in question are defined as the solutions of polynomial equations. Another difficulty is that implicitly defined surfaces do not come equipped with a natural grid, and so special techniques (such as so-called "ray-tracing" methods) must be used to render them. Because of these challenges (and the importance of algebraic geometry), it should come as no surprise that there are a number of programs that specialize in displaying implicit surfaces. On the Macintosh there is Angel Montesinos Amilibia's Superficies program {Sup}. This has the kind of intuitive user interface one expects from a Macintosh program; and in addition to displaying a surface from a user-supplied implicit equation, it will also draw geodesics, asymptotic lines, and curvature lines on the surface.[5] In the UNIX world, there is a program called Surf, written by Stephen Endraß {Surf}. (Endraß has made his source code available under the GNU license.)

[5] *I would like to thank Angel Montesinos Amilibia for permitting me to use some of his algorithms and code for handling implicit curves and surfaces in 3D-Filmstrip.*

Two other notable special-purpose programs are Jeff Weeks's SnapPea {Snap}, for creating and investigating 3-dimensional hyperbolic geometries, and Ken Brakke's Surface Evolver {Evol}, for investigating the evolution of surfaces under various "energy"-minimizing gradient flows.

## Why Write Mathematical Visualization Software?

At this point I should confess that one of my goals is to encourage others to become involved in building the Mathematical Exploratorium. The creation of mathematical visualization software and content is a relatively new and growing area, full of opportunities to make significant, original contributions. I work on mathematical visualization mainly because I enjoy the challenge of making abstract mathematical concepts "come alive" by implementing them in software. But more than that, I think of it as a new form of publication. Part of the obligation (and joy) of the academic life is giving some form of permanent expression to the ideas we have thought hard about. That, after all, is what we mean by publication.

Traditionally, mathematicians have satisfied this obligation by writing books and research articles, and these will no doubt continue to be the primary form of mathematical communication. A program is not a substitute for a theorem, and an assistant professor worried about publishing enough papers to qualify for tenure should probably think twice before becoming involved in a time-consuming software project. Nevertheless, as mathematics gets ever more complex, it becomes increasingly important to have good tools to supplement our intuition and for communicating our intuitive ideas to others.

Until recently graphics systems powerful enough to do interesting geometric modeling existed only in a few centers that could afford the expensive combination of hardware and software that such systems required. Moreover, these systems required special proprietary hardware and drivers so that they could not run even slowly on the standard Macintosh and PC-type workstations that have become ubiquitous in academia. But the supercomputer of a decade ago was no more powerful than today's high-end Macs and PCs, and very respectable mathematical visualization programs can now be written for these machines. The time has clearly arrived to make the powerful geometric modeling algorithms that have been developed in recent years more widely available to the whole mathematical community. It is not easy. The problem is not just to translate the code, but also to create programs with good user interfaces that are easy to use for someone other than the programmer. I am hoping that 3D-Filmstrip will serve as an early example of this kind of mathematical visualization program, one that will stimulate others to create ever better software for giving life to our mathematical imaginings.

## Acknowledgments

Many people have contributed to my education in mathematical visualization, but I would like to express very special thanks to Hermann Karcher, from whom I learned most of what I know. Hermann is a true pioneer in the field. He was creating amazing visualizations on his Atari a dozen years ago, before the subject became fashionable. He is also one of the leading experts in the modern rebirth of minimal surface theory that resulted from the discovery of the Costa surface. The feature of 3D-Filmstrip that many people find most appealing is the large repertory of minimal surfaces it can display, both classic surfaces and recently discovered ones. All the sophisticated mathematical algorithms required to build and render these surfaces came from Hermann, and I shall always remember with pleasure the long programming sessions as we wrote the code that made the screen light up with one after another of these beautiful objects. Hermann's wife, Traudel, is responsible for perhaps the single most striking visualization in 3D-Filmstrip: it models the remarkable gyrations of a charged particle in the Van Allen Belt as it moves under the influence of the Earth's dipole magnetic field.

## References

### Articles

[Ab] J. Abouaf, Variations of perfection: The Séquin-Collins sculpture generator, *IEEE Computer Graphics and Applications* **18** (1998).

[CHH] M. Callahan, D. Hoffman, and J. Hoffman, Computer graphics tools for the study of minimal surfaces, *Comm. ACM* **31** (1988), 641–661.

[FSKB] G. Francis, J. Sullivan, R. Kusner, K. Brakke, C. Hartman, and G. Chappell, The minimax sphere eversion, *Visualization and Mathematics* (Berlin-Dahlem, 1995), Springer, 1997, pp. 3–20.

[HMF] A. Hanson, T. Munzner, and G. Francis, Interactive methods for visualizable geometry, *IEEE Computer* **27** (1994), 78–83; `http://graphics.stanford.edu/papers/visgeom/`.

[H] D. Hoffman, Computer-aided discovery of new embedded minimal surfaces, *Mathematical Intelligencer* **9** (1987).

[HWK] D. Hoffman, F. Wei, and H. Karcher, The genus one helicoid and the minimal surfaces that led to its discovery, *Global Analysis in Modern Mathematics* (K. Uhlenbeck, ed.), Publish or Perish Press, Houston, TX, 1993, pp. 119–170.

[MC] N. Max and W. Clifford, Computer animation of the sphere eversion, *ACM J. of Comput. Graphics* **9** (1975), 32–39; films available from International Film Bureau, 332 S. Michigan Ave., Chicago, IL 60604.

[Ph] A. Phillips, Turning a surface inside out, *Scientific American* (May 1966), 112–120.

[PLM] M. Phillips, S. Levy, and T. Munzner, Geomview: An interactive geometry viewer, *Notices* **40** (October 1993).

[PP] U. Pinkall and K. Polthier, Computing discrete minimal surfaces and their conjugates, *Experimental Mathematics* **2** (1993).

[Sc] Sphere does elegant gymnastics in new video, *Science* **281** (July 31, 1998), 634.

[Sm] S. Smale, A classification of immersions of the two-sphere, *Trans. Amer. Math. Soc.* **90** (1958), 281–290.

## Books

[B] T. F. Banchoff, *Beyond the Third Dimension*, Scientific American Library, New York, 1990.

[DHKW] U. Dierkes, S. Hildebrandt, A. Küster, and O. Wohlrab, *Minimal Surfaces*, Springer-Verlag, Berlin and New York, 1992, two volumes.

[EG] D. Epstein and C. Gunn, *Supplement to Not Knot*, Jones and Bartlett, 1991.

[Fe] C. Ferguson, *Helaman Ferguson: Mathematics in Stone and Bronze*, Meridian Creative Group, 1994.

[Fi] G. Fischer, *Mathematical Models, Vols. I and II*, Vieweg, Braunschweig and Wiesbaden, 1986

[Fo] A. Fomenko, *Mathematical Impressions*, American Mathematical Society, Providence, RI, 1990.

[Fr] G. K. Francis, *A Topological Picturebook*, Springer-Verlag, New York, 1987.

[G] A. Gray, *Modern Differential Geometry of Curves and Surfaces*, CRC Press, Boca Raton, FL, 1993.

[HC] D. Hilbert and S. Cohn-Vossen, *Geometry and the Imagination*, Chelsea, New York, 1952. Translation of *Anshauliche Geometrie* (1932).

[L] S. Levy, *Making Waves*, A. K. Peters, 1995.

[Sc] D. Schattschneider, *Visions of Symmetry*, Freeman, San Francisco, CA, 1990.

[W] J. Weeks, *The Shape of Space*, Marcel Dekker, New York, 1985.

## About the Cover

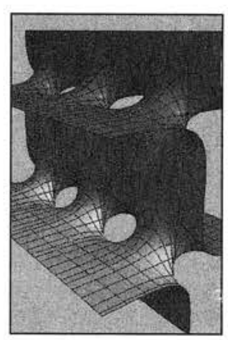
On the cover we see a portion of a minimal surface, the whole of which extends to infinity. Numerical data for parametrizing the surface were created using MATLAB routines written by H. Karcher, and then imported into 3D-Filmstrip for rendering.

A minimal surface is a mathematical model of a soap film, and this fact can be used to compute it numerically: if a closed wire (to be dipped into liquid soap) is described by a mathematical curve, then one can compute the spanning minimal surface numerically by simulating a characteristic property of a soap film, namely that it attempts to "pull itself together" (i.e., minimize its area).

Karcher's numerical algorithm uses a different approach. It starts from the so-called Weierstrass representation of a minimal surface, coming from the field of complex analysis. This has the advantage that the input data (two meromorphic functions on the parameter domain) are closely related to the global geometry of the surface. Moreover, it leads to an efficient and numerically stable algorithm for computing the coordinates of all points of the surface.

The particular surface on the cover is known by the name "Karcher's JE Saddle Towers". (JE refers to a particular Jacobi elliptic function that is part of the Weierstrass data.) This surface exhibits a $Z \oplus Z$ group of translational symmetries. Both generators are visually evident—one is a vertical translation and the other is a translation in the direction of the horizontal straight line that cuts the figure in half. (Rotation by 180 degrees about that line is another symmetry of the surface.) The two sides of the surface have been given slightly different reflectivities. The top of the lower horizontal wing appears lighter than the top of the wing above it because these are on different sides of the surface.

*—H. Karcher and R. Palais*



# Irving Ezra Segal (1918–1998)

*John C. Baez, Edwin F. Beschler, Leonard Gross, Bertram Kostant, Edward Nelson, Michèle Vergne, and Arthur S. Wightman*

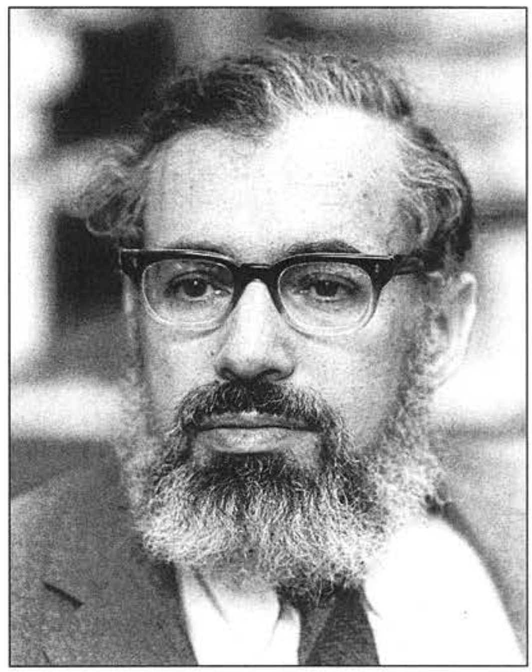
Irving Segal died suddenly on August 30, 1998, while taking an evening walk. He was seventy-nine and was vigorously engaged in research.

Born on September 13, 1918, in the Bronx, he grew up in Trenton and received his A.B. from Princeton in 1937. What must it have been like to be a member of the Jewish quota at Princeton in the 1930s? He told me once that a fellow undergraduate offered him money to take an exam in his stead and was surprised when Irving turned him down.

He received his Ph.D. from Yale in 1940. His thesis was written under the nominal direction of Einar Hille, who suggested that Segal continue his and Tamarkin's investigation of the ideal theory of the algebra of Laplace-Stieltjes transforms absolutely convergent in a fixed half-plane. But, Segal wrote, "For conceptual clarification and for other reasons, an investigation of the group algebra of a general [locally compact] abelian group was of interest." And the thesis was not restricted to abelian groups.

Segal was an instructor at Harvard in 1941, and then war work—first at Princeton and later in the army at the Aberdeen Proving Ground—prevented a full publication of the thesis until 1947.

Looking edgewise at a bound journal volume, one perceives a band spectrum for the articles—the darker the band, the more intensely has the article been studied. Segal's thesis acquired a dark band indeed. Together with M. H. Stone and I. M. Gelfand, he was one of the principal architects of the application of algebraic methods to analysis, vastly simplifying and extending classical results of harmonic analysis.



Irving Segal

After the war Segal spent two years at the Institute for Advanced Study, where he held the first of the three Guggenheim Fellowships that he was to win. Other honors included election to the National Academy of Sciences in 1973 and the Humboldt Award in 1981. At the University of Chicago from 1948 to 1960, he had fifteen doctoral students, and at MIT, where he was professor from 1960 on, formally retiring in 1989, he had twenty-five. Segal's mathematical ancestry runs from Hille and Marcel Riesz through Fejér and Schwarz to Weierstrass.

I had the great fortune to be one of Irving's students. After telling him what I intended to do in my thesis, I was embarrassed to learn from a fellow student that one is supposed to ask for a topic. But Irving never demurred; he gave me free rein and helped launch me on a career. I shall repeat here something I wrote on the occasion of his sixtieth birthday, since it recounts an early experience that helped shape my mathematical life. His encouragement was strong when I was writing a thesis, and equally important was his total lack of encouragement when I found a result unrelated to anything beyond itself. One of the chief characteristics of Segal's work is that his theorems are part of theories, and this sense of the global nature of mathematical research was one of the most valuable things that he imparted to his students.

Segal had an extraordinary intuition for the essential. The work of N. Wiener and of R. H. Cameron and W. T. Martin on Brownian motion was tied to a particular representation; in Segal's hands, it became a general theory of Gaussian integration on Hilbert space. There is no orthogonally invariant Gaussian measure on an infinite-dimensional real Hilbert space, but Segal constructed the corresponding algebra of random variables. And he invariably produced new concrete results that followed from his abstract constructions. Similarly, quantum theory—especially of systems of infinitely many degrees of freedom—was tied to particular representations by operators on some Hilbert space. It was Segal who realized that the structure of physical relevance was the $C^*$-algebra generated by the observables, a discovery that was largely ignored at first and then became taken for granted. These two developments were unified in a theory of algebraic integration that applies to commutative and noncommutative systems alike, with applications to stochastic processes, a Plancherel formula for unimodular Type I locally compact groups, and implementability of canonical transforms in quantum systems of infinitely many degrees of freedom.

In all his work Segal was a pioneer. To mention one example not discussed elsewhere in this article, Sergiu Klainerman, in accepting the Bôcher Prize (*Notices*, April 1999), credits Segal with being the first to point out the role of space-time inequalities for nonlinear hyperbolic equations.

In the 1960s Segal organized two conferences at MIT that were the occasion of an initial breakthrough in constructive quantum field theory. The extraordinary subsequent development, primarily by James Glimm and Arthur Jaffe, was not along lines that Segal favored—a viewpoint that he made painfully clear.

The last thirty years of his professional life were dominated by a discovery he published in 1951. In the last section of a wide-ranging article [1], Segal initiated the theory of deformations of Lie algebras. (Deformations became "contractions" in the physics literature and were "limiting cases" in the article.) Classical mechanics is a limiting case of quantum mechanics as $\hbar \to 0$; the corresponding commutative Lie algebra is a deformation of the Heisenberg algebra. Nonrelativistic mechanics is a limiting case of relativistic mechanics as $c \to \infty$; the Lie algebra of the Galilei group is a deformation of the Lie algebra of the inhomogeneous Lorentz group. But Segal showed that the latter is itself a deformation of the Lie algebra of the conformal group, and now we have reached the end of the road: this Lie algebra is rigid.

Segal's vision was that the universe is the universal cover **M** of the conformal compactification of Minkowski space—Einstein's spherical universe—with the universal cover of the conformal group as symmetry group. He pursued this vision with passion and immense industry. In cosmology it yields an alternative explanation of the redshift as due to the difference between chronometric time and the time measured in an observatory. In quantum field theory the compactness of space in the Einstein universe (it is $S^3$) and a natural time cyclicity mollify the divergence problems. Together with Zhengfang Zhou, Segal constructed quantum electrodynamics and a nontrivial $\phi^4$ quantum field on **M**. Here is a summary he wrote [2] in 1992:

> Universal space-time is a natural candidate for the "bare" arena of the fundamental forces, being the maximal 4-dimensional manifold having physically indicated properties of causality and symmetry. It is locally conformal to Minkowski space, and globally conformal to the Einstein universe $\mathbf{E} \sim \mathbf{R}^1 \times S^3$. The Einstein energy exceeds that in the canonically imbedded Minkowski space, and the difference has been proposed by the chronometric theory to represent the redshift. Although this eliminates adjustable cosmological parameters, the directly observable implications of this proposal have been statistically quite consistent with direct observations in objective samples of redshifted sources. These developments represent a mathematical specification of proposals by Mach, Einstein, Minkowski, and Hubble and Tolman. They suggest that the fundamental forces of Nature are conformally invariant, but that the state of the Universe breaks the symmetry down to the Einstein isometry group. This provides an alternative to the Higgs mechanism, and otherwise has implications for particle physics, including the elimination of ultraviolet divergences in representative nonlinear quantum fields, the formulation of a unified invariant interaction Lagrangian, assignments of observed elementary particles to irreducible unitary positive-energy representations of the conformal group, and the correlation of the $S$-matrix with the action in $\mathbf{E}$ of the generator of the infinite cyclic center of the simply-connected form of the conformal group.

Why has this work not received an adequate evaluation? Part of the reason lies in Segal's style of scientific exchange—at times it resembles that of Giordano Bruno (later burned at the stake), who very shortly after his arrival in Geneva issued a pamphlet on *Twenty Errors Committed by Professor De la Faye in a Single Lesson.* But part of the fault lies with cosmologists and particle physicists intent on defending turf.

The time for polemics is past. Segal's work on the Einstein universe as the arena for cosmology and particle physics is a vast unfinished edifice, constructed with a handful of collaborators. It is rare for a mathematician to produce a life work that at the time can be fully and confidently evaluated by no one, but the full impact of the work of Irving Ezra Segal will become known only to future generations.

—*Edward Nelson*

## *Bertram Kostant*

I was a graduate student at Chicago in the early 1950s, and I became Irving Segal's Ph.D. student in the 1951–52 academic year. I want to say a little bit more about how that came about. To do so, I should say something about what Chicago was like in the early 1950s. It always seemed to me that the graduate school environment at that time and place was unlike anything I have subsequently seen throughout my career. The place was teeming with students, and the intellectual atmosphere was such that one was made to feel that doing mathematics was the most important thing one could do with one's life. Perhaps the person who most contributed to this particular feeling in me was Irving Segal.

But back to the story about how I became his student. Frankly, Segal did not have a great reputation as a teacher. However, Chicago's graduate education system was such that there were certain courses in geometry, algebra, and analysis that one had to take. To fill the latter requirement, I found myself in Irving Segal's course in measure theory. To my surprise and delight it turned out to be a marvelous course. Segal worked very hard on it. Each lecture was slowly and carefully delivered. There were typed notes, there was no waving of hands, and every epsilon and delta was there. In fact, the whole set of notes produced a book, which in my opinion was superior to Halmos's newly published book on measure theory.

One day I noticed I had a counterexample to one of Segal's lemmas. I had never had a personal conversation with him, and my wrong impression was that he would not welcome one. It was at the urging of friends of mine that I finally mustered the courage to go to his office and show him my counterexample. He graciously agreed that I was correct. However, it was only a small matter. He had just neglected to add some rather natural hypothesis. As I was walking out the door he suddenly stopped me and asked, "What do you know about Lie groups?" I replied that I knew something about that subject, since I was currently taking a course with Ed Spanier on Lie groups. Without saying a word he went to his desk and started writing. He then got up, handed me a paper, and said, "Okay, here's your Ph.D. thesis problem." I was totally stunned. This was the beginning of a period in my life when I could not say "no" to Irving Segal. Here I had walked into his office just to discuss some small matter about his course, and I walked out not only having a thesis advisor but also having a particular thesis problem.

After that my graduate career radically changed. Segal was very good to his students. Also, I began to know him quite well on a personal basis. There was an intensity about Irving that resonated with me. He had an apartment off the Midway and on Friday nights held open house. These were the only occasions I can remember at Chicago where one could socially meet faculty members, visitors, and members of other departments. Segal would walk around joining small groups of his guests, becoming a catalyst for good conversations.

It is an understatement to say that he affected the course my life took after I became his student. Here are some details supporting that statement. It was through Irving that I got a two-year appointment, starting in 1953, to the Institute for Advanced Study (even before I began writing my thesis). This was a rare opportunity, since among other things I met such luminaries as Einstein, von Neumann, and Hermann Weyl not very long before their deaths. After my stay at the IAS I am sure it was due to Irving's influence with W. Feller that I received a one-year offer as Higgins Lecturer at Princeton. After that I went to Berkeley on my own. But it was after only a few years, while still an assistant professor, that I received an offer of a full professorship at the University of Chicago. I can only imagine that this was engineered by Irving and perhaps Adrian Albert.

But leaving a rising Berkeley (and the beauty of California) to go to what I sensed was a declining Chicago was not terribly appealing to me. This was my first "no" to Irving. A few years later Irving moved from Chicago to MIT. Not long after that, I received a full professorship offer from MIT. By this time (1961–62) my interest in Berkeley had already peaked. It would be painful to break a strong

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tie I had developed with Gerhard Hochschild, but Irving convinced me that mathematically Boston was the place to be. "The winters are not that bad. Sure, it snows a lot, but you can learn to cross-country ski." I accepted the offer from MIT. But this began the period when I found it easier to say "no" to Irving.

One of the reasons our work went separate ways was that Irving really focused only on those aspects of mathematics, and in particular only on those aspects of representation theory, that he felt dealt directly with physical theory. He ignored the revolution brought about by Harish-Chandra and I. M. Gelfand. Besides becoming interested in that development, I also became interested in geometry and other areas that it seemed Irving found easy to ignore. Irving was single-mindedly driven to find the right mathematical models to describe certain physical theories, such as cosmology and quantum field theory. In his later life, I think, cosmology superseded quantum field theory. At the heart of the cosmology theory that Segal developed was the 15-dimensional Lie group $SU(2,2)$, referred to by physicists as the "conformal group". He focused all of his attention on this group. There are certain properties of this group that he felt were at the heart of understanding important things.

Irving often pointed to certain phenomena that turned out to be the tips of icebergs. For example, he was fascinated by the fact that the conformal group stabilized the solutions of the wave equation even though the wave operator did not commute with the group. He asked me about this, and it seemed indeed to be an interesting question. I thought about it and wrote a paper called "Quasi-invariant differential operators" which made connections between a number of things, including intertwining operators on Verma modules. The latter subject was carried to deeper levels by the Gelfand school and eventually led to the Kazhdan-Lusztig theory, an important development in modern Lie theory.

Another aspect of the conformal group that fascinated him was that its Lie algebra has elements that, for many representations, have a nonnegative spectrum. From his perspective this could make them candidates to represent energy in physical applications. One particular nilpotent element, in the representation of $SU(2,2)$ associated with solutions of Maxwell's equations, defines the standard operator to determine the frequencies of light waves. But Irving focused on another element with a nonnegative spectrum, an element that was elliptic and not nilpotent, but closely related to the above-mentioned nilpotent element via a theorem of Morosov. This elliptic element has beautiful mathematical properties, like generating an invariant cone. This is the tip of another iceberg. I became involved in this study, producing a theorem determining exactly when invariant cones in semisimple Lie algebras exist. A closer study of such cones is today an active subject. This elliptic element is at the heart of Segal's cosmological theory. What he is saying is that it is the elliptic element that should be used to determine the energy of an electromagnetic wave, and not the nilpotent element. There was no big bang and no expansion of the universe. The redshift is not a Doppler effect. It is accounted for by the difference between the elliptic and nilpotent elements—negligible locally, but significant at great distances. Although his cosmological theory has thus far attracted very few supporters, there is clearly much that is unsatisfactory in the widely accepted big bang theory. I have it from a highly reliable but unnamed source that there is a growing group of cosmologists who have come to believe that the correct understanding of the redshift is some sort of fusion of the Doppler effect and Irving's theory. So it is not impossible that Irving could turn out to be correct after all.

Irving Segal was a unique individual who affected the lives and thoughts of a large number of people, certainly including me. With his passing I think the world is a poorer place.

## *Edwin F. Beschler*

I first met Irving when, as acquisitions editor for Academic Press, I was seeking someone to establish a journal in the field of functional analysis. This was in the early 1960s when the boom in specialized journals was about to begin. Irving's name, along with that of Ralph Phillips, with whom I had also spoken, was among the most often mentioned. When I approached him, his response was incisive and immediate—almost as if he had anticipated the question. With a clear understanding of editorial autonomy and assurance of support from Ralph and at least one other colleague, he agreed to undertake the task. In short order he had brought Paul Malliavin into the group, an agreement was reached within a few months of the first discussions, and the first issue of the *Journal of Functional Analysis* (JFA) appeared not more than a year later. Irving was not one to procrastinate.

The concomitance of the three editors' views and the firm leadership provided by Irving was remarkable. Through the next twenty years, editorial board meetings consisted of a get-together of the four of us for coffee or tea every four years at the International Congress of Mathematicians (I missed one or two), with agreement that everything

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was fine. In between, the JFA worked smoothly and efficiently, and it was always a pleasure to deal with Irving and the board. In my tenure I do not recall a single problem that was not handled fairly and expeditiously. If there were editorial problems of which we at the publishers were unaware (and one suspects they arose, as they surely do in even the best-ordered groups of researchers), it was another mark of Irving's style that he settled them with the least amount of fuss possible. He managed to create, from my point of view, a model of that peculiar mix of autocracy and democracy required to make a journal work. The model served me well in the following years, though I cannot say I was often able to replicate it.

On a more personal note, I remember with nostalgic amusement my arrival, along with Irving and at least another one hundred or so members of the AMS, at Shmeretvyo Airport in Moscow in 1966. In those days one did not learn the name of one's hotel assignment until arrival at the airport. Our group found itself lined up in front of a small table, staffed by two Intourist employees with a smattering of English and armed with a ledger book in which was inscribed each of our groups' names, in Cyrillic—and I suspect not even in that alphabet's order. The procedure was that the first person in line pronounced a name and then a search through the list was conducted, attempting to find a reasonable match. It was obvious after the first two or three such searches that the process would take all night. Rising above the growing din of complaints was Irving's voice, coming from far back in the queue as he approached the table, protesting something like "NO, NO, NO!! This will never do!" Irving firmly commandeered the book, began at the top of the list, and called out the name of the first person on the list, then the second, and so on. The Intourist employees were startled and, I think, uncertain as to whether to be angry or simply amazed. They apparently had never seen such a performance nor imagined such a procedure. Irving was in charge, and the sense of gratitude among the group was palpable. He was not able to save us from a six-hour wait in our hotel's lobby for room assignments, but I know he saved us an equal amount of time at the airport.

**Ph.D. Students of Irving Segal**

Isadore M. Singer, Chicago (1950)
Henry A. Dye Jr., Chicago (1950)
Joseph M. Cook, Chicago (1951)
Ernest A. Michael, Chicago (1951)
Ernest L. Griffin Jr., Chicago (1952)
Jacob Feldman, Chicago (1954)
Bertram Kostant, Chicago (1954)
Lester E. Dubins, Chicago (1955)
Edward Nelson, Chicago (1955)
Brian Abrahamson, Chicago (1957)
Ray A. Kunze, Chicago (1957)
W. Forrest Stinespring, Chicago (1957)
Robert J. Blattner, Chicago (1957)
Leonard Gross, Chicago (1958)
David Shale, Chicago (1960)
Walter A. Strauss, MIT (1962)
Roe W. Goodman, MIT (1963)
Matthew Hackman, MIT (1963)
A. Robert Brodsky, MIT (1965)
Richard B. Lavine, MIT (1965)
John Chadam, MIT (1965)
Jan M. Chaiken, MIT (1966)
Robert R. Kallman, MIT (1968)
Michael Weinless, MIT (1968)
Michael J. J. Lennon, MIT (1969)
Niels Skovhus Poulsen, MIT (1970)
Tomas P. Schonbek, MIT (1970)
Arthur Lieberman, MIT (1971)
Abel Klein, MIT (1971)
Stephen Berman, MIT (1972)
Steven Robbins, MIT (1973)
Edmund G. Lee, MIT (1975)
Hans Plesner Jakobsen, MIT (1976)
Bent Ørsted, MIT (1976)
Thomas P. Branson, MIT (1979)
Mark A. Kon, MIT (1979)
Stephen M. Paneitz, MIT (1980)
Derrick C. Niederman, MIT (1981)
John C. Baez, MIT (1986)
Jan Pedersen, MIT (1991)

## *John C. Baez*

I met Irving Segal in 1982 shortly after I came to MIT in order to get my Ph.D. in mathematics. As a slouching, scruffy graduate student who preferred to be barefoot whenever possible, I was somewhat intimidated by his appearance. He was always impeccably dressed in a suit, he wore a goatee shaved short in a no-nonsense sort of way, and he made up for his lack of height by an erect posture and commanding manner. But I decided to work with him because of all the pure mathematics faculty, he seemed the most passionate about physics, not just as a source of mathematics problems, but as an end in itself.

I wanted to work on quantum gravity, but at MIT everyone interested in this subject was working on superstrings, for which I had little taste. Segal himself found Einstein's equations too ill-behaved to bother trying to quantize them. The lack of a conserved energy, the tendency for solutions to develop singularities—these qualities convinced him that general relativity was fatally flawed. My arguments in favor of general relativity failed to convince him, so I wound up working on one of his specialties, the mathematical foundations of quantum field theory.

I learned a lot and successfully completed a thesis, but I did not have much success proving really interesting theorems. Later, as a postdoc, I decided that quantum field theory was too hard for me, so I worked with Segal and Zhengfang Zhou on classical field theory, i.e., nonlinear wave equations, another of Segal's specialties. The three

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of us wrote some papers together and also coauthored a book [3] summarizing Segal's work on quantum fields. Thus I spent about six years in close contact with him and came to know him rather well.

We would typically discuss mathematics in his office, taking turns scribbling equations on the blackboard. He had a devastating way of expressing doubt when my reasoning failed to convince him. Without saying a word, he would gradually raise his eyebrows higher and higher as I spoke. As they slowly climbed up his forehead, it became ever more difficult to keep up the momentum of my reasoning. When I finally lost the thread of what I was saying, he would interrupt and point out my error as he saw it. Being stubborn, I would not always accept these criticisms. As he was even more stubborn, our discussions sometimes became quite heated. Zhengfang Zhou served as a calming influence when he was around.

Segal's office was a cozy, lived-in place, cluttered with decades of accumulated papers. He had a couch where sometimes he would take short naps. He also made coffee in his office, refusing to touch the stuff served in the mathematics department lounge. He took coffee very seriously, grinding the beans in his office, using only distilled water, and heating it to a precisely optimized temperature. (He claimed to have done a study to determine this optimal temperature.) He often let me work on his computer while he worked at his desk or typewriter. Sometimes when he wanted to prove a theorem, he made a great show of setting a kitchen timer, allowing himself no more than thirty minutes to get the job done. This was but one of many ways he emphasized the importance of a businesslike attitude. When I passed my thesis defense, the first thing he said was "Good, now we can get back to work." He never slacked off; he often came to the office on weekends, and his retirement seemed not to slow him down in the least.

People who failed to understand the essentially prickly nature of Segal's relationship to the world would sometimes misinterpret his actions. For example, he recently wrote a review of Alain Connes's *Noncommutative Geometry* for the *Bulletin of the AMS.* While largely positive, the review contained a number of serious criticisms. For example, he expressed disappointment that Connes, with all his mastery of analysis, still treated quantum field theory the way most particle physicists do, using perturbative Lagrangian methods rather than the more rigorous framework of algebraic quantum field theory pioneered by Segal and others. Some mathematicians were greatly upset by these criticisms. What they perhaps failed to understand was that merely by writing the review, Segal was saying that Connes's work was of the highest caliber! Indeed, the only other articles about the work of others I recall his writing concerned von Neumann and Wiener.

In his later years Segal spent most of his time on an alternative to the big bang cosmology in which redshifts were to be explained, not by the expansion of the universe, but by an effect of conformal geometry. According to him, his theory predicted a quadratic redshift-distance relation instead of the usual linear one. He spent a lot of time statistically analyzing redshift-brightness data for quasars and galaxies and wrote papers claiming they supported his theory. Most astronomers disagreed.

I thought long and hard about his derivation of the quadratic redshift-distance law from his theory, and it never seemed right to me. At first I hoped I was making a mistake, so I tried to get him to explain this derivation. His explanation did not convince me. Later I tried to explain what I thought was his error. He became quite angry. When I realized we would never see eye-to-eye on this subject, I tried to avoid it. But this was very difficult, and our relationship became strained. I am sad to say that I eventually wound up avoiding him.

Despite this, I remain very fond of Segal, because he had a real passion for understanding the universe. He did not believe in God and was suspicious of all forms of organized religion. The quest for perfection that some express through religion he expressed through mathematical physics. He could never take it lightly!

## Arthur S. Wightman

I first encountered Irving Segal in the winter of 1946–47 when he spoke in a seminar in (old) Fine Hall at Princeton on the results of his forthcoming paper on postulates for general quantum mechanics. I was only partly prepared for the grand sweep of the talk and the paper that followed. I had studied John von Neumann's book *Mathematical Foundations of Quantum Mechanics* in the Dover reprint of the German edition of 1932, available during the war, and had heard of the work of Gelfand and Naimark on $C^*$-algebras discussed in a mathematics seminar in New Haven, but I did not know of the existence of von Neumann's paper on an algebraic generalization of the quantum mechanical formalism, which Segal mentioned as being most closely connected with his work. Both papers can be regarded in retrospect as part of a mathematical reaction to the physical discoveries of the quantum mechanical revolution of 1925–1927. They had a twofold motivation: on the one hand, to distill the essence of the mathemat-

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ical structure of quantum mechanics and, on the other, to state its principles in a form that might make it possible to go beyond quantum mechanics. The latter was surely a prime impulse of P. Jordan in the paper that led, via the joint investigation of Jordan, von Neumann, and Wigner, to von Neumann's paper.

As Segal pointed out, the most conspicuous example of a system of observables satisfying his postulates is the set of all self-adjoint elements of a $C^*$-algebra. He left as an open problem to prove whether up to isomorphism these were the only such. In the decade after the appearance of the postulates this problem was studied by a number of authors, of whom I will mention only two: David Lowdenslager and Seymour Sherman. These authors constructed a rich class of examples of Segal systems of observables that are not isomorphic to the self-adjoint elements of a $C^*$-algebra. Furthermore, they gave necessary and sufficient conditions for Segal systems that such an isomorphism hold, thereby completing Segal's postulate system. Segal's insight that the $C^*$-algebra is the object with physical meaning and not any particular representation of it on a Hilbert space is now a commonplace of mathematical physics.

Meanwhile, in physics Rudolf Haag was struggling to understand how the fact that physical measurements take place in bounded regions of space-time should affect the structure of algebras generated by observables. He worked originally with algebras of unbounded operators, but over the course of a decade, in part in joint work with Huzihiro Araki and Daniel Kastler, he came to the conclusion that algebras of bounded operators, and in particular $C^*$-algebras, provided a language best suited to the expression of the ideas of quantum field theory, which is what Segal maintained in the first place. In the hands of Haag, Doplicher, and Roberts localization in space-time and the Gelfand-Naimark-Segal construction led to a systematic theory of superselection rules. This was the beginning of a profound theory created over three decades and summarized in Haag's 1992 book.

## *Leonard Gross*

Irving Segal always had lots and lots of ideas. I remember when, in 1958, I returned for a few days to the mother institution, the University of Chicago, for my Ph.D. exam after being away for almost a year. At the end of the visit, as Irving drove me back to the bus station, he used every minute to provide me with a goodly supply of ideas to keep me busy after I went back out into the wilderness. I was not able to absorb much of this. His knowledge base was much more sophisticated than mine. His ideas came forth quickly. Even after I returned to Yale I received letters from him raising interesting questions close to my area of expertise. In retrospect I realize that he was driven not only by his sense of duty to provide his intellectual progeny with plenty of food for the mind but also by his single-minded determination to solve one of the big problems of mathematical physics: the existence of interacting quantum fields. Although much of his work may seem to many mathematicians to be motivated simply by the usual aesthetic considerations—and is certainly justified by the intrinsic beauty of his ideas—Irving told me a few years ago that all of his work was aimed in one way or another at understanding quantum physics.

Among the many papers of Irving's that formed the core of my mathematical education, one group of his papers influenced my own work and the work of my students in two distinct directions. Irving's papers [4, 5, 6] were aimed at understanding the mathematical structure of the Hilbert spaces associated to a variable number of identical quantum mechanical particles. Although a significant part of the problems he addressed pertained to integration over an infinite-dimensional Hilbert space, some of the ideas of these papers are most easily understood in finite dimensions. Let $p_t$ and $\mu_t$, for $t > 0$, be the heat kernels on $\mathbb{R}^n$ and $\mathbb{C}^n$ respectively. One need only write out the convolution $p_t * f$ to see that if $f$ is in $L^2(\mathbb{R}^n, p_t(x)\,dx)$, then $p_t * f$ has an analytic continuation, $h$, to the entire complex space $\mathbb{C}^n$. The map $S_t : f \mapsto h$, the Segal-Bargmann transform, is a unitary operator from $L^2(\mathbb{R}^n, p_t(x)\,dx)$ onto the space $\mathcal{H}_t^2$ consisting of holomorphic functions in $L^2(\mathbb{C}^n, \mu_t(z)\,dx\,dy)$. Furthermore, the Taylor coefficients at 0 of the holomorphic function $h$ may be assembled so as to define an element $\alpha$ of the space of all symmetric tensors over the dual space $(\mathbb{C}^n)^*$. The Taylor map $T : h \mapsto \alpha$ is also unitary, this time with domain $\mathcal{H}_t^2$ and range equal to the "Fock space" $\mathcal{F}_t$ consisting of those symmetric tensors with a finite ($t$ dependent) norm. Now the overall unitary map $TS_t : L^2(\mathbb{R}^n, p_t(x)\,dx) \to \mathcal{F}_t$ can be described in many other ways: there are Hermite polynomials lurking in these maps. But the description of these maps given above provides a stepping stone to some recent extensions. Just a few years ago Brian Hall generalized the Segal-Bargmann transform, replacing $\mathbb{R}^n$ by a compact, connected, simply connected Lie group and $\mathbb{C}^n$ by the complexification of the group. Soon afterward, Bruce Driver proved that the Taylor map in that context is also a unitary map in a natural way. A survey of these theorems and their link to the work of Segal, Bargmann, Cameron and Martin, and P. Krée is given in [2].

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Actually, Irving focused primarily on the infinite-dimensional versions of these isomorphisms over linear spaces: one must replace $\mathbb{R}^n$ by an infinite-dimensional real Hilbert space, $H$. There are substantial problems in giving orthogonally invariant meaning to $L^2(H, p_t(x)\,dx)$ when $H$ is infinite dimensional. For example, if one chooses an orthonormal basis of $H$, and thereby identifies $H$ with $l^2$, then the measure $p_t(x)\,dx$, when $n = \infty$, has a clear interpretation as a product measure on $\mathbb{R}^\infty$. But the subset $l^2$ has measure zero. There is no way to interpret the expression for $p_t(x)\,dx$ as a countably additive measure on $H$. One always needs to choose some kind of enlargement of $H$ on which the measure will sit.

Typically, all really useful enlargements have some orthogonal noninvariance built in. The classical example is that of Wiener space $C$, consisting of all continuous real-valued functions on $[0, 1]$ vanishing at $0$. $C$ carries a natural probability measure, namely Wiener measure. The subspace $C'$ consisting of absolutely continuous functions with square integrable derivative is a Hilbert space. When $H = C'$, the proper interpretation of the informal expression $p_t(x)\,dx$ (for $t = 1$) is precisely Wiener measure on $C$. While $C$ is recoverable from the Hilbert space $C'$ as the completion with respect to the supremum norm on $C'$, this norm is not orthogonally invariant.

In order to emphasize the central role of the Hilbert space $H$, as opposed to the accidental form of some convenient ambient measure space, Irving gave a definition of integration over $H$ with the help of an equivalence class of measure spaces. Although the theorems and technology in these papers have influenced much mathematical activity, the slightly complicated, though orthogonally invariant, meaning that he gave to the expression $p_t(x)\,dx$ has not been as widely adopted. This writer, strongly influenced by Irving's view of the primacy of $H$ in infinite-dimensional Gaussian integration theory but forced by my foray into infinite-dimensional potential theory to have the measure $p_t(x)\,dx$ live in some Banach space, abstracted the ordinary Wiener space: if one completes the Hilbert space $H$ with respect to a second, extremely weak norm, then the completion will support a measure that can, in a precise sense, be interpreted as the measure $p_t(x)\,dx$. The influence of one part of mathematics on another is quite visible here: few of the probabilists who are the current users of these abstract Wiener spaces have an interest in or knowledge of the quantum field theory problems that led Irving to study these structures.

## *Michèle Vergne*

I met Irving Segal at the meeting of the American Mathematical Society in Williamstown in 1973. One year later my mother committed suicide, and this dumped me into devastating thoughts. I stopped working. A friend in the United States, Graciela Chichilnisky, persuaded me, rightly, to move from France to the U.S. Segal was the attractive presence at MIT. Of course, attractive also were the other giant figures in the field of group representations—Sigurdur Helgason and Bert Kostant. But Segal had a special talent for making one feel wanted. In front of him I felt unimportant and little, but I felt that my work was needed. He soon became essential to me. I remember something he said to me: "You do not need to have many friends. One is enough." So I had two friends—my friend Graciela and him—and this was more than enough to make life worth living again. He was fascinating for me, an immense spiritual power in a tiny body. He was passionately interested in his ideas; intellectual work was ranked by him above all other activities. Maybe in a more radical manner, all other work, especially all traditional feminine duties, were considered as no work at all, just pleasurable distractions. To his credit, unlike most of us, he would also take care of all material issues. In fact, nothing seemed to be difficult for him. He cared for others, especially children, with great pleasure. My daughter, when she was a little girl, loved to come into his office, get an orange, and start a spirited conversation with him. My father came to the U.S. to visit me. Segal kindly invited us to his house. What a shock for my father to see a man of his age, and a professor, serving him. But he was not doing so as an obligation due to liberal beliefs. He was just happy taking care of others. Indeed, there was something highly charming in him that nobody could resist.

With Hugo Rossi I had done some work before 1974 on certain special unitary representations of semisimple Lie groups. This work was of high interest for Segal's cosmological theory. My past work gained immediate significance. Segal had projects where my contribution was impatiently expected. Due to his influence and strong will, I was able to work again. In fact, I remember those first years at MIT as one of the most happy periods in my life. I would again work and work and work and report on my work almost every day to Segal. Hans Jakobsen and Bent Ørsted were Danish students of Irving. They were bright, friendly, and amusing. Birgit Speh, a student of Bert Kostant, was also very often with us. Later on, there was also Steve Paneitz, who died tragically when swimming with Segal in a lake. We would all meet regularly for an informal seminar in his office. We could also go for long walks along the Charles River or have dinner at his home. As if prepared by a genie of fairy tales, suddenly in his house there was a dinner ready for

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everybody, prepared by him, while we discussed cosmology passionately.

The model that Segal proposed for space-time is a model where space is finite but the time infinite. This space-time, the 3-dimensional sphere for space variables and the real line for the time variable, can be equipped at each point with the cone of possible directions of the future. The group of causal transformations of this manifold is the universal cover of the identity component of the indefinite orthogonal group $O(2,4)$, a 15-dimensional symmetry group. This group, the conformal group, became my favorite group. It contains the Poincaré group of symmetries of the usual Minkowski space. Segal's cosmological space is deduced from the Minkowski space by compactification of the space variables. Let us call the infinitesimal generator of time translation in Segal's space the Segal energy. A representation of the conformal group (more precisely of its universal cover) has positive energy if Segal's energy has positive discrete eigenvalues. Many questions were raised by Segal for describing all positive energy representations, their tensor products, the description of their $K$-types, etc. Segal's work is sometimes highly conceptual, as are his fundamental discoveries of the metaplectic representation or of the abstract Plancherel theorem, and sometimes very applied and concrete. In particular, Segal's work led to a detailed study of representations of the conformal group.

It was challenging for me to apply my knowledge of small representations to this special group. It was not easy to obtain concrete results as needed and to recognize well-known physical equations in my purely mathematical world. In these projects everybody around Segal was adding his or her own contribution to Segal's work. We were all working incredibly hard. Many results were obtained in a small amount of time. Results obtained in the particular example of the conformal group had impact for the general theory of representations. The invariance of the wave equation under the conformal group had a fundamental significance for Irving Segal. It was proved by Bert Kostant. Masaki Kashiwara and I showed that invariance of the wave equation implied invariance of the Maxwell equation. Hans Jakobsen proved the unitarity of the representation of the conformal group in the space of solutions of the Maxwell equation. Birgit Speh described the list of $K$-types of some of the positive energy representations. This list of asymptotic directions in $K$-types led to the general concept of singular support of a representation. Bent Ørsted studied relations of these representations to nilpotent orbits contained in an invariant convex cone. Steve Paneitz studied the image of some of the nilpotent orbits of the conformal group under the moment map. He also classified all possible invariant cones. Bert Kostant and David Vogan were consulted as experts on all these issues.

There was a friendly competition among us. Work was the most important part of my life. But, following Segal's example, I found nothing more pleasurable in life than thinking and working. In fact, between 1975 and 1981 all my work on representations was inspired by Segal's demands. I was not, properly speaking, working for him; I was pursuing my own research, but I was cheered up by the pleasant idea that it was useful to him. Now many mathematicians continue to work following paths Segal opened on positive energy representations, semigroups of causal transformations, and decomposition of representations related to the metaplectic representation.

*Spoken at the memorial service*: Once again I am here at MIT. But this time, Irving, I will not be able to knock at your door; enter your office; see you, a very small man welcoming me warmly behind huge piles of papers. You would start an impish conversation about mathematicians, colleagues, astronomers, life. It would be highly amusing. You had posted proudly in your office a drawing done by your daughter, Karen, representing you as a little devil. It was quite true to life; indeed, you loved to be provocative. To be sad or depressed was a form of weakness, to be sick was not allowed, to be unsure of myself was to draw your fire on me. In front of me, you considered women with open contempt, maybe just to know how I would react. But you certainly were influential in attracting me to MIT and took me onto the board of editors of your journal. Today I am very sad. I also feel that I did not always behave right towards you. I loved you, but it was not easy to be oneself and stand in front of you.

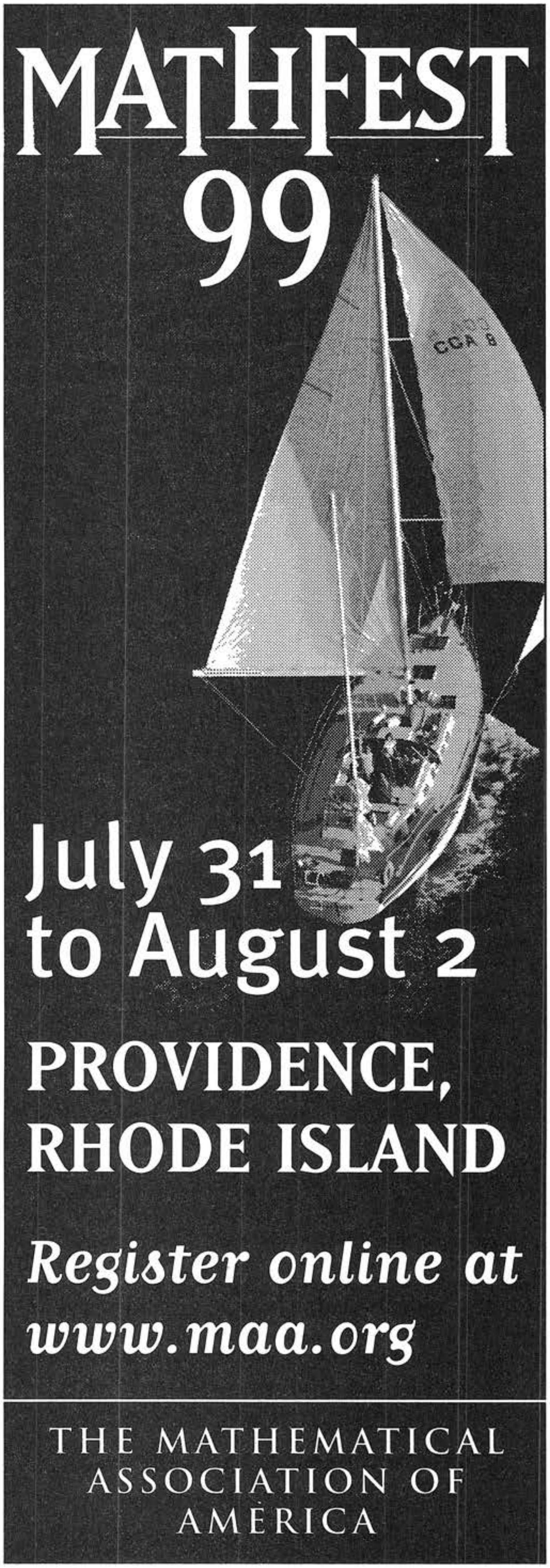
Dear Irving, you had the strong power to influence the directions of people's lives. You have given to many people the love of research. You employed your charm to develop the creativity of those around you. I am very grateful to you. You gave me essential help when my life was darkened by tragic sorrows. You made me a better mathematician. You taught me that friendship was sacred. If I needed you, you would always be there. And today, you are here.

## References


[1] JOHN C. BAEZ, IRVING E. SEGAL, and ZHENGFANG ZHOU, Introduction to algebraic and constructive quantum field theory, Princeton Series in Physics, Princeton Univ. Press, Princeton, NJ, 1992.

[2] L. GROSS and P. MALLIAVIN, Hall's transform and the Segal-Bargmann map, *Ito's Stochastic Calculus and Probability Theory* (Ikeda, Watanabe, Fukushima, Kunita, eds.), Springer-Verlag, Tokyo, 1996, pp. 73–116.

[3] I. E. SEGAL, A class of operator algebras which are determined by groups, *Duke Math. J.* **18** (1951), 221–265.





[4] ____ , Tensor algebras over Hilbert spaces, *Trans. Amer. Math. Soc.* **81** (1956), 106–134.

[5] ____ , Mathematical characterization of the physical vacuum for a linear Bose-Einstein field, *Illinois J. Math.* **6** (1962), 500–523.

[6] ____ , The complex wave representation of the free boson field, *Topics in Functional Analysis: Essays Dedicated to M. G. Krein on the Occasion of His 70th Birthday*, Adv. in Math. Suppl. Stud. **3** (I. Gohberg and M. Kac, eds.), Academic Press, New York, 1978, pp. 321–344.

[7] ____ , Fundamental physics in universal space-time, *Physics on Manifolds* (Paris, 1992), Kluwer, Dordrecht, 1994, pp. 253–264.

# Interview with D. J. Lewis

In July 1999 D. J. Lewis will complete a four-year stint as director of the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF). He will return to his home institution of the University of Michigan in Ann Arbor. Lewis will be succeeded by Philippe Tondeur of the University of Illinois at Urbana-Champaign (see "Philippe Tondeur Appointed DMS Director", *Notices*, April 1999, page 475; see also the correction in the "For Your Information" section of this issue of the *Notices*.). The following is an edited version of an interview with Lewis conducted in January 1999 by *Notices* senior writer and deputy editor Allyn Jackson.

***Notices:*** *At the time you came to the NSF, the DMS was funding two mathematics institutes: the Institute for Mathematics and its Applications at the University of Minnesota, and the Mathematical Sciences Research Institute in Berkeley. One of the major undertakings during your time as DMS director was the recompetition of these institutes. Since the final funding decisions have not yet been made, you probably cannot discuss specifics, but can you tell me about the general philosophy you followed in figuring out what kinds of mathematics institutes the DMS should fund?*[1]

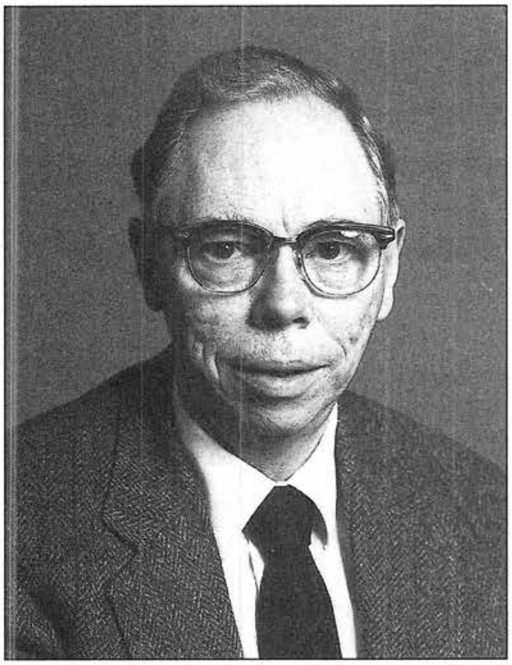
**Lewis:** We really were sitting back and seeing what the community would define as the activities they'd like. If anything, we were disappointed that they were copying too much of what we had in place. We were forced by the NSF director's office to put in more education requirements than I liked. I was really looking forward to some proposals for straight think tanks, and I still think we need that.

Everything I had heard had led me to believe that mathematicians felt they needed an Oberwolfach-type conference center.[2] We didn't see any proposals like that. I feel right now that the current institutes are running too many conferences, overburdening their facilities, and creating too much noise and distraction. I like the Isaac Newton Institute [in Cambridge, England]. They have thematic programs, but they don't run a lot of conferences. They don't worry about postdocs. They're under less pressure than what the NSF puts on its institutes for outreach. I think the NSF is asking the institutes to do too much. It's not just the institutes; they've done the same thing with the NSF Science and Technology Centers. I think different facilities have different roles to play. Every institute shouldn't have to play all the roles.

I think we need more institutes, but then you run into the question, Is it better to spend \$2 million and have another institute or to fund another twenty-five or so researchers each year? It's a question of trying to keep the discipline alive and thriving. There's no doubt the really big ideas in mathematics come from maybe 5 percent of the people, but you need a broad base to nourish that 5 percent and to work out all the details as they move on to more adventuresome things. Look at, say, mathematicians at Group III universities. It's a rarity when they get funding. How do you keep them in the system? If you don't, they will turn out stu-

[1] *The "Reference" section of the May issue of the* Notices *carried a listing of some of the major mathematics institutes in the world, four of which are in the United States: Center for Discrete Mathematics and Theoretical Computer Science (DIMACS), Institute for Advanced Study (IAS), Institute for Mathematics and its Applications (IMA), and Mathematical Sciences Research Institute (MSRI). All four receive substantial NSF funding. DIMACS is supported through the NSF-wide program of Science and Technology Centers, and the School of Mathematics at the IAS has received substantial NSF grants for support of mathematical research. However, the recompetition for the DMS-funded institutes pertained only to IMA and MSRI. The reason is that these two institutes were established in the first DMS competition for mathematics institutes, which took place in the 1980s. The decisions on recompetition may have been made by the time this article reaches Notices readers.*

[2] *The Mathematics Research Institute at Oberwolfach, located in the Black Forest in Germany, is a center for mathematics conferences.*



Photograph by University of Michigan Photo Services.

D. J. Lewis

dents working on problems they learned about when *they* were thesis students. We've got to find a way to incorporate the larger community.

Institutes and conference centers can and do serve this purpose. The western European mathematical community is about the same size as that in the U.S., yet they have at least seven institutes and three conference centers, and Germany has about half a dozen *Sonderforschungsbereiche*, which are a cross between NSF Science and Technology Centers and its focused research groups. The Canadian mathematical community is about one-tenth the size of that in the U.S., and they have two research institutes. By these numbers the case can be made that the U.S. needs many more institutes than it currently has.

***Notices:*** *During your time at the NSF, two "benchmarking" reports came out: one from the NSF and one from the National Academy of Sciences [NAS].*[4] *These reports attempted to evaluate the international standing of U.S. mathematics. What was the effect of these reports?*

**Lewis:** I don't think the National Academy report has had much effect, partly because they only took a snapshot of here and now and didn't do any projections. In fact, the NAS committee was forbidden by the Academy to say anything much about the future. Both reports were basically responses to GPRA [Government Performance and Results Act]. Congress seems to be very much insisting on quantitative measures, and GPRA could have a devastating effect on science.

OSTP [Office of Science and Technology Policy] and some members of Congress have seen the NSF report, and a few have responded favorably. And it's had a definite impact on [Robert] Eisenstein [NSF assistant director for Mathematical and Physical Sciences]. The little bit of favoritism that's been given to mathematics in the last two years I think is somewhat attributable to the report. But we didn't get as much as we should have gotten, just because the budget was so flat and so targeted. In some sense it was viewed as a very dramatic report inside the NSF, but there haven't been a lot of funds coming in to respond to it. There is evidence that it might well have some effect on the fiscal year 2001 budget if the budget isn't too politicized. We'll have to wait and see.

***Notices:*** *Parts of that report were surprisingly bold in what they said.*

**Lewis:** The panel was pretty bold. This is because they were outside the system. We couldn't have anybody on the panel who was supported by the DMS. This was OMB's [Office of Management and Budget's] requirement. I think the report had an impact because the panel didn't have anything to gain from it. We had people who had been very involved in these kinds of assessments in their own countries. One trouble with the NAS report was that the panel consisted of leaders in American mathematics, and if they criticized too much, they were criticizing themselves. The NSF panel had nothing to lose by criticizing. On the whole, I think they made some pretty constructive recommendations. Also, we had some U.S. scientists who weren't mathematicians, and they were awfully tough. They felt that mathematics had gotten too self-centered, and yet they particularly saw the need for mathematics.

***Notices:*** *You have had three changes of bosses in your time at the NSF: William Harris was assistant director for MPS when you came to the NSF, then John Hunt was acting assistant director for a while, and now Robert Eisenstein is assistant director. And you have had another change in the top NSF position, from Neal Lane to Rita Colwell. How much do those changes affect what goes on at DMS?*

**Lewis:** They set the overall guidelines, and they set the budgets. It's a very hierarchical arrangement. I have to make my pitch for budgets to Eisenstein. He either buys them or he doesn't, and he forwards them upstairs. So I don't get a chance to make my case to Colwell at all. I thought that all three assistant directors I had were very supportive of mathematics. Math, in the four years I've been there, has been in one sense better treated than any of the other divisions in MPS. The percentage increases have been good, but the problem is our base is so small [the DMS budget for the current fiscal year is $100.9 million]. They didn't have a lot of money to give. In the first two years, DMS got one-tenth of the entire increase that the Foundation got, which is pretty good. On the other hand, it was peanuts—about $9 million.

[As DMS director] you have to be aggressive without being obnoxious. In the five or six years before I arrived all increases were for the so-called strategic initiatives. It was a question of whether you could play in the game. Judy Sunley and Fred Wan were division directors then, and they did reasonably well in capturing funds—of course, not

[4] *See the article "Reports Assess U.S. Standing in Mathematics",* Notices, *August 1998, pages 880–82.*

as well as CISE [Computer and Information Sciences and Engineering] did via the High Performance Computing initiative. Some of the divisions, like Physics, didn't play at all. So they were actually flat for three or four years. Literally flat. They wanted to just continue doing the same old thing. They refused to play and got no increase.

The basic thing when you're running something like this is to increase your budget. Legally, with initiatives, strings are attached, but usually three to five years later people will forget what the strings were, and you can reallocate. If you sit back and wait for ideal conditions, your budget is not going to grow as fast.

***Notices:** I've heard people criticize NSF, saying, "They're going in too much for applications, like the KDI [Knowledge and Distributed Intelligence] initiative and the material science project with ARPA [Advanced Research Projects Agency]." They are saying that the DMS is putting too much money toward those kinds of things rather than into core research.*

**Lewis:** The ARPA thing cost DMS about $80,000 in total. I pulled a deal for the NSF contribution to come from OMA [Office of Multidisciplinary Activities] and got about three and a half dollars from ARPA to every OMA dollar. And KDI—that was the only new money coming in last year. It was a Foundation-wide activity. I was given the job of writing the prospectus and the solicitation, primarily because John Hunt and Neal Lane saw that mathematics would be one of the biggest players in KDI. You're only going to grow the budget if you start serving other people.

*If you start reaching out to the other sciences, you can make a fantastic case for the support of the core base of mathematics, which is that you've got to keep developing it so that you have the mathematics to use.*

***Notices:** How did the financial contribution from DMS to KDI work?*

**Lewis:** That was taxed. It was put in a central pot, and it was run as a central activity. Mathematicians could go after the money that was in the central pot. It had to be multidisciplinary, so it had to be a mathematician with somebody from another discipline.

***Notices:** Does it look like mathematicians have recouped what the DMS contributed?*

**Lewis:** Yes, about twice as much on grants where a mathematician was the PI. But there were also many proposals that were funded that had a mathematician on the team of researchers. Mathematicians did very well, especially when compared with other divisions in MPS. I expect this year, in fiscal 1999, they will do even better. KDI was the direction the Foundation was going. You either played with it or you didn't play. I think it provided a fantastic opportunity for mathematicians. Unfortunately, in fiscal 2000 KDI will not exist, and the funding will be directed to biocomplexity. Mathematicians will be able to be involved here, but the spin will be quite different.

***Notices:** Are there certain DMS programs that stand out as having a lot of very good, unfunded proposals?*

**Lewis:** Algebra and Number Theory is perhaps under the greatest strain. And one that should be under the same strain really is Geometry/Topology. But quite frankly, over the last three years that program made too many very small grants, and so the strain is hidden. Recent review panels in Analysis and Applied Math found it was especially distressing to see how many excellent proposals cannot be funded. So perhaps the strain is being felt rather universally. From my perspective, the math community is much too quiet and acquiescent. I think with some of these programs, the mathematicians ought to send a delegation in to talk to the assistant director.

***Notices:** Do they do that in other disciplines?*

**Lewis:** To some extent, but NSF is a small player in a lot of the disciplines. NSF may provide 25 percent of the funding for chemistry. For mathematics, it's over 60 percent and going onto 70 percent because the DOD [Department of Defense] agencies are pulling out of math. The rumor is that the Air Force [Office of Scientific Research] is taking a 30 percent cut, and ONR [Office of Naval Research] is basically out of mathematical funding. It puts a lot more pressure on NSF. I made the case to Eisenstein, but I don't think anybody from the math community has gone and talked to him about this loss of funding and how it should be made up.

***Notices:** Currently what is the percentage of DMS proposals that get funded?*

**Lewis:** I think about 35 percent, which is about standard at the NSF. But the problem is, we get that by giving very small grants. We're under terrific pressure to increase the size of our grants. If we did what the [National Science] Board wants us to do, we would fund 800 people instead of 1,400. It's a question of whether DMS did the right thing when they pulled so many people down to one month of summer support. This took some of the pressure off the Foundation to put more money in mathematics. Suppose we funded only 800 people. How much noise would it create? Would there be a march on Washington? I often think that's the way to go. See whether mathematicians would stand up for themselves or whether they'd just meekly accept. In chemistry, people get declined, and in two months they turn around with another proposal. Mathematicians—they get declined twice, and they fold. I think mathematicians have such a personal investment in their problems that if you turn down their proposals, they take it as if you're judging them as mathematicians. They're not as flexible and often don't seem to be able to move to another class of problems. We fund proposals, not individuals.

***Notices:*** *One of the things you started at the NSF was VIGRE [Vertically Integrated Grants for Research and Education]. What has the reaction been from the math community?*

**Lewis:** A lot of proposals, and some very good ones. It's causing a real cultural change in departments. They're having to look at the undergraduate program. They are expected to do discovery learning and REUs [Research Experiences for Undergraduates], or send the kids out for internships. And they have to have a goal of getting their Ph.D.s done in five years. Mathematicians are beginning to recognize that we do not have enough domestic students entering mathematics. To reverse this, more attention will need to be given to undergraduates. VIGRE asks that this be done. Many mathematics departments are running graduate programs strictly in order to have a cheap way to do their teaching. At some of the very well-established departments, you would be shocked at how much teaching they expect those kids to do. That's probably the reason it takes so long to get their degrees. With VIGRE we hope to provide fellowship funds so the teaching is reduced and they complete their degrees more quickly. With an increased number of postdoctoral opportunities, it should be possible to provide a broader education so those who will go into research will have more time and opportunity to develop.

A goal of VIGRE is to try to get the funding of mathematics graduate students on a par with the rest of the sciences. It's ridiculous—every physics student is totally funded after the first year. Our goal is to get $40 million for VIGRE. Right now it is somewhere between $13 million and $15 million. Forty million is about the amount that the NSF's Chemistry Division puts into graduate students and postdocs. But remember, they're putting in only 25 percent of the total amount of support for chemistry graduate students. So our $40 million is a pretty low target. But we've got to grow it; we can't take it out of the research grants, so it is best to have a realistic goal. The response within NSF is very positive, and I believe that if Philippe Tondeur keeps this as a goal, it will be attained.

***Notices:*** *One person I talked to who had applied for a VIGRE and didn't get it said that it seemed to him that the VIGRE grants were going to the same fancy places that get all the grants.*

**Lewis:** We have made eleven awards to date. Three of the awards went to departments that are not considered to be in the top twenty-five departments, maybe not in the top fifty. But those departments understood the goals of VIGRE and made quite a compelling case for funding. It is true that the elite places are going to have a better chance because they have better programs and better students. If you're going to invest money in students, you want to invest in students that can really achieve. It's not an equal opportunity program. Put it this way: There are some very big name departments that got turned down. We're expecting them all to come back this year and learn how to write the proposals. We will be making something like eight to ten more awards this summer. An imaginative program seeking to achieve the goals of VIGRE will get funded.

***Notices:*** *After your time at the NSF, do you have any advice for the math community about what they should be doing to try to improve the funding for mathematics?*

**Lewis:** I don't think that up to this date they've made a very good case for why they should be funded. The bottom line is, What are you doing for the citizens of the country?

***Notices:*** *When you say "make the case," what do you mean concretely? Do groups of mathematicians have to descend on Capitol Hill?*

**Lewis:** They've got to do some demonstrations of what mathematics has accomplished for the good of society. One of the things mathematicians have done is education. For example, if mathematicians took seriously the job of training elementary and middle school teachers, they could make some claim that they really improve things. Also, science is getting so complicated, it can be done only with the help of mathematics. Is the math community willing to step up and participate?

If so, they will have nonmathematicians making the case for greater funding of mathematics. It is always best to have outsiders make your case for you. Once upon a time I thought going to Capitol Hill would be effective. I don't think it will get very far if mathematicians go to Capitol Hill without the support of others. These days information technology and biology and medicine are the themes that echo well with the president and Congress.

If you start reaching out to the other sciences, you can make a fantastic case for the support of the core base of mathematics, which is that you've got to keep developing it so that you have the mathematics to use. Furthermore, there will certainly be problems that arise in science for which the necessary mathematics has yet to be developed. There has to be a very substantial, core mathematics group to advance the subject all the time. The big thing is for them to be open to problems arising in science.

Early on when I came to the Foundation, I was talking to Neal Lane about the importance of mathematicians being part of the scientific research program. His response was, "I agree with you, and I'm prepared to put money into it if you can guarantee me you can deliver the mathematicians." If I could deliver the mathematicians, I could double the budget. I could farm out part of the increase to core mathematics, but I would have to have some people doing multidisciplinary things.

One thing I've done is to change very strongly the direction of things funded by Applied Math and Computational Math. Too much of applied math in this country has been applied analysis working on toy problems. Now these programs fund problems only where you really can document that somebody in another discipline is interested in what you're doing and can use it. Otherwise, you have to come in and compete in Analysis or another program. The old-time applied mathematicians are very, very unhappy [with this change]. But it's exactly because of this change that we've increased the amount of joint funding with other NSF divisions. The other divisions have more money than we do, so quite often when we co-fund, we put in less than a third.

If you go back one hundred fifty years, there was just science. Later it fragmented into math and chemistry and physics and so forth. What we're seeing now is that you've got to bring all these pieces back together. You can't do the kind of science that you want to do today without having the mathematician and the chemist, or the physicist, or the biologist working together—and maybe all four. Basically, science can't move now without the mathematicians' participation.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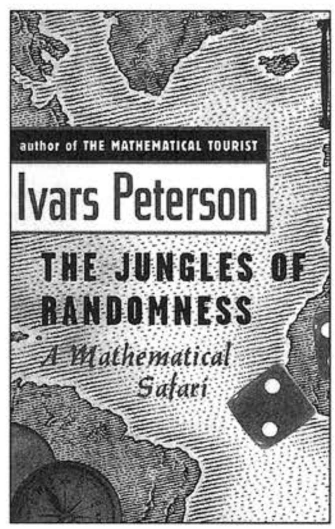
Book Review

# The Jungles of Randomness: A Mathematical Safari

*Reviewed by Rick Durrett*

**The Jungles of Randomness: A Mathematical Safari**
*Ivars Peterson*
*John Wiley & Sons, 1997 (1998 softcover)*
*Hardcover, 239 pages, $24.95, ISBN 0-4711-6449-6*
*Softcover, 240 pages, $14.95, ISBN 0-4712-9587-6*




Ivars Peterson is the mathematics and physics editor for *Science News* and the author of four previous books, including the *The Mathematical Tourist: Snapshots of Modern Mathematics*, where he had the good taste to mention some of my work. Thus I approached his most recent book, *The Jungles of Randomness*, expecting to like it. However, two hundred pages later when my mathematical safari was completed, I had mixed emotions about my trip.

The writing is choppy. Thirty-second sound bites may be good for the evening news, but they make for tiring reading, and in a number of cases they completely miss the point. Peterson's discussion of self-avoiding walks on pages 156–7 concentrates on the problem of enumerating random walks and how difficult this becomes as the number of steps $n$ increases. However, even though Peterson has clearly spoken to Gordon Slade, the book makes no mention of the spectacular achievement of Hara and Slade showing that in dimension $d > 4$ end-to-end displacements scale like $n^{1/2}$, as ordinary random walks do. Nor does he mention the interesting and still unresolved problem of computing the scaling behavior of self-avoiding walks in dimensions $1 < d < 4$, where the self-avoiding constraint makes them wander a distance of order $n^a$ with $a > 1/2$.

A second problem with sound bites is that they make the underlying mathematics sound strange: "Ramsey theory implies that complete disorder is impossible." Physicists' notion of self-organized criticality is reduced to the triviality "Big events occur less frequently than small events, a relationship that can in many cases be expressed by a simple mathematical formula." The remarkable insight in the Black-Scholes formula becomes the enigmatic remark "The direction of price change doesn't matter. Instead, the only thing that matters is how much the stock price is likely to vary."

I guess in a popular math book one is not allowed to write down a formula like $X_t = X_0 \exp(\mu t + \sigma B_t)$ for the Black-Scholes stock price model in order to be able to say precisely that the price of an option depends only on the volatility $\sigma$ but not on the drift $\mu$. However, one can easily explain the essence of this surprising conclusion to undergraduate mathematics majors, or even MBA students, by considering a simple example. Suppose

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that a stock starts with a price of 100, one has an option to buy it in three months at 110, and at that time the price of the stock will be either 90 or 120. To be precise, our profits in the two situations when the option sells for $c$ are

| | profit from stock | profit from option |
|---|---|---|
| up | 20 | $10 - c$ |
| down | $-10$ | $-c$ |

If we buy $x$ units of the stock and $-3x$ of the option, then our payoff in either case is $(3c - 10)x$. If $c > 10/3$, we would make a lot of money with no possibility of loss by taking $x$ large. If $c < 10/3$, we could do the same by selling the stock and buying the option in a one-to-three ratio. The remarkable thing about this conclusion is that it does not depend on the probabilities of the two events.

In addition to errors of omission, there are a few mistakes in the mathematical explanations given. Peterson correctly states the fact that in a sequence of $n^2 + 1$ distinct numbers there is either an increasing subsequence or a decreasing subsequence of length $n + 1$. However, he bungles the well-known "proof by solitaire". Write the numbers on cards. Then put each card on top of the leftmost stack where it is larger than the top card. Each stack is an increasing sequence, while the cards you can see will always be a decreasing sequence (or otherwise you put a card in the wrong place). Since there are $n^2 + 1$ cards, there must either be a pile of size $> n$ or $> n$ piles. Peterson makes a simpler error in the definition of Lévy's random flight: steps larger than $\ell$ should be taken proportionally to a power of $1/\ell$ if one wants to have a process flexible enough to cover the applications indicated in the book.

At this point, Peterson and some of his fans are probably ready to scream, "The objections just raised are not important," and they are right. The book presents a lot of interesting material. For instance, in connection with Lévy's flight it mentions data on flights of the wandering albatross collected by the British Antarctic survey. Furthermore, when Peterson takes the time to actually explain things, the book is very interesting. A good example is the work of Diaconis and Mosteller on coincidences. Here the sound bites work: "If something happens to only one in a million people per day and the population of the U.S. is 250 million, then you expect 250 amazing coincidences a day." A concrete example of an event that can be explained by this type of reasoning is the fact that in 1986 a New Jersey woman won a million-dollar lottery prize twice in four months. The chance that some person specified in advance will do this in a given four-month period is a zillion-to-one shot, but leaving the person and the time interval unspecified drops the probability to about 1 in 30, according to calculations of Diaconis and Mosteller.

A more technical situation that is also nicely explained is Mark Kac's problem "Can you hear the shape of a drum?" Peterson spends more than seven pages developing the story from the initial positive results that motivated the question to Milnor's 16-dimensional drums, Buser's 3-dimensional sound-alike bells, and finally Gordon and Webb's 2-dimensional domains. One of eight color plates in the center of the book shows the results of an experiment by physicist Srinivas Sridhar at Northwestern, who made copper boxes with the Gordon-Webb shapes and introduced microwaves through tiny holes to make pictures of the first three eigenfunctions. The striking differences in the patterns make the mathematical result seem an even more remarkable achievement.

Peterson's book contains a wealth of information, and even experts will find within their subjects some new tidbits of knowledge. In the first chapter, "The Die Is Cast", among the old chestnuts that include Chevalier de Mere's sucker bet (can you roll a six in four tries?) is the new nutty fact that the sums of the faces of two dice (one with sides 1,2,2,3,3,4 and one with sides 1,3,4,5,6,8) have the same probabilities as ordinary dice, and this is the only alternative numbering that works. In the "Sea of Life" we start with the well-known and easy-to-prove fact that in a group of six people there is either a triangle of friends or a triangle of strangers, but we soon come to the less famous Budapest café problem, "Given five points positioned on a flat surface so that no three lie on a line, show that four of the points define a convex quadrilateral."

One of the things that makes Peterson's treatment of the last problem appealing is that he takes the time to paint a picture of Paul Erdős, George Szekeres, and Esther Klein sitting around a table at a café "talking politics and feeding their passion for mathematics," and he describes the solution of the problem. Some more details would have been welcome later in the chapter when he mentions Erdős's use of probabilistic reasoning to get lower bounds on Ramsey numbers. Peterson explains only that Erdős flipped coins to see who was related and then showed that "the probability of getting a party with a desired mix of strangers and acquaintances is practically certain beyond a certain size of the group," an observation that seems to me to be going in the wrong direction.

Almost half of the book concerns areas that are far from my experience, so there I just went with the flow, nodding my head as if I understood what he was saying and generally enjoying myself. The "Call of the Firefly" concerns synchronization of oscillators. The "Noise Police" concerns error correction and encryption. I am interested in biology, so I struggled to understand the "Shell Game", a chapter about viruses folding themselves into structures that resemble geodesic domes, but all

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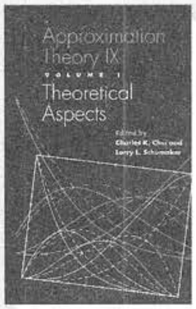
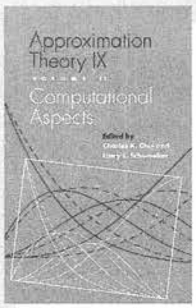
# INNOVATIONS IN APPLIED MATHEMATICS

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that I came away with is the notion that these are interesting problems that mathematics has something to say about.

The reader can probably guess the subject of "Complete Chaos". There one finds an interesting story about pinball games in the 1930s near the Massachusetts Institute of Technology. One finds a strange claim that the amusement ride Tilt-A-Whirl is exciting because its dynamics are chaotic and hence is sensitive to its initial conditions. From there the chapter makes an excursion into the cardiac rhythms where chaos = death and relates this to an incredible analysis (in the literal sense of the words) by Pincus and Singer of Standard and Poor's index of 500 stocks. Their "calculations show that fluctuations in the index's value are generally quite far from being completely irregular or random. One striking exception occurred during the two-week period immediately preceding the stock market crash of 1987, when the approximate entropy indicated nearly complete irregularity. That change flagged the incipient collapse." Thus, I guess we should refer to the "defibrillation" rather than the crash of October 1987. Of course, such catastrophic events are much easier to predict after they happen.

The random samples of Peterson's book above should give you an idea of its content. I agree with Robert Osserman's quote on the book jacket that "Every reader, regardless of background, is bound to find something new and interesting in this book." Personally, I would have enjoyed the book much more if it had spent more time on fewer topics. However, in this case other readers might have enjoyed it less. Hyperbolic prose seems inevitable in books of this type, but in Peterson's book it is not as abundant or as annoying as in other books I have read. Last but not least, as a $15 paperback this book is one-fifth as expensive and three times as entertaining as your typical technical math book, so if you are intrigued by the topics, then give it a try. The book comes with a four-page appendix and fifteen pages of references that will help you start to figure out the underlying math if you are so inclined.

# NSF Fiscal Year 2000 Budget Request

*This article is the 27th in an annual series of reports outlining the president's request to Congress for the budget of the National Science Foundation. Last year's report appeared in the May 1998 issue of the* Notices, *pages 616–618.*

On February 1, 1999, President Clinton sent to Congress his budget request for fiscal year 2000, which begins October 1, 1999. For the second year in a row the government is projecting a large surplus, which for FY 2000 comes to $117 billion. However, the budget request contains only modest increases for research and development (R&D). Under the terms of the request, federal funding for R&D would decline by 1%, mostly due to cuts in defense research. Civilian R&D, which would rise 3%, now comprises more than half of all federal spending on R&D. Funding for basic research would increase by 4%, and the budget for the primary funder of mathematical sciences research, the National Science Foundation (NSF), would rise by 5%. The administration's request is just one step in the budget process, and the numbers could look quite different when Congress actually appropriates funds.

The government has a surplus, and support for science is strong in the administration and Congress. Why then are the requested increases for R&D not larger? A number of factors come into play. One is that the Clinton administration has other, higher priorities for the use of the surplus, such as shoring up Social Security and Medicare. Another factor is the pressure caused by the spending caps that were enacted in 1997. In fact, as Richard M. Jones put it in the electronic newsletter *FYI*,[1] these caps are "proving to be impossible to follow." Last year Congress, unable to hold spending below the caps, did not manage to pass its traditional taxing and spending blueprint and ended up using funds from the surplus.

Further complicating the outlook for science funding are the increasing demands to quantify the return on government investment in science. The Government Performance and Results Act (GPRA), passed in 1993, called on all federal agencies to come up with specific goals and metrics for measuring progress toward those goals. Agencies like the NSF have been struggling with the question of how to formulate appropriate metrics to measure progress in basic research. These agencies have come under increasing pressure from Congress to provide proof, as stipulated by GPRA, that the research they are supporting has worthwhile benefits for the nation. In mid-February the National Academies of Science and Engineering and the Institute of Medicine released a new report by their Committee on Science, Engineering, and Public Policy entitled "Evaluating Federal Research Programs: Research and the Government Performance and Results Act".[2] This report recommends different forms of what it calls "expert review" to measure performance outcomes in R&D. The first performance results mandated by GPRA are due in March 2000.

Last year saw a change in the top position at the NSF, when Neal Lane left the Foundation to become science advisor to President Clinton. Lane's successor is Rita Colwell, a molecular biologist and former head of the University of Maryland Biotechnology Institute. Colwell is best known for saving lives in countries like Bangladesh by the observation that filtering water through sari cloth can eliminate cholera bacteria. Since coming to the NSF in August 1998 she has moved swiftly to put her stamp on the Foundation by establishing new programs, such as one that provides fellowships for graduate students and advanced undergraduates to assist schoolteachers with science and mathematics content in K–12 courses.

Colwell has also embraced the administration's new initiative in information technology, called $IT^2$, as the NSF's main priority for FY 2000. Of the NSF's requested increase of $181 million, $110 million is slated to go to $IT^2$. The NSF is the lead agency in this six-agency effort, for which the administration has requested a total of $366 million in additional funds. $IT^2$ grew out of a report issued

[1] FYI: The American Institute of Physics Bulletin of Science Policy News *is available by sending an e-mail message to* fyi@aip.org.

[2] *This report may be found on the Web at* http://www.nap.edu/readingroom/books/gpra/.

last year by the President's Information Technology Advisory Committee, which outlined the importance of information technology to the nation's economy and warned that support for research in this area was lagging.

For its part of $IT^2$, the NSF will use the requested increment of $110 million to support research on software systems, scalable information infrastructure, and high-end computing, as well as research on how information technologies influence society, the economy, and the work force. This part of the initiative will be centered in the NSF's Computer and Information Sciences and Engineering (CISE) Directorate and will be funded as a program separate from existing CISE programs. Another part of the $IT^2$ initiative focuses on the development of "terascale" computing systems, high-capacity systems that will allow researchers to address problems that are too large for systems currently available. This part of the initiative, amounting to $36 million, would be supported by funds in the NSF's Major Research Equipment program.

The other big priority for the NSF for FY 2000 is an initiative called Biocomplexity in the Environment. This multidisciplinary effort seeks to understand interdependencies among living organisms and their environments. The budget request calls for an increment of about $70 million for the NSF to support activities in connection with the biocomplexity initiative. Unlike the funds for $IT^2$, which are centered in the CISE Directorate, most of the funding for the biocomplexity initiative comes under the rubric of Integrative Activities and is not centered in a specific disciplinary directorate. As a result, the funds for the biocomplexity initiative are likely to be spread more widely around the NSF. Because some of the research involves computation, data analysis, and modeling, there are opportunities for mathematicians to take part in this initiative.

There are also opportunities for mathematicians to take part in $IT^2$. Nevertheless, the way that initiative was planned must have been a disappointment to the NSF's Division of Mathematical Sciences (DMS). Last year the NSF launched an ini-

## Table 1: National Science Foundation (Millions of Dollars)

| | 1996 Actual | Change | 1997 Actual | Change | 1998 Actual | Change | 1999 Plan | Change | 2000 Request |
|---|---|---|---|---|---|---|---|---|---|
| (1) Mathematical Sciences Research Support | $ 87.7 | 5.9% | $ 92.9 | 0.7% | $ 93.6 | 7.8% | $ 100.9 | 4.4% | $ 105.3 |
| (2) Other Research Support (Note a) | 2381.0 | 2.8% | 2447.2 | 4.5% | 2557.2 | 10.8% | 2834.3 | 5.3% | 2983.7 |
| (3) Education and Human Resources (Note b) | 601.2 | 3.0% | 619.1 | 2.3% | 633.2 | 8.8% | 689.1 | 3.2% | 711.0 |
| (4) Salaries and Expenses (Note c) | 136.5 | 2.3% | 139.6 | 1.5% | 141.7 | 5.4% | 149.3 | 3.5% | 154.5 |
| (5) Totals | 3206.3 | 2.9% | 3298.8 | 3.8% | 3425.7 | 10.2% | 3773.7 | 4.8% | 3954.5 |
| (6) (1) as a % of the sum of (1) and (2) | 3.55% | | 3.66% | | 3.53% | | 3.44% | | 3.41% |
| (7) (1) as a % of (5) | 2.73% | | 2.82% | | 2.73% | | 2.67% | | 2.66% |

**Note a:** Support for research and related activities in areas other than the mathematical sciences. Includes scientific research facilities and instrumentation, and the Antarctic program. **Note b:** The programs in this category provide support in all fields, including the mathematical sciences. **Note c:** Administrative expenses of operating the Foundation, including the Office of Inspector General.

## Table 2: Directorate for Mathematical and Physical Sciences (Millions of Dollars)

| | 1996 | | 1997 | | 1998 | | 1999 | | 2000 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual | % of Total | Actual | % of Total | Actual | % of Total | Plan | % of Total | Request | % of Total |
| (1) Mathematical Sciences | $ 87.7 | (13.3%) | $ 92.9 | (13.4%) | $ 93.6 | (13.6%) | $ 100.9 | (13.7%) | $ 105.3 | (14.0%) |
| (2) Astronomical Sciences | 108.7 | (16.5%) | 113.5 | (16.4%) | 113.6 | (16.5%) | 118.8 | (16.2%) | 122.2 | (16.2%) |
| (3) Physics | 131.9 | (20.0%) | 138.6 | (20.0%) | 142.7 | (20.8%) | 162.5 | (22.1%) | 167.4 | (22.2%) |
| (4) Chemistry | 127.7 | (19.3%) | 133.7 | (19.3%) | 130.1 | (18.9%) | 135.6 | (18.5%) | 138.5 | (18.4%) |
| (5) Materials Research | 175.1 | (26.5%) | 185.0 | (26.7%) | 178.9 | (26.0%) | 186.6 | (25.4%) | 190.5 | (25.3%) |
| (6) Office of Multidisciplinary Activities | 29.5 | (4.5%) | 29.8 | (4.3%) | 28.3 | (4.1%) | 30.0 | (4.1%) | 30.0 | (4.0%) |
| (7) Totals | 660.5 | (100%) | 693.5 | (100%) | 687.2 | (100%) | 734.4 | (100%) | 754.0 | (100%) |

tiative called Knowledge and Distributed Intelligence (KDI), and DMS director D. J. Lewis was closely involved in its formulation. KDI was crafted in such a way that mathematics was a central player and its funds were available to all areas supported by the NSF. As it turned out, mathematicians did very well in competing for KDI funds. For FY 2000, KDI was transformed and expanded to become $IT^2$ and, in the process, went from being an NSF-wide effort to one that is centered in a single directorate. Indeed, the overall outlook for the DMS was much rosier last year, when the budget request contained a whopping 17.4% increase for the DMS. When the appropriation came through, the increase for the DMS for FY 1999 had been whittled down to 7.8%, which was still quite good.

For FY 2000, the DMS is starting out with a requested increase of just 4.4%. In fact, this is the largest percentage increase for any division within the Mathematical and Physical Sciences (MPS) Directorate. In addition, mathematics is mentioned in the MPS budget writeup for the second year in a row as an area of high priority. These signs of support for mathematics simply do not translate into many dollars, given that the budget request for MPS overall is just 2.7%. In fact, there is constraint on programs across the Foundation, with most receiving requested increases in the 2%-4% range. Of special concern in mathematics, where support for graduate students is meager compared to other disciplines, is the fact that the budget for the program overseeing the NSF Graduate Fellowships is set for a decrease of 5.4%. Another factor increasing the strain on the DMS budget is the continuing decline in support for mathematical sciences research at the agencies of the Department of Defense.[3] This has led some mathematicians who in the past received support from the defense agencies to send their proposals instead to the DMS.

An important activity of the DMS for the past couple of years has been the recompetition of the mathematics institutes it funds. According to the NSF budget request document, the two existing institutes—the Mathematical Sciences Research Institute in Berkeley and the Institute for Mathematics and its Applications at the University of Minnesota—will be joined by a third institute.The institutes are funded through the DMS account called Infrastructure Support, which is slated to receive a \$3 million increase to \$32 million for FY 2000. Another program under Infrastructure Support is VIGRE (Vertical Integration of Research and Education), which has a requested budget of \$16 million for FY 2000. The decrease of \$3 million in the VIGRE budget between 1999 and 2000 reflects the fact that there were two VIGRE competitions in 1999 and there will be only one in 2000. The DMS category Research Project Support, which oversees traditional grants to individual investigators and small groups, has a requested budget of \$73.3 million, up from \$71.9 million for fiscal 1999. This increase, amounting to just 1.9%, barely covers inflation.

For further information on the NSF Fiscal Year 2000 Budget Request, consult the Web site `http://www.nsf.gov/home/budget/start.htm`.

*—Allyn Jackson*

[3] *For information on support for mathematical sciences research across the federal government, see the article "Mathematical Sciences in the FY 2000 Budget" in this issue of the* Notices.

## **Table 3:** 5-Year Compilation of the NSF Budget, 1994–2000 (Millions of Dollars)

| | 1994 Actual | 1995 Actual | 1996 Actual | 1997 Actual | 1998 Actual | 1999 Plan | 2000 Request | 1994–1998 Change | 1994–2000 Change |
|---|---|---|---|---|---|---|---|---|---|
| (1) **Mathematical Sciences Research Support** | \$ 78.0 | \$ 85.3 | \$ 87.7 | \$ 92.9 | \$ 93.6 | 100.9 | 105.3 | 20.0% | 35.0% |
| *Constant Dollars* | 52.6 | 56.0 | 55.9 | 57.9 | 57.4 | | | 9.1% | |
| (2) **Other Research Support** | 2212.8 | 2439.6 | 2381.0 | 2447.2 | 2557.2 | 2834.3 | 2983.7 | 15.6% | 34.8% |
| *Constant Dollars* | 1493.1 | 1600.8 | 1517.5 | 1524.7 | 1568.8 | | | 5.1% | |
| (3) **Education and Human Resources** | 569.0 | 611.9 | 601.2 | 619.1 | 633.2 | 689.1 | 711.0 | 11.3% | 25.0% |
| *Constant Dollars* | 383.9 | 401.5 | 383.2 | 385.7 | 388.5 | | | 1.2% | |
| (4) **Salaries and Expenses** | 127.4 | 133.5 | 136.5 | 139.6 | 141.7 | 149.3 | 154.5 | 11.2% | 21.3% |
| *Constant Dollars* | 86.0 | 87.6 | 87.0 | 87.0 | 86.9 | | | 1.0% | |
| (5) **Totals** | 2987.2 | 3270.3 | 3206.3 | 3298.8 | 3425.7 | 3773.7 | 3954.5 | 14.7% | 32.4% |
| *Constant Dollars* | 2015.7 | 2145.9 | 2043.5 | 2055.3 | 2101.7 | | | 4.3% | |

Current dollars are converted to constant dollars using the Consumer Price Index (based on prices during 1982–1984).

# Mathematical Sciences in the FY 2000 Budget

*Daniel Goroff*

*This article originally appeared in "AAAS Report XXIV: Research and Development, 1999", published by the American Association for the Advancement of Science in April 1999. It is a report on the federal budget request submitted by the president to the Congress in February 1999 and does not reflect subsequent congressional action. The comparable report for 1998 appeared in the September 1998* Notices, *pages 988–990.*

## Overview

Mathematical research studies the logical structures and processes that all scientists rely on to make sense of the world, from chaos to cryptography, from medical imaging to movie graphics, and from large data set algorithms to the calculus of infinitesimals. That is why mathematics is often at the center of multidisciplinary initiatives large and small. Compared with laboratory scientists, for example, mathematicians can also accomplish much with grants of relatively modest size involving a small number of experts and students working on special-seeming problems with relatively little equipment. When awarding such grants, detailed priorities and targets set in advance are less crucial than when decisions must be made between large and mutually exclusive projects. Indeed, curiosity-driven, investigator-initiated, and peer-reviewed funding mechanisms work especially well in this field, where the applications of research to areas both within mathematics as well as in other disciplines, whether immediate or after many years, tend to be solid, surprising, and significant.

The role of the United States as world leader in mathematical research should be maintained by the president's budget request and throughout the federal budgeting process. Most research on mathematics takes place at institutions of higher education and in government laboratories. Mathematicians also do valuable work throughout the economy, yet few private firms can afford to invest much in research whose payoffs, while great in total, may be distributed too widely in space and time to be adequately rewarded by the market. Government also has a role in drawing the attention of researchers to new fields and opportunities faster than might happen without federal involvement.

Three federal agencies supply the vast majority of funding for mathematical research in the United States: the National Science Foundation (NSF), the Department of Defense (DoD), and the Department of Energy (DoE). NSF provides more than half of all federal support for the mathematical sciences and is able to focus more on basic research than other mission agencies. Programs located in the Army, Navy, Air Force, and Defense Advanced Research Project Agency (DARPA) at DoD together account for about a third of federal support for the mathematical sciences. DoE's Mathematical, Information, and Computational Sciences (MICS) program makes up most of the rest of the dedicated spending on mathematics.

Other federal agencies, such as the National Aeronautics and Space Administration (NASA), the National Institutes of Health (NIH), the National Institute for Standards and Technology (NIST), the Department of Transportation (DoT), and the Environmental Protection Agency (EPA), are also involved with mathematics in many ways. For example, mathematical research at NIST focuses on "analytical and computational methods for solving scientific problems of interest to American industry," and NIH has begun facilitating grants that include support for mathematicians and other fundamental researchers. Because spending related to mathematical research at these agencies is generally integrated into other categories of work rather than budgeted as dedicated programmatic funds for mathematics, the scale of their support is difficult to estimate in advance. This report, therefore, focuses on explicit expenditure plans at NSF, DoD, and DoE.

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*The author thanks Lewis-Burke Associates for its assistance in preparing this report.*

## Highlights

- The Division of Mathematical Sciences (DMS) at the National Science Foundation is requesting $105.3 million, an increase of $4.4 million (4.4%) over FY 1999.
- Basic research accounts at the Department of Defense would remain flat overall, receiving $1.113 billion, an increase of only 0.5% above the FY 1999 level of $1.108 billion.
- The Department of Energy's Mathematical, Information, and Computational Sciences (MICS) program would increase by $45.8 million (33%) above the $138.8 million provided in FY 1999. The MICS request includes $52.0 million in new funding for the Strategic Simulation Initiative, DoE's portion of the administration's FY 2000 information technology initiative ($IT^2$).
- In terms of incremental as opposed to core funding, the centerpiece of the president's FY 2000 research budget request is a $366 million initiative for information technology, known as $IT^2$. Of the six participating agencies, the three largest shares go to NSF ($146 million), DoD ($100 million), and DoE ($70 million). Mathematical research is critical to achieving the goals of this initiative. However, the mechanisms for involving disciplines other than computer science are not yet clear.

## FY 2000 R&D Funding Requests, by Agency

The table at the end of this report shows the FY 2000 budget request for mathematical research programs at NSF, DoE, and DoD. Below are brief descriptions of each of these programs and the funding levels requested by the president.

**National Science Foundation**

NSF's Division of Mathematical Sciences (DMS) supports a wide range of projects aimed at developing and exploring the properties and applications of mathematical structures. In FY 2000, DMS would receive $105.3 million in total, an increase of $4.4 million (4.4%) over FY 1999. Research sponsored by DMS is conducted in areas including analysis, geometry, topology, foundations, algebra, number theory, applied mathematics, statistics, probability, biomathematics, and computational mathematics, as well as various multidisciplinary areas. Funding for DMS research projects would remain relatively flat, increasing $1.4 million (1.9%) to $73.3 million. Through its many programs, DMS also plays a key role in ensuring both the vitality of the discipline itself and its availability as a resource for progress in science, technology, and industry. DMS Infrastructure Support, responsible for postdoctoral research fellowships, graduate education, research conferences, workshops, and shared research equipment, would increase $3.0 million (10.3%) to $32.0 million. The Vertical Integration of Research and Education in the Mathematical Sciences (VIGRE) program funds innovative educational programs "in which research and education are integrated, and in which undergraduates, graduate students, postdoctoral fellows, and faculty are mutually supportive." Begun in FY 1998 with only eight awards, VIGRE expanded from $4.5 million in FY 1998 to nearly $19.0 million in FY 1999, including some funding carried over from the previous year, and would receive $16.0 million in FY 2000.

**Department of Energy**

The Mathematical, Information, and Computational Sciences (MICS) Division investigates the mathematical underpinnings of challenges that range from supercomputing to the human genome project, and from chemical structures to mechanical engineering. The Applied Mathematics Program, for example, funds research in the mathematics of physical systems, optimization and mathematical programming, dynamic systems theory and chaos, geometric and symbolic computation, as well as numerical analysis and scientific computation. In FY 2000, the MICS program would receive $184.6 million, up $45.8 million (33%) from the $138.8 million provided in FY 1999. Of this total, MICS would be asked to dedicate $52.0 million for the Strategic Simulation Initiative, DoE's portion of the administration's information technology for the twenty-first century program ($IT^2$). MICS also would provide $14.6 million for the Next Generation Internet initiative, the same amount appropriated in FY 1999. Additionally, the FY 2000 budget also requests $1.9 million for new science education activities to support college faculty and student research participation at DoE laboratories.

**Department of Defense**

*Defense Advanced Research Projects Agency (DARPA):* The Applied and Computational Mathematics program seeks to combine new mathematical techniques with high-performance computing hardware technology "to revolutionize the DoD's modeling and simulation capability" to improve over "previous methods such as engineering trial and error." Supported research focuses on developing new mathematical algorithms, such as those based on wavelets and partial differential equation techniques for image processing and data compression, as well as on control strategies for advanced materials processing. Because of the limited release of program-level budget request data by DoD, the FY 2000 request for this program is unknown.

*National Security Agency (NSA):* By its own account, NSA is one of the largest employers of mathematicians in the U.S. and perhaps the world. Since 1987 the NSA Mathematical Sciences Program has funded critical mathematical research in the areas of algebra, number theory, discrete mathematics, probability, statistics, and cryptology. Using these techniques, mathematicians at NSA contribute directly to the two missions of the agency: while some "help design cipher systems that will protect the integrity of U.S. information systems, others search for weaknesses in adversaries' codes." For security reasons, the NSA does not disclose the exact amounts it will spend, but the agency does state that it will continue to "vigorously" support mathematics research proposals.

*Air Force Office of Scientific Research (AFOSR):* AFOSR's Mathematics and Computer Sciences Division is located within the Directorate of Mathematics and Space Sciences, which is responsible for basic research in mathematical, computer, and space sciences. Many critical research activities are multidisciplinary and involve support from the other scientific directorates within AFOSR. For example, the control theory and mathematical modeling research supported by this directorate complements many structural, fluid mechanics, and propulsion research programs run by the Directorate of Aerospace and Materials Sciences. Mathematical research supported by the Air Force spans a range of fields in mathematics, including, for example: optimization and discrete mathematics, including linear and nonlinear programming; computational geometry; physical mathematics and applied analysis, including nonlinear optics, the mathematics of materials, inverse problems, and theoretical fluid dynamics; signal processing, probability, and statistics, drawing on wavelet methods and reliability analysis; and computational mathematics using novel parallel computing, reliable numerical methods, and spectral techniques. The FY 2000 budget request for Mathematics and Computer Sciences is $32.9 million, a decrease of $1.5 million, or 4.4%.

*Army Research Office (ARO):* Mathematical sciences play a key role in the analysis and modeling issues that arise in military science, engineering, and operations. For example, ARO explains that some promising approaches to computer vision for automatic target recognition (ATR) require research in a wide range of mathematical areas including constructive geometry, numerical methods for stochastic differential equations, Bayesian statistics, tree-structured methods in statistics, probabilistic algorithms, and distributed parallel computation. The ARO's Mathematics and Computer Science Division therefore attempts systematically to advance fundamental knowledge that relates to the Army's needs, supporting extramural basic research in applied analysis and physical mathematics, computational mathematics, stochastic analysis, applied probability and statistics, systems and control, software and knowledge-based systems, and discrete mathematics and computer science. In particular, ARO supports several centers and institutes that fall under the University Research Initiative (URI). Because of the limited release of program-level budget request data by DoD, the FY 2000 request for this program is unknown.

*Office of Naval Research (ONR):* The Mathematical, Computer, and Information Sciences Division, part of the ONR's Information, Surveillance, and Electronics Department, supports "fundamental investigations into mathematical foundations for models, computability, and processes." This includes research in the mathematical areas of applied analysis, discrete mathematics, numerical analysis, operations research, visualization, and probability and statistics in support of the naval mission. Applications range from enhancing surveillance techniques to improving human-computer interaction. Because of the limited release of program-level budget request data by DoD, the FY 2000 request for this program is unknown.

**Federal Support for the Mathematical Sciences**
**FY 1998–FY 2000 (in millions of dollars)**

| Agency | FY 1998 Actual | FY 1999 Estimate | FY 2000 Request | FY 1999–2000 Percent |
|---|---|---|---|---|
| National Science Foundation | | | | |
| DMS | $ 93.6 | $100.9 | $105.3 | 4.4% |
| Department of Defense | | | | |
| AFOSR | $ 30.5 | $ 34.4 | $ 32.9 | −4.4% |
| ARO | 12.0 | 12.0 | * | * |
| ONR | 7.7 | 7.0 | * | * |
| DARPA | 22.5 | 19.5 | * | * |
| Department of Energy | | | | |
| MICS | $124.0 | $138.8 | $184.6 | 33.0% |

*Unknown at time of publication.

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# MATHEMATICAL CHALLENGES OF THE 21ST CENTURY

## UNIVERSITY OF CALIFORNIA LOS ANGELES
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The purpose of the meeting is to demonstrate, not just to the mathematical community, but to the world at large, the power of mathematical ideas across the landscape of the sciences and practical affairs, while still maintaining a close link to ongoing developments. These leaders in their fields have agreed to give plenary talks. There will be 30 in all who will provide broad perspectives on mathematics in science and practical applications.

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# Mathematics People

## 1999 AMS Centennial Fellowships Awarded

The AMS has awarded four Centennial Fellowships for 1999–2000. The recipients are CHARLES REZK, BIN WANG, CHANGYOU WANG, and TONGHAI YANG.

### Charles Rezk

Charles Rezk received his Ph.D. from the Massachusetts Institute of Technology in 1996 under the supervision of Michael Hopkins. Since then Rezk has been a Ralph P. Boas Visiting Assistant Professor at Northwestern University.

His research has centered on algebraic topology and homotopy theory. He has worked on the problem of realizing homotopy-algebraic structures using operads and on problems in abstract homotopy theory. His current interests include elliptic cohomology and modular forms and the relation of these to homotopy groups of spheres. He will use his Centennial Fellowship to visit the Institute for Advanced Study in Princeton.

### Bin Wang

Bin Wang received a Ph.D. in 1994 from Brown University under the direction of Bruno Harris. Since then Wang has been a visiting assistant professor at Boston College and a Gibbs Instructor at Yale University, and currently he is a visiting assistant professor at Brown University.

His research interests are algebraic geometry and arithmetic geometry, more specifically the application of the Archimedean height pairing (or complex linking number), which comes from Arakelov geometry, to problems in complex algebraic geometry. This has been a main focus of his research. Along these lines, he studied the asymptotic behavior of the Archimedean height pairing and constructed the incidence structure for a smooth projective variety proposed by Barry Mazur. In work based on these ideas, Wang is currently completing a proof of Clemens's conjecture, which asserts that there are finitely many smooth rational curves of given degree on a generic quintic 3-fold.

Wang is going to use the Centennial Fellowship to visit Harvard University.

### Changyou Wang

Changyou Wang received his Ph.D. in 1996 from Rice University under the supervision of Robert Hardt. Wang has been a Dickson Instructor at the University of Chicago (1996–1999) and an assistant professor at Loyola University of Chicago (1998–1999). He will be an assistant professor at the University of Kentucky starting in the fall of 1999.

Wang's area of research is partial differential equations and geometric analysis. His work includes results on analytic aspects of harmonic maps and heat equations of harmonic maps, such as partial regularity, behavior of singularities, blowing-up analysis, and bubbling phenomena. Recently, he has been interested in issues related to biharmonic maps and variational problems in $L^\infty$.

He plans to use the Centennial Fellowship to visit the Courant Institute of Mathematical Sciences at New York University, and Princeton University.

### Tonghai Yang

Tonghai Yang received his Ph.D. from the University of Maryland in 1995 under the direction of Stephen S. Kudla. After a year at the Institute for Advanced Study, Yang became a Hildebrandt assistant professor at the University of Michigan. He was a visitor at the Max-Planck-Institut für

Charles Rezk

Bin Wang

Changyou Wang

Tonghai Yang

Mathematik in Bonn during the summers of 1997 and 1998. Since fall 1998 he has been an assistant professor at the State University of New York at Stony Brook.

Yang's research area is number theory. He is interested in number theory, representation theory, and arithmetic geometry, and especially their interactions. He studies special values and derivatives of arithmetic $L$-series and Eisenstein series at the center via representation theory, and the underlying arithmetic. He also studies the relationship between theta functions and periods of abelian varieties with complex multiplications.

He plans to use the Centennial Fellowship to visit Harvard University. He also plans to visit the Institute for Advanced Study for two months.

**Please note:** Information about the competition for the 2000–01 AMS Centennial Fellowships will be published in the "Mathematics Opportunities" section of an upcoming issue of the *Notices.*

—*Allyn Jackson*

# Sloan Fellows Announced

The Alfred P. Sloan Foundation has announced the names of one hundred outstanding young scientists and economists who have been selected to receive Sloan Research Fellowships. Grants of $35,000 for a two-year period are administered by each Fellow's institution. Once chosen, Fellows are free to pursue whatever lines of inquiry most interest them, and they are permitted to employ fellowship funds in a wide variety of ways to further their research aims.

More than four hundred nominations for the 1999 awards were reviewed by a committee of distinguished scientists. The mathematicians on the committee were George C. Papanicolaou, Stanford University; Peter Sarnak, Princeton University; and Karen Uhlenbeck, University of Texas, Austin.

The Sloan Fellows in mathematics are: Anne Gelb, Arizona State University; Alain Goriely, University of Arizona; Jingyi Chen, University of British Columbia; Rahul Pandharipande, California Institute of Technology; Terence Tao, University of California, Los Angeles; Igor Mezic, University of California, Santa Barbara; Jie Qing, University of California, Santa Cruz; Benson Farb, University of Chicago; Matthias Schwarz, University of Chicago; Shankar Venkataramani, University of Chicago; Irena Peeva, Cornell University; Dihua Jiang, University of Minnesota; Qing Han, University of Notre Dame; Ken Ono, Pennsylvania State University; Tony Pantev, University of Pennsylvania; Mary C. Pugh, University of Pennsylvania; Carson C. Chow, University of Pittsburgh; Wenzhi Luo, Princeton University; Jim Bryan, Tulane University; and Almut Burchard, University of Virginia.

—*Alfred P. Sloan Foundation announcement*

# Guggenheim Fellowships Awarded

The John Simon Guggenheim Memorial Foundation has announced the names of 179 artists, scholars, and scientists who were selected as Guggenheim Fellows from nearly 2,800 applicants in the 1999 competition. The awards totaled $6,062,000. Guggenheim Fellows are appointed on the basis of distinguished achievement in the past and exceptional promise for future accomplishment.

The following is a list of awardees who work in the mathematical sciences, together with their affiliations and areas of research interest.

Percy Alec Deift, Courant Institute, New York University: Riemann-Hilbert problems in pure and applied mathematics; Aaron L. Fogelson, University of Utah: Processes of platelet aggregation and coagulation; Cameron Gordon, University of Texas, Austin: Studies in three-dimensional manifolds; Yanguang Li, University of Missouri, Columbia: Chaos in partial differential equations; Roberto H. Schonmann, University of California, Los Angeles: Percolation and related processes on graphs; Joel Spruck, Johns Hopkins University: Nonlinear problems in geometry; Brian White, Stanford University: Minimal surfaces and mean-curvature flow; and Xin Zhou, Duke University: Oscillatory Riemann-Hilbert problems.

—*From a Guggenheim Foundation news release*

# 1999 Rollo Davidson Prizes

The trustees of the Rollo Davidson Trust have awarded Rollo Davidson Prizes for 1999 to RAPHAEL CERF of the Université Paris-Sud for his work on geometric probability and the large deviation theory of percolation in three dimensions, and GARETH ROBERTS of the University of Lancaster for his work on the theoretical properties of simulation procedures, including Markov chain and Monte Carlo methods, important in the Bayesian paradigm in statistics.

*—From Rollo Davidson Trust announcement*

# Deaths

JULIA WELLS BOWER, retired chair, Connecticut College, New London, died on February 19, 1999. Born on December 27, 1903, she was a member of the Society for 73 years.

CHARLES L. CARROLL, of Indialantic, FL, died on October 18, 1999. Born on September 16, 1916, he was a member of the Society for 61 years.

CHARLES H. CUNKLE, professor emeritus, Slippery Rock University of PA, died on December 19, 1998. Born on May 28, 1915, he was a member of the Society for 46 years.

IVAN FRANIC, of Zagreb, Croatia, died on February 8, 1998. Born on January 19, 1950, he was a member of the Society for 3 years.

CAROLYN SPENCER GALE, of Dayton, OH, died on September 28, 1998. Born on June 10, 1947, she was a member of the Society for 26 years.

CHARLES H. GOLDBERG, of The College of New Jersey, Trenton, died on December 18, 1998. Born on October 26, 1939, he was a member of the Society for 28 years.

MARIO O. GONZALEZ, of Coral Gables, FL, died on February 14, 1999. Born on September 14, 1913, he was a member of the Society for 58 years.

ROGER HOLVOET, of Katholieke Univ. Leuven, Louvain, Belgium, died on July 6, 1998. Born on July 5, 1938, he was a member of the Society for 29 years.

MARSHALL PHILLIP JONES, of Memphis, TN, died on March 9, 1999. Born on November 23, 1937, he was a member of the Society for 39 years.

PAUL J. KELLY, of Santa Cruz, CA, died on July 10, 1995. Born on June 26, 1915, he was a member of the Society for 56 years.

RUFUS A. MOORE, of Brackettville, TX, died on January 24, 1998. Born on February 8, 1923, he was a member of the Society for 41 years.

SUBHASHIS NAG, of the Institute of Mathematical Science, Chennai, India, died in December 1998. Born on August 14, 1955, he was a member of the Society for 21 years.

FRANCISCO J. NAVARRO, of Lincoln University of PA, died on September 16, 1998. Born on August 4, 1935, he was a member of the Society for 36 years.

STEPHEN C. PERSEK, of Lake Worth, FL, died on March 6, 1999. Born on May 4, 1945, he was a member of the Society for 29 years.

WILLIAM G. ROSEN, former head of the mathematical sciences section at the National Science Foundation and former professor of mathematics at the University of Mary land, College Park, died on March 19, 1999. Born on Ma 13, 1921, he was a member of the Society for 50 years.

GIAN-CARLO ROTA, professor of applied mathematics an philosophy at the Massachusetts Institute of Technolog died on April 19, 1999. Born on April 27, 1932, he was member of the Society for 44 years. He received the Steel Prize from the AMS in 1988.

DARRELL R. SHREVE, of Jackson, MS, died on March 27, 1993 Born on February 20, 1908, he was a member of the Society for 55 years.

TAFFEE TANIMOTO, professor emeritus at the University of Massachusetts at Boston, died on December 11, 1998. Born on December 15, 1917, he was a member of the Society for 52 years.

ANGUS ELLIS TAYLOR, former University of California provost, died on April 6, 1999. Born on October 13, 1911, he was a member of the Society for 63 years.

DAVID C. TISCHLER, of Queens College, CUNY, died on February 22, 1999. Born on June 22, 1943, he was a member of the Society for 32 years.

HUGH LONSDALE TURRITTIN, retired professor of mathematics from the University of Minnesota, Minneapolis, died on April 8, 1999. Born on April 24, 1906, he was a member of the Society for 69 years.

# Mathematics Opportunities

## NSF Announces Program on Large Scientific and Software Data Set Visualization

The National Science Foundation (NSF) has announced a research initiative on large-scale visualization for scientific data sets and for assisting software development. This program will support research to improve the ability to understand large data sets, simulation results, and software systems. It encourages use of these improved methods on data sets from experiments and simulations of real scientific interest and on large software systems.

The initiative focuses on two specific areas:

1. Very large visualizations. The overall goal is to develop general, extensible methods that enable understanding of very large (multigigabyte to terabyte) data sets from simulations, experiments, and data collections from the natural and social world. Subtopics of particular interest include interactive exploration of very large data sets; processing and presentation of real-time data from high-bandwidth sources; access and visualization of distributed data sets; extraction of features and behaviors, including uncertainty, for study; and building scalable software systems for visualization. Applicants should have at least 100 gigabytes of data or simulation output available for visualization.

2. Visualization as a tool for assisting software robustness and usability. The overall goal is to provide new techniques and tools for program understanding and development. Subtopics of particular interest include online and a posteriori visualization of program states; performance measurement and visualization; new depictions of program behaviors; and use of visualization in program development, debugging, and performance analysis. Applicants should be doing research work in graphical programming tools and similar topics.

Proposals may be submitted only by U.S. universities and U.S. nonprofit research institutions not part of the United States Government on behalf of individual investigators or small groups of investigators. Only one proposal may be submitted by a principal investigator, and he or she may collaborate on only one other proposal as a coinvestigator.

It is anticipated that 12 to 18 awards in the form of three-year standard grants will be given in fiscal year 1999. A total of approximately $10 million is available for awards. The awards are expected to be given in September 1999. The deadline for full proposals is **July 6, 1999.**

The program officer overseeing this program for Mathematical and Physical Sciences is James Rosenberger, Division of Mathematical Sciences, Room 1025, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230; telephone: 703-306-1883; e-mail: `jrosenbe@nsf.gov`. For further information consult the NSF's Web site at `http://www.nsf.gov/cgi-bin/getpub?nsf99105/`.

*—From an NSF announcement*

## CAREER/PECASE Program Guidelines on Web

Program guidelines for the National Science Foundation (NSF) CAREER/PECASE programs are now available on the World Wide Web. The new CAREER program announcement can be found at `http://www.nsf.gov/home/crssprgm/career/guide.htm`. The announcement number is NSF 99-110. Note that proposals must be submitted electronically via FastLane.

The CAREER program is intended for the support of excellent proposals from junior faculty who combine strong research activity with a genuine and substantive involvement in education. Proposals will be evaluated on the basis of both research and education. The duration of the awards will be at least four but not more than five years. The total award, including administrative costs, will not be less than

$200,000 for a five-year award. The deadline for proposals is **July 22, 1999.**

The NSF will select from the most meritorious awardees supported by the CAREER program the nominees for Presidential Early Career Awards for Scientists and Engineers (PECASE). PECASE awards recognize outstanding scientists and engineers who, early in their careers, show exceptional potential for leadership at the frontiers of knowledge. This presidential award is the highest honor bestowed by the United States government on scientists and engineers beginning their independent careers.

It is expected that the Division of Mathematical Sciences (DMS) will make a small number of CAREER awards. In previous years, either four or five awards were made. The division continues to encourage proposals to its "traditional" research grant programs that integrate research and education activity or that have significant education components. Applicants are encouraged to confer with program directors.

Before preparing a CAREER proposal, applicants are strongly urged to consult the CAREER "Frequently Asked Questions (FAQ)" document (CAREER-FAQ) available on the CAREER Web page, as well as the program announcement, for more extensive information. The mailing address for the NSF is National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230. The telephone number for the DMS is 703-306-1870.

*—National Science Foundation Announcement*

# AWM Workshops for Women Graduate Students and Postdocs

Over the past eleven years, the Association for Women in Mathematics (AWM) has held a series of workshops for women graduate students and recent Ph.D.'s in conjunction with major mathematics meetings. The workshops are also supported by the Office of Naval Research and the National Science Foundation.

The next AWM workshop to be held in conjunction with the annual Joint Mathematics Meetings will be in Washington, DC, January 19–22, 2000. The workshop is scheduled to be held on Saturday, January 22, 2000, with an introductory dinner tentatively scheduled for Thursday evening, January 20, 2000.

Twenty women will be selected in advance of the workshop to present their work; the selected graduate students will present posters, and the postdocs will give 20-minute talks. AWM will offer funding for travel and two days' subsistence for the selected participants. The workshop will also include a panel discussion on issues of career development, a luncheon, and a dinner with a discussion period. Participants will have the opportunity to meet with other women mathematicians at all stages of their careers. All mathematicians (female and male) are invited to attend the program. Departments are urged to help graduate students and postdocs who do not receive funding to obtain some institutional support to attend the workshop presentations and the associated meetings.

The AWM also seeks volunteers to lead discussion groups and to act as mentors for workshop participants. Anyone interested in volunteering should contact the AWM office.

Applications are welcome from graduate students who have made substantial progress toward their theses and from women who have received their Ph.D.'s within approximately the last five years. (The word "postdoc" refers to recent Ph.D.'s, whether or not they currently hold a postdoctoral or other academic position.) Women with grants or other sources of support are still welcome to apply. All non-U.S. citizens must have a current U.S. address. All applications should include a curriculum vitae, a concise description (two to three pages) of research, and the title of the proposed talk/poster. All applications should also include at least one letter of recommendation; in particular, graduate students should include a letter of recommendation from their thesis advisors. Nominations by other mathematicians (along with the information described above) are also welcome.

Send *five* complete copies of the application materials (including the cover letter) to: Workshop Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, MD 20742-2461; telephone: 301-405-7892; e-mail: `awm@math.umd.edu`.

Please note that nominations via e-mail or fax are not acceptable. The deadline for receipt of nominations at the AWM office is **September 1, 1999.**

*—AWM announcement*

# Fulbright Awards for 2000–2001 for U.S. Faculty and Professionals

The Fulbright Scholar Program offers opportunities for lecturing or advanced research in nearly 130 countries to college and university faculty and professionals outside academe. U.S. citizenship and a Ph.D. or comparable professional experience are required. For lecturing awards, university or college teaching experience is expected. Foreign language skills are needed in some countries, but most lecturing assignments are in English.

The deadlines are: **August 1, 1999,** for lecturing and research grants in the academic year 2000–01; **November 1, 1999,** for international education and academic administrator seminars; and **January 1, 2000,** for NATO advanced research fellowships and institutional grants.

For further information contact the USIA Fulbright Scholar Program, Council for International Exchange of Scholars, 3007 Tilden Street, NW, Suite 5L, Box GNEWS, Washington, DC 20008-3009; telephone: 202-686-7877; World Wide Web: `http://www.cies.org/`. Requests for application materials only may be sent by e-mail to apprequest@ies.iie.org.

—*CIES announcement*

# 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 exceeding 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, MD 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, 1999.**

—*AWM announcement*

# Call for Nominations for AWM Schafer Prize

The Executive Committee of the Association for Women in Mathematics (AWM) calls for nominations for the Alice T. Schafer Mathematics Prize, to be awarded to an undergraduate woman for excellence in mathematics. All members of the mathematical community are invited to submit nominations for the prize. The nominee may be at any level in her undergraduate career, but must either be a U.S. citizen or have a school address in the United States. The prize will be awarded at the Joint Prize Session at the Joint Mathematics Meetings in Washington, DC, in January 2000.

The Schafer Prize was established in 1990 by the Executive Committee of the AWM and is named for AWM former president and one of its founding members, Alice T. Schafer, who has contributed a great deal to women in mathematics throughout her career.

A letter of nomination should include, but not be limited to, an evaluation of the nominee on the following criteria: (1) quality of performance in advanced mathematics courses and special programs, (2) demonstration of real interest in mathematics, (3) ability to do independent work in mathematics, and (4) performance in mathematical competitions at the local or national level, if any. A copy of transcripts and an indication of the candidate's undergraduate level should be included with a letter of nomination. Supporting materials (e.g., reports from summer work using mathematics, copies of talks given in student chapters, recommendations, etc.) should be enclosed with the nomination, if applicable.

Send *five* complete copies of nominations for this award to: The Alice T. Schafer Award Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, MD 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 receipt of nominations at the AWM office is **October 1, 1999.**

—*AWM announcement*

# For Your Information

## Scientists Weigh In against Data Disclosure Law

A provision that would require scientists to provide research data in response to requests made under the Freedom of Information Act (FOIA) has caused an outcry in the scientific community. A number of groups, including the AMS Committee on Science Policy, have issued public statements calling for repeal of the provision.

Inserted at the last minute as an amendment to the omnibus spending bill passed by Congress last October, the provision is the work of Senator Richard Shelby, Republican of Alabama. The Shelby amendment mandates revision of a set of rules of the Office of Management and Budget (OMB), called Circular A-110, which pertain to disclosure of data by researchers supported by federal funding agencies. According to the amendment, OMB must now require these agencies "to ensure that all data produced under an award will be made available to the public through the procedures established under the Freedom of Information Act." Under FOIA, any person, including non-U.S. citizens, can request government agency records, subject to certain exemptions like national security and personal privacy. The Shelby amendment also states that the agencies may collect "reasonable user fees" equal to what it would cost to produce requested data.

Scientists have expressed deep concern over possible ramifications of this provision. One of the biggest problems is that the term "data" is not clearly defined. The law could apply to raw research data that has not yet been checked or analyzed, or to personal or medical data about human subjects in clinical trials. The law also does not exclude the possibility of an extreme interpretation of the word "data" to include computer programs, drafts of research papers, e-mail correspondence, and other documents involved in scientific research. The provision could also endanger foreign patent rights of researchers, since citizens of foreign countries where patent laws differ from those in the U.S. might be able to use FOIA to obtain information about inventions. A statement passed by the AMS Committee on Science Policy stated that the Shelby amendment "will lead to unintended and deleterious consequences to U.S. researchers and to research accomplishments."

As government regulation has increasingly come to be based on the results of scientific research, confidentiality of research data has become a thorny issue. A story in the February 5, 1999, issue of the *Chronicle of Higher Education* noted that business and industry have long lobbied Congress for access to research data, arguing that, because of the cost of complying with regulations that are based on federally funded research, they have a right to conduct independent reviews of the data on which the research is based. The *Chronicle* story also said that some researchers "fear that businesses will exploit the [Shelby amendment] to attack research that is not favorable to their industry."

Following the outcry over the Shelby amendment, the OMB issued in February 1999 a proposed revision to Circular A-110 that was intended to limit the scope of the Shelby amendment to apply only to "research findings used by the federal government in developing policy or rules." In response to the OMB's invitation for comment on the revision, many scientific organizations continued to express the same concerns as they had before. "We believe that the Shelby amendment and OMB's well-intentioned efforts to limit its scope are fatally flawed," wrote

Bruce Alberts, president of the National Academy of Sciences (NAS), in a letter to OMB. His letter noted that the revision added further detail but let stand the directive to make "all data" available under FOIA. "Our view is that new legislation will be needed, either to repeal the Shelby amendment or to provide a more reasonable approach for making selected data collected under particular research grants available to the public." A number of groups have suggested that the NAS could study the issue of data access and provide guidance to Congress.

The commentary period for the OMB revision ended on April 5, 1999, but it is expected that the debate will continue in the months to come. The organizations issuing public statements on the matter, apart from the AMS and the NAS, include the American Association for the Advancement of Science, the Joint Policy Board for Mathematics, and the National Science Foundation. Further information, including the complete statement of the AMS Committee on Science Policy, may be found on the AMS Web site at `www.ams.org/csp/`.

—*Allyn Jackson*

# National Academy Report on Evaluating Research

The effectiveness of federally funded research programs, both basic and applied, can be assessed meaningfully on an annual basis as required by law, says a new report from the Committee on Science, Engineering, and Public Policy, a joint committee of the National Academies of Sciences and Engineering and the Institute of Medicine. However, different criteria should be used for different types of research to ensure that assessments fairly gauge progress.

"Measuring the performance of basic research is particularly challenging because major breakthroughs can be unpredictable and difficult to assess in the short term," said committee chair Phillip A. Griffiths, director, Institute for Advanced Study in Princeton. "Federal agencies should use a method we call 'expert review' to assess the quality of research they support, the relevance of that research to their mission, and the leadership of the research. This will ensure that funds spent on the research will generate the kinds of knowledge that in the past have brought great practical benefits."

During the course of its study, the committee heard two conflicting viewpoints on approaches to measuring basic research. One held that it is possible to measure research annually and provide quantitative measures of the useful outcomes of both basic and applied research. The other viewpoint was that given the long-range nature of basic research, no sensible way exists to respond to the annual measurement requirement. Therefore, some agencies may resort to using measures that seem to respond to federal law—such as a list of the agency's top 100 discoveries of the preceding year—but are actually meaningless.

"We concluded that both basic and applied research can be evaluated meaningfully on a regular basis," said Griffiths. "But it is important that agencies evaluate their research programs using measurements that match the character of the research." Differences in character will lead to differences in the appropriate time scale for measurement, in what is measurable and what is not, and in the expertise needed by those who contribute to the measurement process, the report says.

All federal agencies are mandated by law, under the Government Performance and Results Act (GPRA), to set goals and use performance measures to encourage greater efficiency, effectiveness, and accountability. GPRA requires that agencies write strategic plans with annual performance targets and produce an annual report that demonstrates whether these targets are met. The first performance reports are due in March 2000.

The most effective means of evaluating federally funded research programs, the committee said, is expert review, which should be used to assess both basic and applied research. The committee outlined three forms of expert review and their applications: quality review, relevance review, and benchmarking.

To assess quality, peer review should be used, the committee said. Relevance review draws on not only the views of experts in the field but also of potential users and experts in related fields to evaluate the relevance of the research to an agency's mission. Benchmarking reviews use panels of experts from the United States and elsewhere to judge the international leadership status of the United States in research.

Basic research involves theoretical or experimental investigation to advance scientific knowledge without immediate practical application as a direct objective. Because many years can pass before an advancement is achieved, the outcomes or results of basic research cannot be measured on an annual basis but only in retrospect, the committee concluded. However, agencies can regularly assess the progress of basic research in terms of quality and relevance to agency goals and intended users. Another proposed measure is leadership—that is, whether the research is being performed at the forefront of scientific and technological knowledge and leads the world in that particular field.

Applied research uses knowledge gained through theoretical or experimental investigation to make things or create situations that will serve a practical purpose. Programs in applied research usually include a series of milestones to be reached by particular times and a description of the intended outcomes as well as their significance to society. Progress toward these milestones can be measured annually, the committee found.

To produce and benefit from advances in science and technology, the nation also must have a continuing supply of well-educated and highly trained scientists and engineers, the committee said. Strategic and performance plans should focus more attention on the goal of developing and maintaining human talent in fields critical to the agencies' missions. To ensure this, agencies should require and evaluate education and training components in research programs.

In conducting its study, the committee reviewed and assessed the strategic and performance plans of ten federal agencies: the U.S. Departments of Agriculture, Defense, Energy, and Transportation, as well as the National Institutes of Health (NIH), the National Science Foundation (NSF), NASA, the Environmental Protection Agency, the National Institute of Standards and Technology, and the National Oceanic and Atmospheric Administration. The study was sponsored by the National Research Council, NSF, NIH, NASA, and the U.S. Departments of Agriculture, Transportation, and Defense.

Copies of *Evaluating Federal Research Programs: Research and the Government Performance and Results Act* are available from the National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone: 202-334-3313 or 1-800-624-6242. The cost of the report is $18.00 (prepaid) plus shipping charges of $4.00 for the first copy and $.50 for each additional copy. More information about the report and the committee's work is available at `http://www2.nas.edu/cosepup/`.

*—from NAS news release*

# New NSF FastLane Implementation

In July 1998 the Directorate for Mathematical and Physical Sciences (MPS) of the National Science Foundation (NSF) announced the implementation of its FastLane system in phases beginning in fiscal year 1999 and reaching completion by the end of fiscal year 2000. According to the schedule, the FastLane system will be implemented in all MPS programs starting July 1, 1999. Under this system, full electronic submission is required for all MPS proposals, with the exception of those sent in response to Foundation-wide solicitations. Further information and complete instructions for using FastLane functions can be found at the World Wide Web site `http://www.fastlane.nsf.gov/`.

The mathematical sciences contact within MPS is Keith Crank, telephone: 703-306-1885, e-mail: `Dmsfl@nsf.gov`. The FastLane coordinator is Florence Rabanal, telephone: 703-306-1998, e-mail: `frabanal@nsf.gov`.

*—From an NSF announcement*

# Sloan Dissertation Fellowships Program to End

The Dissertation Fellowship program sponsored by the Alfred P. Sloan Foundation will close at the end of 1999. Each year the program awarded fellowships to 50 graduate students: 25 in mathematics and 25 in economics. The fellowships provided full tuition and a stipend for one year. Fellowship recipients were chosen in a national competition in which leading doctoral departments were invited to nominate candidates.

Michael S. Teitelbaum, program director at the Sloan Foundation, explained that the Dissertation Fellowships were started in 1984 in response to declines in federal support for graduate students. Although the program was always intended to be limited in time, he said, it has endured far longer than any other Sloan Foundation program except the Sloan Research Fellowships, which were started in 1955.

The Dissertation Fellowship program has run smoothly and efficiently and has supported high-quality students, Teitelbaum said. However, "we believe that sixteen years—unusually long for us, and longer than was intended at the program's initiation in 1984—is a reasonable period to have sustained this program."

Information about Sloan Foundation programs may be found on the Web site `www.sloan.org/`, or by writing to: Alfred P. Sloan Foundation, Suite 2550, 630 Fifth Avenue, New York, NY 10111-0242.

*—Allyn Jackson*

# 1999 Arnold Ross Lectures

Each year the AMS sponsors the Arnold Ross Lectures, a special one-day program of talks by prominent research mathematicians presented to an audience of talented high school mathematics students and their teachers.

The 1999 Arnold Ross Lectures were held on April 13 at the Museum of Science in Boston. The lecturers were I. M. Singer of the Massachusetts Institute of Technology and Ingrid Daubechies of Princeton University. About seventy-six students and teachers from the greater Boston area, as well as groups from two New Hampshire high schools, attended.

Singer, a recipient of the AMS Bôcher Prize, the Wigner Medal, and the National Medal of Science, is an institute professor at MIT. His lecture was entitled "The Gauss-Bonnet Theorem".

Daubechies, the first woman to hold a tenured professorship in mathematics at Princeton, received a MacArthur Fellowship in 1992 and the AMS Satter Prize in 1997. The title of her lecture was "What do engineers, mathematicians, and physicists have in common? Wavelets!"

In her opening remarks Deborah Tepper Haimo, of the University of California, San Diego, and chair of the Arnold Ross Lectures Committee, provided some history of the Arnold Ross Lectures. The High School Lecture Series was begun in 1988 by Paul J. Sally Jr. of the University of Chicago. The lectures that year, as in 1999, were held at the Boston Museum of Science. Other locations over the years have been San Diego (1990); Chicago (1992); Columbus, Ohio (1993); Minneapolis (1994); Houston (1995); and College Park, Maryland (1996). The lectures were renamed in 1993 and dedicated to Arnold Ross, a professor at Ohio State University, in honor of his many significant contributions to the development of mathematical talent among high school students.

*—Sandra Frost*

# Mathematicians in Mathematics Education Project

The Math Forum is now collecting information on how mathematicians can be effectively involved in school education. The purpose is to document and encourage productive involvement of mathematicians in education from kindergarten through grade 12. The emphasis is on low (or no) budget involvement in the schools: special math days, working with students, working with teachers, lending expertise to schools and school systems, getting on and working on school boards, and so forth.

More information about the project, as well as descriptions already submitted, can be found at the Mathematicians in Mathematics Education Web site, `http://forum.swarthmore.edu/mathed/mime/`. Descriptions of what you have done can be submitted to Web site organizers Judy Roitman, `roitman@oberon.math.ukans.edu` and Susan Addington, `susan@math.csusb.edu`.

*—Math Forum announcement*

# Call for Descriptions of Mathematics Ph.D. Programs

The Center for Instructional Development and Research and the Graduate School at the University of Washington have received a $515,000 grant from the Pew Charitable Trusts to develop an extensive nationwide inventory of initiatives to reform doctoral education. The Re-envisioning the Ph.D. Project intends to include any projects in mathematics that call for modification in the requirements to obtain a Ph.D. and also programs designed to change the way doctoral students are prepared to become college and university professors. Researchers are currently reviewing the literature on the subject of doctoral education and interviewing representatives of industries, businesses, and government agencies that hire doctoral graduates, as well as individuals in key educational institutions and organizations.

To ensure that the discipline is represented in the data and in the discussions, mathematicians are encouraged to contact the researchers at `re-envision@cidr.washington.edu` with responses to the following questions: (1) Have the requirements of the Ph.D. changed in your department or are changes anticipated? (2) Have you or your colleagues produced materials, praise, or criticism related to the Ph.D.? (3) Are there examples of current and promising practices or programs that mathematics departments have implemented? (4) Are there key individuals who should represent mathematics on the project advisory committee?

American graduate education has come under attack in recent years from critics demanding a profound rethinking of its traditional emphases and practices. One major complaint is that the traditional doctorate is too exclusively concerned with scholarly research. This narrow focus leaves students inadequately prepared for the other responsibilities of faculty life and unprepared for the growing percentage of job opportunities for doctoral graduates in business, industry, and government.

An advisory committee of eight to ten people representing the many segments of society who care about the Ph.D. has been formed for the purpose of reviewing the progress of the research and contributing to it. This group will also commission papers describing promising ideas and avenues to pursue based on the information thus far collected and analyzed. The culmination of the project will be a conference to be held at the University of Washington in the spring of 2000.

Further information is available online at `http:// depts.washington.edu/envision/` or by calling 206-543-6588.

*—From a news release of the Re-envisioning the Ph.D. Project*

# DMS Recommends Funding for Three Institutes

The competition for mathematics institutes funding from the National Science Foundation (NSF) has ended in a recommendation that the NSF fund three institutes. On May 6, 1999, the NSF's Divison of Mathematical Sciences (DMS) made the recommendation to the NSF Director and to the National Science Board, the governing body of the Foundation. The extensive competition and review process began in late 1996.

The DMS has recommended renewal of awards to the two institutes it currently funds: the Mathematical Sciences Research Institute (MSRI) in Berkeley and the Institute for Mathematics and its Applications (IMA) at the University of Minnesota. It has also recommended the establishment of a new institute, the Institute for Pure and Applied Mathematics (IPAM) at the University California, Los Angeles. MSRI focuses on core mathematics, IMA on applied and industrial mathematics, and IPAM on interdisciplinary research involving mathematics.

The final decision about the funding of the three institutes had not been made at the time of this writing. The *Notices* will publish further information when it becomes available.

*—Allyn Jackson*

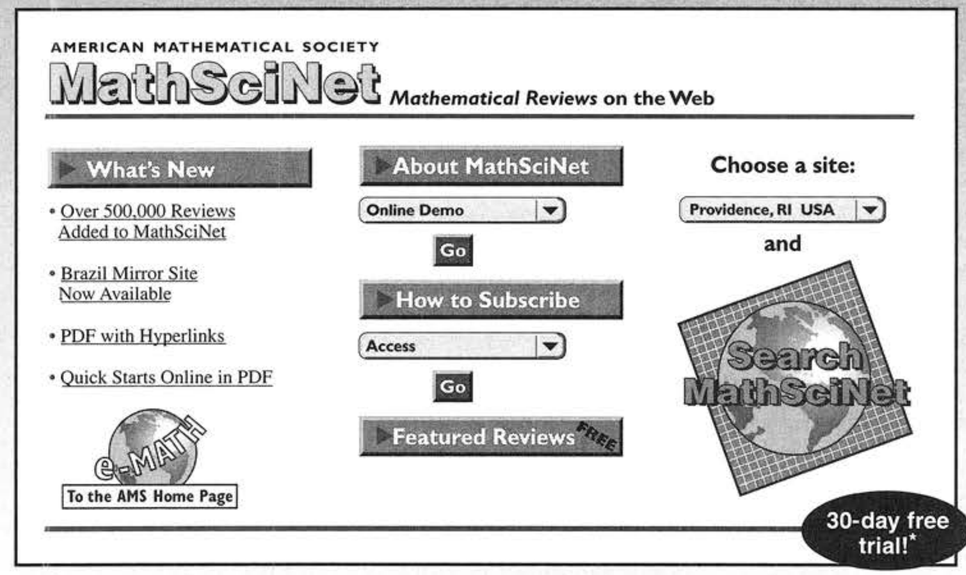
# Correction

The April 1999 issue of the *Notices* carried an announcement about the appointment of Philippe Tondeur as director of the Division of Mathematical Sciences at the National Science Foundation. The announcement contained an error concerning his appointment at the University of Illinois at Urbana-Champaign. Tondeur joined the faculty of that university in 1968 and became a full professor there in 1970. The announcement also underestimated his number of publications. At this writing MathSciNet lists 90 publications by him.

# AMERICAN MATHEMATICAL SOCIETY

# MathSciNet

## www.ams.org/mathscinet/

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**—*Journal of Electronic Publishing*, University of Michigan Press**

**MathSciNet**—available on the Web by subscription—provides searching of over 58 years of *Mathematical Reviews* and *Current Mathematical Publications*. New features and enhancements include:

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You can now view mathematical symbols online and retain hypertext functionality within a review. Marked records can also be displayed in PDF format.

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In addition to searching and browsing the journals database, you can display or download the entire *Abbreviations of Serials*. You can also search and browse the 1991 *Mathematics Subject Classification* and display or download the entire publication.

### Links to all AMS Bookstore items, including the *AMS Chelsea Publishing* series

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# Reference and Book List

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

### Upcoming Deadlines

**July 6, 1999:** Deadline for proposals for NSF Program on Large Scientific and Software Data Set Visualization. For more information, see "Mathematics Opportunities" in this issue.

**July 19, 1999:** Deadline for proposals for the second VIGRE Grant competition. For more information, consult the NSF Web site at `http://www.nsf.gov/cgi-bin/getpub?nsf9916`.

**July 22, 1999:** Deadline for proposals for the NSF CAREER/PECASE awards. For more information, see "Mathematics Opportunities" in this issue.

**July 30, 1999:** Deadline for submission of proposals for Long-Term Project Development grants from the Office of International Affairs of the National Research Council. For more information, see the "Mathematics Opportunities" section, March issue, or contact the Office of International Affairs, National Research Council, 2101 Constitution Avenue, NW (FO 2060), Washington, DC 20418; telephone 202-334-3680; fax 202-334-2614; e-mail: `ocee@nas.edu`; World Wide Web `http://www2.nas.edu/oia/22da.html`.

**August 1, 1999:** Deadline for applications for the Fulbright Scholar Program lecturing and research grants for the academic year 2000-2001. For more information, see "Mathematics Opportunities" in this issue.

**September 1, 1999:** Deadline for receipt of applications for the AWM workshop for women graduate students and postdocs. For more information, see "Mathematics Opportunities" in this issue.

**October 1, 1999:** Deadline for receipt of nominations for the AWM Louise Hay Award. For more information, see "Mathematics Opportunities" in this issue.

**October 1, 1999:** Deadline for receipt of nominations for the AWM Alice T. Schafer Mathematics Prize. For more information, see "Mathematics Opportunities" in this issue.

**October 1, 1999:** Deadline for applications for NSF/AWM Travel Grants

### Where to Find It

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

for Women. For more information, see the AWM Web site, `http://www.awm-math.org/travelgrants.html`; or telephone 301-405-7892 or send e-mail to `awm@math.umd.edu`.

**November 1, 1999:** Deadline for applications for the Fulbright Scholar Program international education and academic administrator seminars. For more information, see "Mathematics Opportunities" in this issue.

**January 1, 2000:** Deadline for applications for the Fulbright Scholar Program NATO advanced research fellowships and institutional grants. For more information, see "Mathematics Opportunities" in this issue.

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

## Board on Mathematical Sciences, National Research Council

The list of members of the Board on Mathematical Sciences appeared in the April 1999 issue of the *Notices* (p. 479). Following is additional staff and contact information.

### BMS Staff

**Scott Weidman**, Director

To contact the BMS:

**Board on Mathematical Sciences**
National Academy of Sciences
Room NAS 340
2101 Constitution Avenue, NW
Washington, DC 20418
telephone: 202-334-2421
fax: 202-334-2422
e-mail: `bms@nas.edu`
World Wide Web:
`http://www2.nas.edu/bms/`

## Book List

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

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

*Against the Gods: The Remarkable Story of Risk*, by Peter L. Bernstein. John Wiley & Sons, 1996. ISBN 0-471-12104-5. (Reviewed January 1999)

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

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

*The Apprenticeship of a Mathematician*, by André Weil, translation by Jennifer Gage, Birkhaüser Boston, 1992. ISBN 0-817-62650-6. (Reviewed April 1999.)

*A Beautiful Mind: A Biography of John Forbes Nash, Jr.*, by Sylvia Nasar, Simon & Schuster, 1998. ISBN 0-684-81906-6. (Reviewed November 1998.)

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

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

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

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

*Fashionable Nonsense: Postmodern Intellectuals' Abuse of Science*, by Alan Sokal and Jean Bricmont. English version of *Impostures Intellectuelles* (reviewed August 1998). St. Martin's Press, 1998. ISBN 0-312-19545-1.

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

*Geometry Civilized: History, Culture, and Technique*, by J. L. Heilbron, Oxford University Press, 1998. ISBN 0-19-850078-5.

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

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

*In the Light of Logic*, by Solomon Feferman. Oxford University Press, 1998. ISBN 0-19-508030-0.

*The Invention of Infinity: Mathematics and Art in the Renaissance*, by J. V. Field. Oxford University Press, 1997. ISBN 0-198-52394-7.

*Jacques Hadamard, A Universal Mathematician*, by Vladimir Mazýa and Tatyana Shaposhnikova. AMS/London Mathematical Society, 1998. ISBN 0-8218-0841-9.

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

*The Jungles of Randomness: A Mathematical Safari*, by Ivars Peterson. Paperback edition, John Wiley & Sons, 1998. ISBN 0-471-29587-6. (Reviewed in this issue.)

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

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

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

*The Magical Maze: Seeing the World through Mathematical Eyes*, by Ian

Stewart. John Wiley & Sons, 1998. ISBN 0-471-19297-X.

*The Man Who Loved Only Numbers: The Story of Paul Erdős and the Search for Mathematical Truth*, by Paul Hoffman. Hyperion, 1998. ISBN 0-786-86362-5. (Reviewed October 1998.)

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

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

*Mathematical Reasoning: Analogies, Metaphors, and Images*, edited by Lyn English. Lawrence Erlbaum Associates, 1997. ISBN 0-805-81979-7. (Reviewed May 1999.)

*Mathematics for the Curious*, by Peter M. Higgins. Oxford University Press, 1998. ISBN 0-192-88072-1.

*Mathematics: From the Birth of Numbers*, by Jan Gullberg, Peter Hilton. W. W. Norton and Company, 1997. ISBN 0-393-04002-X.

*The Mathematics of Ciphers; Number Theory and RSA Cryptography*, by S. C. Coutinho. AK Peters, 1998. ISBN 1-568-81082-2.

*Modern Mathematics in the Light of the Fields Medals*, by Michael Monastyrsky. AK Peters, 1997. ISBN 1-568-81065-2.

*The Moment of Proof: Mathematical Epiphanies*, by Donald C. Benson. Oxford University Press, March 1999. ISBN 0-19-511721-2.

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

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

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

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

*Once Upon a Number: A Mathematician Bridges Stories and Statistics*, by John Allen Paulos. Basic Books, 1998. ISBN 0-465-05158-8.

*Paul Dirac: The Man and His Work*, by Abraham Pais, Maurice Jacob, David Olive, and Michael Atiyah. Cambridge University Press, 1998. ISBN 0-521-58382-9. (Reviewed October 1998.)

*Philosophy of Mathematics: An Introduction to a World of Proofs and Pictures*, by James Robert Brown. Routledge, 1998. ISBN 0-415-12274-0.

*Polyhedra*, by Peter Cromwell. Cambridge University Press, 1997. ISBN 0-521-55432-2. (Reviewed September 1998)

*The Pleasures of Counting*, by T. W. Körner. Cambridge University Press, 1997. ISBN 0-521-56087-X; 0-521-56823-4. (Reviewed March 1998.)

*Privacy on the Line: The Politics of Wiretapping and Encryption*, by Whitfield Diffie and Susan Landau. MIT Press, 1998. ISBN 0-262-04167-7. (Reviewed June/July 1998.)

*Proofs from the Book*, by Martin Aigner and Günter Ziegler. Springer-Verlag, 1998. ISBN 3-540-63698-6.

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

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

*Reasoning with the Infinite: From the Closed World to the Mathematical Universe*, by Michel Blay (translated by M. B. DeBevoise). University of Chicago Press, 1998. ISBN 0-226-05834-4.

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

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

*The Universe and the Teacup: The Mathematics of Truth and Beauty*, by K. C. Cole. Hartcourt Brace, 1998. ISBN 0-151-00323-8. (Reviewed March 1999.)

*Visual Explanations—Images and Quantities, Evidence and Narrative*, by Edward R. Tufte, Graphics Press, 1997. ISBN 0-961-39212-6. (Reviewed January 1999.)

*What's Happening in the Mathematical Sciences, 1998-1999*, by Barry Cipra. AMS, 1999. ISBN 0-8218-0766-8.

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

*Women in Mathematics: The Addition of Difference*, by Claudia Henrion. Indiana University Press, 1997. ISBN 0-253-33279-6. (Reviewed May 1998.)

*The World According to Wavelets*, by Barbara Burke Hubbard. AK Peters, second edition, 1999. ISBN 1-568-81072-5.

# Add this Cover Sheet to all of your Academic Job Applications

**How to use this form**

1. Using the facing page or a photocopy, (or a TEX version which can be downloaded from the e-math "Employment Information" menu, `http://www.ams.org/employment/`), fill in the answers which apply to *all* of your academic applications. Make photocopies.

2. As you mail each application, fill in the remaining questions neatly on one cover sheet and include it *on top of* your application materials.

The Joint Committee on Employment Opportunities has adopted the cover sheet on the facing page as an aid to job applicants and prospective employers. The form is now available on e-math in a TEX format which can be downloaded and edited. The purpose of the cover form is to aid department staff in tracking and responding to each application.

Mathematics Departments in Bachelor's, Master's and Doctorate granting institutions have been contacted and are expecting to receive the form from each applicant, along with any other application materials they require. Obviously, not all departments will utilize the cover form information in the same manner. Please direct all general questions and comments about the form to: `emp-info@ams.org` or call the Professional Programs and Services Department, AMS, at 800-321-4267 extension 4105.

**JCEO Recommendations for Professional Standards in Hiring Practices**

The JCEO believes that every applicant is entitled to the courtesy of a prompt and accurate response that provides timely information about his/her status. Specifically, the JCEO urges all institutions to do the following after receiving an application:

(1) Acknowledge receipt of the application—immediately; and
(2) Provide information as to the current status of the application, as soon as possible.

The JCEO recommends a triage-based response, informing the applicant that he/she
(a) is not being considered further;
(b) is not among the top candidates; or
(c) is a strong match for the position.

*Academic Employment in Mathematics*

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**Year of Ph.D. (optional)** ______________________________

**Ph.D. Advisor** ______________________________

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***Indicate*** *the mathematical subject area(s) in which you have done research using, if applicable, the 1991 Mathematics Subject Classification printed on the back of this form. If listing more than one number, list first the one number which best describes your current primary interest.*

Primary Interest ______________________________

Secondary Interests *optional* ______________________________

***Give a brief synopsis*** *of your current research interests (e.g. finite group actions on four-manifolds). Avoid special mathematical symbols and please do not write outside of the boxed area.*

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**Most recent, if any, position held** *post Ph.D.*

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☐ Postdoctoral Position ☐ 2+ Year Position ☐ 1 Year Position

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# 1991 Mathematics Subject Classification

**00** General
**01** History and biography
**03** Logic and foundations
**04** Set theory
**05** Combinatorics
**06** Order, lattices, ordered algebraic structures
**08** General mathematical systems
**11** Number theory
**12** Field theory and polynomials
**13** Commutative rings and algebras
**14** Algebraic geometry
**15** Linear and multilinear algebra, matrix theory
**16** Associative rings and algebras
**17** Nonassociative rings and algebras
**18** Category theory, homological algebra
**19** K-theory
**20** Group theory and generalizations
**22** Topological groups, Lie groups
**26** Real functions
**28** Measure and integration
**30** Functions of a complex variable
**31** Potential theory
**32** Several complex variables and analytic spaces
**33** Special functions
**34** Ordinary differential equations
**35** Partial differential equations
**39** Finite differences and functional equations
**40** Sequences, series, summability
**41** Approximations and expansions
**42** Fourier analysis
**43** Abstract harmonic analysis
**44** Integral transforms, operational calculus
**45** Integral equations
**46** Functional analysis
**47** Operator theory
**49** Calculus of variations, optimal control
**51** Geometry
**52** Convex and discrete geometry
**53** Differential geometry
**54** General topology
**55** Algebraic topology
**57** Manifolds and cell complexes
**58** Global analysis, analysis on manifolds
**60** Probability theory and stochastic processes
**62** Statistics
**65** Numerical analysis
**68** Computer science
**70** Mechanics of particles and systems
**73** Mechanics of solids
**76** Fluid mechanics
**78** Optics, electromagnetic theory
**80** Classical thermodynamics, heat transfer
**81** Quantum theory
**82** Statistical mechanics, structure of matter
**83** Relativity and gravitational theory
**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

# NEW BOOKS FROM KLUWER

## SUPERANALYSIS

by **Andrei Khrennikov,** *Växjö University, Sweden and Moscow State University of Electronic Engineering, Russia*

This work can be recommended as an extensive course in superanalysis, the theory of functions of commuting and anticommuting variables. It follows the so-called functional superanalysis approach where superspace is defined as a set of points on which commuting and anticommuting coordinates are given. It will be of interest to researchers and postgraduate students whose work involves functional analysis, Feynman integration and distribution theory on infinite-dimensional (super)spaces and its applications to quantum physics, supersymmetry, superfield theory and supergravity.

**March 1999 372 pp. Hardbound**
**ISBN 0-7923-5607-1 $177.00**

### *Also by Andrei Khrennikov...*

**NON-ARCHIMEDEAN ANALYSIS:**
**Quantum Paradoxes, Dynamical Systems and Biological Models**
**September 1997 392 pp. Hardbound**
**ISBN 0-7923-4800-1 $197.50**

**p-ADIC VALUED DISTRIBUTIONS IN MATHEMATICAL PHYSICS**
**October 1994 280 pp. Hardbound**
**ISBN 0-7923-3172-9 $166.50**

## HANDBOOK OF SPLINES

by **Gheorghe Micula,** *Faculty of Mathematics, University of Cluj-Napoca, Romania;* and **Sanda Micula,** *Western Oregon University, Monmouth, USA*

The purpose of this book is to give a comprehensive approach to the theory of spline functions, from the introduction of the phrase `spline' by I.J. Schoenberg in 1946 to the newest theories of spline-wavelets or spline-fractals, emphasizing the significance of the relationship between the general theory and its applications. In addition, this volume provides new material on spline function theory, as well as a fresh look at basic methods in spline functions.

**December 1998 620 pp. Hardbound**
**ISBN 0-7923-5503-2 $297.00**

## HANDBOOK OF COMBINATORIAL OPTIMIZATION, Volumes I - 3

by **Ding-Zhu Du,** *University of Minnesota, Minneapolis, USA;* and **Panos M. Pardalos,** *Dept. of Industrial & Systems Engineering, University of Florida, Gainesville, USA*

This multi-volume set deals with several algorithmic approaches for discrete problems as well as with many combinatorial problems. The editors have brought together almost every aspect of the enormous field with emphasis on recent developments.

The 3-volume *Handbook* is addressed not only to researchers in discrete optimization, but to all scientists who use combinatorial optimization methods to model and solve problems. Experts in the field as well as nonspecialists will find the material stimulating and helpful.

**October 1998 2410 pp. Hardbound Set**
**ISBN 0-7923-5019-7 $1325.00**
***INTRODUCTORY PRICE: $995.00***
*valid until 30 June 1999*

## HANDBOOK OF THE HISTORY OF GENERAL TOPOLOGY

edited by **C.E. Aull,** *Dept. of Mathematics, Virginia Polytechnic Institute and State University, Blacksburg, USA;* **R. Lowen,** *University of Antwerp, Belgium*

The first two in a handbook of several volumes, contributions contained in these works concern individual topologists, specific schools of topology and specific periods of development.

Together, these and forthcoming volume(s) present important views and insights into the problems and development of topological theories and applications of topological concepts, and into the life and work of topologists. As such it will encourage not only further study in the history of the subject, but also further mathematical research in the field. It is an invaluable tool for topology researchers and topology teachers throughout the mathematical world.

**Volume 1 March 1997 408 pp. $183.00**
**Hardbound ISBN 0-7923-4479-0**
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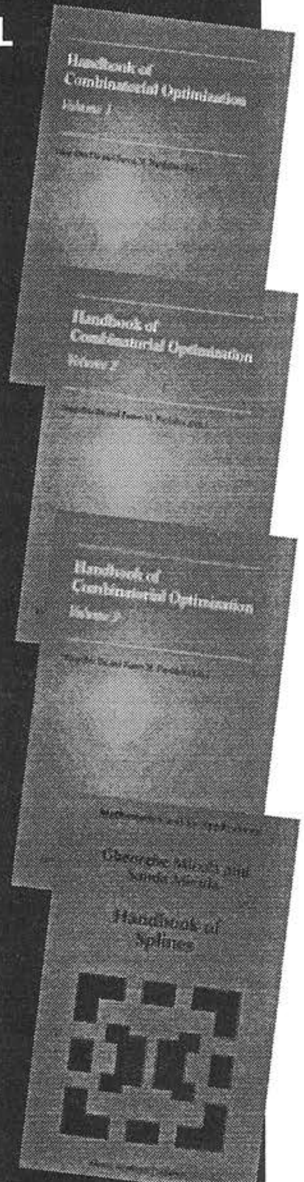

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# Mathematics Calendar

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

## June 1999

1-3 **International Conference on Differential Equations and Related Topics**, Pusan National University, Pusan, Korea. (Jan. 1999, p. 66)

1-4 **Day on Diffraction'99**, St. Petersburg Branch of Steklov Mathematical Institute, St. Petersburg, Russia. (Nov. 1998, p. 1377)

2-4 **Joint DIMACS-DIMATIA Workshop on Algebraic Methods and Arithmetic Circuits**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Mar. 1999, p. 374)

3-5 **Applications of Heavy Tailed Distributions in Economics, Engineering and Statistics**, American University, Washington, DC. (Jan. 1999, p. 66)

4-9 **Geometry, Analysis, and Mathematical Physics: Analysis and Geometry**, Obernai(near Strasbourg), France. (May 1999, p. 587)

4-9 **Geometry, Analysis & Mathematical Physics: Analysis & Geometry**, Obernai (near Strasbourg), France. (Jan. 1999, p. 66)

6-12 **International Conference on Rational Approximation (ICRA99)**, University of Antwerp, Antwerp, Belgium. (May 1999, p. 587)

6-19 **Second Summer School of Mathematical Biology**, Termoli, Italy. (Feb. 1999, p. 276)

7-9 **Canadian Operational Research Society Conference (CORS '99)**, Windsor, Ontario, Canada. (May 1999, p. 587)

7-9 **Theoretical, Experimental & Computational Mechanics**, Cincinnati, Ohio. (Oct. 1998, p. 1230)

7-11 **11th International Conference on Formal Power Series and Algebraic Combinatorics (FPSAC'99)**, Universitat Politecnica de Catalunya, Barcelona, Spain. (Feb. 1999, p. 276)

7-11 **From Individual to Aggregration: Modeling Animal Grouping**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

7-11 **International Society of The Arts, Mathematics, and Architecture (ISAMA99)**, San Sebastian, Spain. (Jan. 1999, p. 67)

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://www.acad.bg/BulRTD/math/dimov2.html or e-mail I. Dimov at dimov@copern.bas.bg.

10-12 **1999 International Conference on Preconditioning Techniques for Large Sparse Matrix Problems in Industrial Applications**, University of Minnesota, Hubert H. Humphrey Institute, Minneapolis, Minnesota. (Nov. 1998, p. 1378)

11-12 **Mathematical Physics and Quantum Field Theory**, University of California, Berkeley, California. (May 1999, p. 587)

11-13 **20th Annual Meeting of the Canadian Applied and Industrial Mathematical Society (CAIMS-99)**, Université Laval, Que-

**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.)

bec, Canada. (Apr. 1999, p. 483)

* 11-13 **Rigidity, Fundamental Groups and Dynamics, in the Vein of M. Gromov and G. A. Margulis**, Institut de Recherche Mathematique Avancee de Strasbourg, France.
**Organizer**: P. Foulon.
**Sponsors**: SMF, CNRS, formation permanente du CNRS—Delegation Alsace, DRA1, Univ. Louis Pasteur et IRMA.
**Lecturers**: M. Babillot (Univ. de Paris 6), R. Feres (Univ. de Washington), F. Labourie (Univ. de Paris Sud), A. Zeghib (ENS, Lyon).
**Information and Registration**: `http://www-irma.u-strasbg.fr/irma/`.

13-17 **Conference on The Mathematics of Public-Key Cryptography**, The Fields Institute, Toronto, Ontario, Canada. (Sept. 1998, p. 1051)

13-17 **Computability Theory and Applications (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado. (Mar. 1999, p. 374)

13-17 **From Manifolds to Singular Varieties (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado. (Mar. 1999, p. 374)

* 13-18 **The International Conference on Differential Equations and Computational Simulations**, Chengdu, People's Republic of China.
**Focus**: This conference will focus on nonlinear dynamics and computational simulation with applications to models in electronic circuits, advanced materials, nonlinear waves, fluid flow, nonlinear optics, networks of neurons, genetics, physiology, and related fields.
**Scientific Committee**: P. W. Bates (USA), S.-N. Chow (cochair, USA), B. Guo (China), C. Li (cochair, USA), J. M. Paret (USA), Z. F. Zhang (China).
**Organizing Committee**: D. Bai (China), Z. Han (China), Y. Liu (chair, China), K. Lu (USA), Z. Lu (China), D. Xu (cochair, China), W. Zhang (China).
**Information**: Details of the conference are available on the Web page `http://www.math.byu.edu/~klu/conference/`. For further information, please contact D. Xu or W. Zhang, Department of Mathematics, Sichuan Univ., Chengdu 610064, China; e-mail: `nic2601@scuu.edu.cn` (with subject "Daoyi Xu & Weinian Zhang") or `dyxu@pridns.scuu.edu.cn`.

* 14-18 **Householder Symposium XIV, 1999**, Chateau Whistler, Whistler, British Columbia.
**Sponsors**: The Math Works, Inc., Univ. of British Columbia, Univ. of Waterloo, Pacific Institute of Mathematical Sciences, Boeing Company.
**Information**: `http://roadmap.ubc.ca/hholder/`.

14-19 **MATHTOOLS'99, 2nd International Conference "Tools for Mathematical Modelling"**, Saint-Petersburg State Technical University, Saint-Petersburg, Russia. (Dec. 1998, p. 1501)

* 14-24 **NATO Advanced Studies Institute on Mathematical Problems Arising from Biology**, Fields Institute, Toronto, Canada.
**Organizing Committee**: R. Durrett (Cornell Univ.), C. Neuhauser (Univ. of Minnesota).
**Program Committee**: D. Dawson (Fields Institute), O. Diekmann (Univ. of Utrecht), R. Durrett (Cornell Univ.), S. Levin (Princeton Univ.), C. Neuhauser (Univ. of Minnesota).
**Invited Speakers**: O. Diekmann (Univ. of Utrecht), P. Donnelly (Oxford Univ.), J. Felsenstein (Univ. of Washington), B. Golding (McMaster Univ.), B. Grenfell (Cambridge Univ.), A. Greven (Univ. of Erlangen), R. Griffiths (Monash Univ.), A. von Haeseler (Univ. Munchen), A. Hastings (Univ. of California, Davis), R. Hudson (McMaster Univ.), N. Kaplan (National Institute of Environmental Health Sciences, Research Triangle Park), S. Levin (Princeton Univ.), H. Metz (Leiden Univ.), D. Mollison (Heriott-Watt Univ.), S. Pacala (Princeton Univ.), D. Rand (Univ. of Warwick), D. Sankoff (Centre de Recherches Mathematiques, Univ. de Montreal), S. Tavare (Univ. of Southern California).
**Focus**: The workshop will focus on the many interesting mathematical problems that are motivated by a desire to understand the workings of various biological systems. In order to facilitate and stimulate interdisciplinary research, the workshop will bring together a broad range of biologists, mathematical biologists, and mathematicians. Each invited speaker will deliver two lectures. The emphasis in the first week will be ecological models, and in the second will be population genetics.
**Information**: Further information may be found at `http://www.fields.utoronto.ca/biol.html`. The Fields Institute for Research in Mathematical Sciences, 222 College Street, Second Floor, Toronto, Ontario, M5T 3J1, Canada; tel: 416-348-9710; fax: 416-348-9385; Web site: `http://www.fields.utoronto.ca/`.

* 14-25 **Workshop on Mathematical Physiology**, University of British Columbia, Vancouver, British Columbia.
**Topics**: This session is divided into three main topics: neurophysiology, cardiology, and endocrinology.
**Speakers**: B. Ermentrout (Univ. of Pittsburgh), L. Glass (McGill Univ.), J. P. Keener (Univ. of Utah), J. Keizer (Univ. of California at Davis), A. Sherman (NIDDK/MRB), J. Rinzel (Courant Institute of Mathematical Sciences).
**Information**: `http://www.pims.math.ca/sections/activities/physio.html`.

16-19 **Joint Conference of the 5th Barcelona Logic Meeting and the 6th Kurt Gödel Colloquium**, Casa de la Caritat, Barcelona, Spain. (May 1999, p. 588)

16-19 **Theoretical Fluid Dynamics and Related Topics**, Centro de Matemática e Aplicações Fundamentais da Universidade de Lisboa, Lisbon, Portugal. (Mar. 1999, p. 374)

* 16-20 **1st Canadian Conference on Nonlinear Solid Mechanics**, University of Victoria, Victoria, British Columbia.
**Sponsored By**: Univ. of Victoria, Department of Mechanical Engineering, Department of Mathematics and Statistics, The Pacific Institute for the Mathematical Sciences.
**Information**: `http://www.CanCNSM.uvic.ca/`.

* 17-20 **Budapest-Chemnitz-Praha-Torun Algebra Colloquium**, Department of Mathematics, Charles University, Prague, Czech Republic.
**Invited Speakers**: G. Bobinski (Torun), K. Bongartz (Wuppertal), M. Domokos (Budapest), P. Draexler (Bielefeld), J. Jezek (Praha), H. Lenzing (Paderborn).
**Information**: This is the fourth Algebra Colloquium, this time held in Prague. To participate in the conference, contact either J. Trlifaj (`trlifaj@karlin.mff.cuni.cz`) or R. El Bashir (`bashir@karlin.mff.cuni.cz`). Postal address is Dept. of Algebra, MFF UK, Sokolovska 83, Praha 8, 186 75, Czech Republic. More information is available at `http://www.karlin.mff.cuni.cz/katedry/ka/`.

17-20 **Six Projects in Mathematics and Physics–A Cooperation Project between Scientists from the CIS and Germany**, Technische Universitaet Berlin, Germany. (Aug. 1998, p. 899)

19-23 **NSF-CBMS Regional Conference on Mathematical Analysis of Viscoelastic Flows**, University of Delaware, Newark, Delaware. (Apr. 1999, p. 483)

19-25 **Dynamics of Patterns**, Anogia, Crete, Greece. (May 1999, p. 588)

* 20-24 **Groupoids in Physics, Analysis and Geometry (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado.
**Information**: See `http://www.ams.org/meetings/src.html` for more information.

20-24 **Homotopy Methods in Algebraic Topology (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado. (Mar. 1999, p. 375)

20-24 **The Sixth Conference of The Canadian Number Theory Association (CNTA '99)**, University of Manitoba, Winnipeg, Canada. (Jan. 1999, p. 67)

* 20-24 **Wave Phenomena in Complex Media (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado.
**Information**: See `http://www.ams.org/meetings/src.html` for more information.

21-25 **International Workshop on Special Functions: Asymptotics, Harmonic Analysis, and Mathematical Physics**, City

University of Hong Kong, Hong Kong, China. (Nov. 1998, p. 1378)

21–26 **Conference on Symplectic Geometry**, Instituto Superior Tecnico, Lisboa, Portugal. (May 1999, p. 588)

21–27 **European Summer Courses 1999, C.I.M.E.: Computational Mathematics Driven by Industrial Applications**, Martina Franca (Taranto), Italy. (May 1999, p. 588)

21–July 2 **Computational Algebra With Applications**, University of Wyoming, Laramie, Wyoming. (Jan. 1999, p. 67)

21–July 3 **PDEs in Models of Superfluidity, Superconductivity and Reactive Flow (NATO Advanced Study Institute)**, Cargese, Corsica, France. (May 1999, p. 588)

23–25 **Bar-Ilan Symposium on The Foundations of Artificial Intelligence (BISFAI-99)**, Ramat Gan, Israel. (Jan. 1999, p. 67)

*23–25 **Workshop on Smoothing Applications**, University of British Columbia, Vancouver, British Columbia.

**Invited Speakers**: K. Berhane (Univ. of Southern California), C. Dean (Simon Fraser Univ.), I. Gijbels (Catholic Univ. of Louvain), N. Heckman (UBC, organizer), H. Muller (UC Davis), J. Ramsay (McGill Univ.), J. Rice (UC Berkeley).

**Format**: The emphasis of the workshop is on the applications of smoothing methods to data. Several sessions will be centered around discussion of specific data sets, which will be available beforehand via this Web site. We hope that workshop participants will take a look at the data sets before the workshop. Other sessions will consist of more traditional-style presentations.

**Information**: `http://www.stat.ubc.ca/smoothing/`.

23–26 **Nonlinear Modeling and Control, An International Seminar**, Nayanova University, Samara, Russia. (Mar. 1999, p. 375)

*24–27 **5th IMACS Conference on Applications of Computer Algebra, ACA '99**, El Escorial, Spain.

**Focus**: The meeting will focus on actual or possible applications of nontrivial computer algebra techniques to other fields and substantial interactions of computer algebra with other fields.

**General Chair**: E. Roanes-Lozano, Dept. of Algebra, Univ. Complutense de Madrid, Paseo Juan XXIII s/n, 28040 Madrid, Spain; e-mail: `eroanes@eucmos.sim.ucm.es` or `imacs-aca99@ccedu.ucm.es`.

**Meeting Format**: The meeting will be run in the standard IMACS format where individuals are invited to organize a special session. Individuals can propose a special session by contacting the program chair. Paper submissions may be directed to an organizer of an appropriate special session (which will be listed at the Web site) or mailed to the conference chair, who will forward the paper.

**Information**: `http://math.unm.edu/ACA/1999.html`, or contact the IMACS secretariat.

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. (Sept. 1998, p. 1052)

25–30 **Number Theory and Arithmetical Geometry: Arakelov Geometry and Applications**, Obernai(near Strasbourg), France. (May 1999, p. 588)

26–July 2 **Algebra and Discrete Mathematics, Infinite Combinatorics and their Impact on Algebra**, Hattingen, Germany.

26–July 2 **Holomorphic Dynamics**, Anogia, Crete, Greece. (May 1999, p. 589)

27–July 1 **1999 Summer Conference on Brauer Groups**, University of Montana, Missoula, Montana. (Jan. 1999, p. 67)

*27–July 1 **Differential Geometric Methods in the Control of Partial Differential Equations (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado.

**Information**: See `http://www.ams.org/meetings/src.html` for more information.

*27–July 1 **Structured Matrices in Operator Theory, Numerical Analysis, Control, Signal and Image Processing (Joint Summer Research Conference Series)**, University of Colorado, Boulder, Colorado.

**Information**: See `http://www.ams.org/meetings/src.html` for more information.

27–July 4 **ACACSE'99: Applied Clifford Algebra in Cybernetics, Robotics, Image Processing and Engineering International Workshop as a Special Parallel Session of the 5th International Conference on Clifford Algebras and their Applications in Mathematical Physics**, Ixtapa, Zihuatanejo, Mexico. (Jan. 1999, p. 67)

27–July 4 **Local and Global Problems for Dirac Operators**, Ixatapa, Zihuatanejo, Mexico. (May 1999, p. 589)

*27–July 18 **PIMS Mini-Program in Geometric Functional Analysis**, University of British Columbia, Vancouver, British Columbia.

**Information**: `http://www.pims.math.ca/`.

27–July 25 **Summer Mathematics Program for Undergraduate Women**, Carleton and St. Olaf Colleges, Northfield, Minnesota. (Feb. 1999, p. 277)

28–30 **International Conference on Geometry**, University of Porto, Portugal. (Mar. 1999, p. 375)

28–July 1 **The 5th Experimental Chaos Conference**, Orlando, Florida. (May 1999, p. 589)

28–July 2 **Fourth Hungarian Colloquium on Limit Theorems in Probability and Statistics**, Balatonlelle, Hungary. (Mar. 1999, p. 376)

28–July 2 **Nonlinear Partial Differential Equations: An International Conference in Memory of S. N. Kruzhkov**, Université de Franche-Comté, Besançon, France. (Mar. 1999, p. 376)

28–July 6 **European Summer Courses 1999, C.I.M.E.: Iwahori-Hecke Alebras and Representation Theory**, Martina Franca (Taranto), Italy. (May 1999, p. 590)

29–July 3 **Theory and Mathematics in Biology and Medicine (TMBM99)**, Vrije Universiteit, Amsterdam, The Netherlands (Sept. 1998, p. 1052)

30–July 1 **International Workshop on Implicit Computational Complexity (ICC'99)**, Trento, Italy. (Mar. 1999, p. 376)

30–July 2 **First International Symposium on Imprecise Probabilities and Their Applications**, Ghent, Belgium. (Mar. 1999, p. 376)

*30–July 12 **The 1999 Federated Logic Conference**, Trento, Italy.

**Focus**: Logic has been called "the calculus of computer science", playing a crucial role in diverse areas such as artificial intelligence, computational complexity, distributed computing, database systems, hardware design, programming languages, and software engineering. The Federated Logic Conference brings together four synergetic conferences that apply logic to computer science.

**Conference Highlights**: IEEE Symposium on Logic in Computer Science (LICS'99), July 2–5, with invited talks by H. Friedman, J.-Y. Girard, J. Halpern, U. Montanari, and L. Paulson; Conference on Rewriting Techniques and Applications (RTA'99), July 2–4, with invited talks by B. Courcelle, F. Otto, and F. van Raamsdonk; Conference on Automated Deduction (CADE'99), July 7–10, with invited talks by E. Grädel, R. Nieuwenhuis, and T. Nipkow; Conference on Computer-Aided Verification (CAV'99), July 7–10, with tutorials by R. Alur, E. Clarke, D. Dill, and J. Sifakis on July 6; and invited talks by E. Brinksma, A. Deutsch, Z. Manna, and G. Stalmarck.

**Keynote Events**: July 5: "Using formal verification methods in an industrial environment for a decade. Conclusions and perspectives" by G. Roucairol (Groupe Bull R&D president); July 6: Panel on "Current trends in research funding in the use of logic and formal methods in computer science", R. Bajcsy (NSF) and G. Metakides (Information Technologies, European Commission).

**Information**: `http://www.cs.bell-labs.com/cm/cs/what/floc99/`; `http://www-rocq.inria.fr/verso/floc99/`; `http://floc99.itc.it/home.htm` (after April 5).

## July 1999

*1–4 **Second Italian-Spanish Meeting on Financial Mathematics**, Second University of Naples, Naples, Italy.

**Sponsors**: Univ. of Almería, Second Univ. of Naples, Univ. of Naples "Federico II", and Italian Institute for Philosophical Studies.
**Organizers and Contacts**: A. G. S. Ventre, e-mail: alventre@unina.it; and S. C. Rambaud, e-mail: scruz@ualm.es.
**Topics**: Financial mathematics, actuarial mathematics, portfolio theory, term structure of interest rates, financial models, financial markets.
**Deadline**: Papers up to 12 pages long should be submitted no later than June 5, 1999.

1-10 **European Summer Courses 1999, C.I.M.E.: Theory and Applications of Hamiltonian Dynamics**, Cetraro(Cosenza), Italy. (May 1999, p. 590)

*1-September 15 **Mini-Program in Invariants of Three Manifolds**, University of Calgary, Calgary, Alberta.
**Information**: http://www.pims.math.ca/.

2-5 **Fourteenth Annual IEEE Symposium on Logic in Computer Science**, Trento, Italy. (Dec. 1998, p. 1501)

2-5 **VIIIth Oporto Meeting on Geometry, Topology and Physics**, Dep. Matematica Pura, Fac. Ciencias, Oporto University, Oporto, Portugal. (May 1999, p. 590)

2-10 **The 1999 Federated Logic Conference (FLoC '99)**, Trento, Italy. (Sept. 1998, p. 1052)

3-9 **Computer Vision and Speech Recognition: Statistical Foundations and Applications**, Anogia, Crete, Greece. (May 1999, p. 590)

4-9 **Geometry and Quantization of Symplectic Manifolds and Quantum Integrable Systems**, Centro Stefano Franscini, Ascona, Switzerland. (Mar. 1999, p. 376)

4-11 **Paul Erdős and His Mathematics**, Hungarian Academy of Sciences, Budapest, Hungary. (Jan. 1999, p. 68)

5 **Mathematical Finance Workshop**, Edinburgh, Scotland. (May 1999, p. 590)

5-9 **The Fourth International Congress on Industrial and Applied Mathematics**, Edinburgh, Scotland. (Dec. 1997, p. 1500)

5-9 **Quadratic Forms and Their Applications**, University College, Dublin, Ireland. (May 1999, p. 590)

5-August 21 **Summer Semester on Complex Potential Theory and its Applications**, Feza Gursey Institute, Istanbul, Turkey. (May 1999, p. 591)

6 **Intuitionistic Modal Logics and Applications, IMLA'99 (Satellite to LICS'99)**, Trento, Italy. (May 1999, p. 591)

6-16 **Advanced Course on Mathematical Aspects of Image Processing**, Centre de Recerca Matemàtica and Centre de Visió per Computador, Barcelona, Spain. (May 1999, p. 591)

7-15 **European Summer Courses 1999, C.I.M.E.: Global Theory of Minimal Surfaces in Flat Spaces**, Martina Franca (Taranto), Italy. (May 1999, p. 591)

8-9 **100 Years After Sophus Lie**, University of Leipzig, Leipzig, Germany. (Feb. 1999, p. 277)

8-17 **School on Singularities in Algebraic Geometry and String Theory**, Complexo Interdisciplinar of Universidade de Lisboa, Lisbon, Portugal. (May 1999, p. 592)

8-24 **XXIXth Probability Summer School**, Saint-Flour (Cantal), France. (May 1999, p. 592)

*9-10 **Mathematics and Its Applications throughout the Curriculum**, Indiana University, Bloomington, Indiana.
**Focus**: Did you ever think that, together with a colleague in another discipline, you could come up with materials and approaches that could be used to teach undergraduate mathematics in that area? Come to this workshop and see examples of such collaborations. Representatives of the seven consortia who have been participating in this NSF-sponsored initiative will describe their multidisciplinary courses and modules and help you design your own. If you are already involved in such a project, you should plan to exhibit your materials at the workshop-long poster session. Many of the courses incorporate computer technology and the Internet to increase student ability to apply mathematics in real-world problem solving.
**Support**: Financial support is available for qualifying two-person teams.
**Information**: For more information and registration form, see http://matc.siam.org/workshop/, or contact P. Harnett, Department of Mathematics, Swain Hall, Indiana Univ., Bloomington, IN 47405; pharnett@indiana.edu.

9-17 **Computation in Group Theory and Geometry**, University of Warwick, Coventry, England. (Jan. 1999, p. 68)

11-August 15 **Seventh Annual Canada/USA Mathcamp**, University of Washington, Seattle, Washington. (Dec. 1998, p. 1502)

12-14 **Feynman Integrals and Related Topics**, Yonsei University, Seoul, Korea. (May 1999, p. 592)

12-15 **On-Line Decision Making**, Rutgers University, Busch Student Center, Piscataway, New Jersey. (May 1999, p. 592)

12-16 **British Combinatorial Conference 1999**, University of Kent at Canterbury, Canterbury, Kent CT2 7NF, UK. (May 1999, p. 592)

12-16 **First International Joint Meeting of the American Mathematical Society and the Australian Mathematical Society**, Melbourne, Australia. (Nov. 1998, p. 1378)

12-17 **Journees Arithmetiques 1999**, Rome, Italy. (May 1998, p. 642)

12-17 **Workshop on "Model Theory and Permutation Groups"**, University of Trento, Italy. (May 1999, p. 592)

12-18 **Third International Conference on Symmetry in Nonlinear Mathematical Physics**, Kiev, Ukraine. (Jan. 1999, p. 68)

13-16 **International Conference on Applied Partial Differential Equations**, Tongji University, Shanghai, China. (Oct. 1998, p. 1230)

13-22 **International Conference on Biomathematics-Bioinformatics and Applications of Functional Differential Difference Equations**, Akdeniz University, Antalya, Turkey. (May 1999, p. 592)

*15-16 **Geometric and Combinatorial Methods in the Hermitian Sum Spectral Problem**, University of Coimbra, Portugal.
**Organized By**: Centro Internacional de Matematica, Centro de Matematica da Universidade de Coimbra.
**Organizing Committee**: E. Marques de Sa, J. F. Queiro, A. P. Santana.
**Aim**: A problem in matrix theory which has interested mathematicians for many years is the following: Given two Hermitian matrices $A$ and $B$, describe the spectrum of $A+B$ in terms of the spectra of $A$ and $B$. Recently there were decisive developments in this problem, with contributions from algebraic geometry, representation theory, combinatorics, and harmonic analysis. The workshop will gather experts from different fields who have worked on this problem.
**List of Speakers**: J. Day (San Jose State Univ.), S. Friedland (Univ. of Illinois, Chicago), A. Klyachko (Bilkent Univ., Ankara, Turkey), A. Knutson (Brandeis Univ.), N. Wildberger (Univ. of New South Wales, Sydney, Australia), A. Zelevinsky (Northeastern Univ.).
**Information**: http://www.mat.uc.pt/~jfqueiro/wrkshp2.html.

15-17 **Applications of Physics in Financial Analysis**, Trinity College, Dublin, Ireland. (Feb. 1999, p. 277)

16-18 **ESA'99 - Seventh Annual European Symposium on Algorithms**, Prague, Czech Republic. (Jan. 1999. p. 68)

16-18 **Olga Taussky Todd Celebration of Careers in Mathematics for Women**, Mathematical Sciences Research Institute, Berkeley, California. (Jan. 1999, p. 68)

17-23 **Groups of Tree Automorphisms and Lattices**, Anogia, Crete, Greece. (May 1999, p. 593)

18-23 **Vision Geometry VIII (SD90)**, Colorado Convention Center, Denver, Colorado. (Jan. 1999, p. 69)

18-28 **Foundations of Computational Mathematics (FoCM)**, University of Oxford, Oxford, England. (Mar. 1999, p. 377)

19-22 **2nd International Symposium on Finite Volumes for Complex Applications—Problems and Perspectives**, University of Duisburg, Germany. (May 1999, p. 593)

19-23 **Statistical Inference from Genetic Data on Pedigrees**, Houghton, Michigan. (May 1999, p. 593)

19-24 **CT99 - International Category Theory Meeting**, University of Coimbra, Coimbra, Portugal. (May 1999, p. 593)

19-30 **Symmetries and the Moment Mapping**, CIRM (Marseille-Luminy), France. (Apr. 1999, p. 485)

*19-30 **Workshop on Mathematical Epidemiology**, University of British Columbia, Vancouver, British Columbia.
**Aim**: Mathematical epidemiology is concerned with modeling the spread of infectious disease in a population. The aim is generally to understand the time course of the disease with the goal of controlling its spread. Such models are used, for example, to guide policy in vaccination strategies for childhood diseases. Classical epidemic models assumed that the total population is constant and were formulated as a system of ordinary differential equations. When the disease causes death (e.g., HIV/AIDS), the assumption of a constant population may not be valid. During the last twenty years, models with variable population size have been formulated and analyzed. Such models combine demographic and epidemic effects. Striving for more realism, more complex models include such detail as time delays, spatial heterogeneity, age structure, two sexes, multigroups, vectors, and stochastic variation. The dynamical systems that result are highly nonlinear and complex.
**Speakers**: L. Allen (Texas Tech. Univ.), S. Blower (Univ. of California at San Francisco), C. Castillo-Chavez (Cornell Univ.), K. Hadeler (Univ. Tuebingen), H. Hethcote (Univ. of Iowa).
**Information**: `http://www.pims.math.ca/sections/activities/epid.html`.

19-December 17 **Structure Formation in the Universe**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Mar. 1999, p. 377)

20-24 **IMA "HOT TOPICS" Workshop: Decision Making Under Uncertainty: Energy and Environmental Models**, Institute for Mathematics and Its Applications, University of Minnesota, Minneapolis, Minnesota. (Mar. 1999, p. 377)

*25-30 **Workshop on Discrete Optimization 1999 (DO'99)**, RUTCOR, Rutgers University, Piscataway, New Jersey.
**Sponsor**: DIMACS Center.
**Organizers**: E. Boros and P. Hammer, Rutgers Univ.
**Goal**: The main goal of DO'99 is to survey the state of the art in discrete optimization through presentation of expository lectures presenting the major subareas of the field, including its theoretical foundations, methodology, and applications. DO'99 will also provide a forum for the presentation of new developments in discrete optimization through a series of contributed talks, presenting the latest research of the participants.
**Local Arrangements**: P. Pravato, DIMACS Center; `pravato@dimacs.rutgers.edu`; tel: 732-445-5929.
**Information**: e-mail: `DO99@rutcor.rutgers.edu`; WWW: `http://dimacs.rutgers.edu/Workshops/index.html`.

25-August 7 **The 14th International Conference on Banach Algebras**, Pomona College, Claremont, California. (Sept. 1998, p. 1052)

26-30 **Conference on Functional Differential and Difference Equations**, Instituto Superior Técnico, Lisbon, Portugal. (Mar. 1999, p. 377)

26-30 **ENUMATH 99 - Third European Conference on Numerical Mathematics and Advanced Applications**, University of Jyvaskyla, Jyvaskyla, Finland. (Sept. 1998, p. 1052)

26-30 **International Conference on Theory of Fixed Points and its Applications**, São Paulo, Brazil. (Mar. 1999, p. 378)

26-August 6 **SMS-NATO ASI: Integrable Systems: From Classical to Quantum**, Université de Montréal, Montréal, Canada. (Jan. 1999, p. 69)

*26-August 11 **International Conference and Workshop on Valuation Theory**, Saskatoon, Saskatchewan, Canada.
**Aim**: This conference is dedicated to Paulo Ribenboim in recognition of his extensive contributions to the subject. Tutorials will be given on July 26 and 27. The conference will be held from July 28 through August 4. There will be a special session in honor of Paulo Ribenboim on July 31, and the informal workshop will be held from August 5 through August 11. The conference is intended to cover recent developments in valuation theory and its applications: algebraic geometry (especially local uniformization), real algebraic geometry (and quadratic forms), Galois theory, rigid analysis and curves over valuation rings, model theory of valued fields (especially in positive characteristic), o-minimal expansions of the reals (and Hardy fields), ultrametric spaces and spherically complete fields, p-adic numbers, noncommutative valuation theory.
**Scientific Committee**: H. Brungs (Univ. of Alberta), B. Green (Univ. of Stellenbosch), W. Luetkebohmert (Univ. Ulm), A. Prestel (Univ. Konstanz), S. Priess-Crampe (Univ. Muenchen), M. Spivakovsky (Univ. of Toronto), B. Teissier (École Normale Superieure, Paris).
**Organizers**: A. Carson, D. Haskell (College of the Holy Cross), F.-V. Kuhlmann, S. Kuhlmann (Univ. of Saskatchewan), M. Marshall (Univ. of Saskatchewan), H. Schoutens (Wesleyan Univ.).
**Confirmed Speakers**: S. Abhyankar (Purdue), C. Andradas (Madrid), R. Brown (Hawaii), A. Buium (Urbana), G. Christol (Paris), V. Cossart (Versailles), M. Coste (Rennes), T. Craven (Hawaii), D. Cutkosky (Missouri), N. Dubrovin (Vladimir), J. Engler (Campinas), Y. Ershov (Novosibirsk), J. Graeter (Potsdam), U. Hartl (Ulm), R. Huber (Wuppertal), S. Khanduja (Chandigarh), H. Knaf (Heidelberg), J. Koenigsmann (Konstanz), K. H. Leung (Singapore), Q. Liu (Bordeaux), F. Loeser (Paris), J. Madden (Baton Rouge), J. Minac (Western Ontario), F. van Oystayen (Antwerpen), O. Piltant (Paris), F. Pop (Bonn), P. Popescu-Pampu (Paris), V. Powers (Emory), A. Reguera (Valladolid), P. Ribenboim (Kingston), P. Roquette (Heidelberg), M. Saidi (Bonn), T. Scanlon (Berkeley), C. Scheiderer (Regensburg/Duisburg), E. Schoerner (Munich), N. Schwartz (Passau), J. Shackell (Canterbury), P. Speissegger (Toronto), M. Vaquie (Paris), A. Wadsworth (San Diego).

*26-August 13 **1999 Summer Research Institute**, University of Washington, Seattle, Washington.
**Information**: See `http://www.ams.org/meetings/`.

26-August 13 **School on Algebraic Geometry**, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy. (Mar. 1999, p. 378)

27-August 1 **Loops'99**, Czech University of Agriculture, Prague, Czech Republic. (Mar. 1999, p. 378)

*28-31 **International Symposium on Symbolic and Algebraic Computation**, SFU Harbour Centre, Vancouver, British Columbia.
**Information**: `monagan@cecm.sfu.ca/`.

*30-August 1 **The Second Annual Conference of Bridges: Mathematical Connections in Art, Music, and Science**, Southwestern College, Winfield, Kansas.
**Suggested Topics**: Fractals, math and music, tessellations, geometry in quilting, M. C. Escher work, math and 3-dimensional art, origami, mathematics and architecture, computer-generated art, math and art in culture, art in hyperbolic geometry.
**General Session Contributors**: B. Collins (Kansas City, MO), D. Daniel (Southwestern College), M. Field (Univ. of Houston, TX), N. Friedman (Univ. of New York, Albany), J. Kappraff (New Jersey Inst. of Tech.), I. Rousseau (Summit, NJ), C. H. Séquin (Univ. of California, Berkeley), J. Sullivan (Univ. of Illinois, Urbana-Champaign).
**Special Session and Paper Contributors**: A. Assadi, E. Demaine, M. Demaine, N. A. Diaz, D. Dunham, S. Eberhart, H. Eghbalnia, R. Enrich, R. Fathauer, C. Federico, D. Gerhard, G. R. Greenfield, J. K. Haack, L. Holbrook, K. Hopper, D. Isaksen, A. Karkowski, E. Knoll, P. LaFollette, A. Lubiw, K. Manske, S. Marcus, B. Mayhew, D. Meyer, J. Meyer, S. Morgan, R. Morrison, R. Sarhangi, D. R. Schol, C. Singer, D. Thoman, K. Williams.
**Information**: For more information (or if you want to add your e-mail to the mailing list) you may contact: R. Sarhangi,

Bridges, Southwestern College, 100 College Street, Winfield, KS, 67156; e-mail: sarhangi@jinx.sckans.edu; tel: 316-221-8373; home page: http://www.sckans.edu/~bridges/. You may also contact the following Bridges Advisory Board members regarding the conference: East: N. Friedman, Dept. of Mathematics and Statistics, Univ. at Albany, State Univ. of New York, Albany, NY 12222; e-mail: artmath@math.albany.edu; tel: 518-442-4621; West: C. Séquin, Computer Science Division, EECS Dept., Univ. of California, Berkeley, CA 94720; e-mail: sequin@cs.berkeley.edu; tel: 510-642-5103.

31-August 2 **Mathfest 99**, Mathematical Association of America, Providence, RI. (May 1999, p. 593)

## August 1999

August-December **MSRI Program in Galois Groups and Fundamental Groups**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 1998, p. 1053)

August-May 2000 **MSRI Program in Noncommutative Algebra**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 1998, p. 1053)

1-6 **1999 ASL European Summer Meeting (Logic Colloquium '99)**, Utrecht, The Netherlands. (Jan. 1999, p. 69)

1-7 **EQUADIFF 99**, Free University, Berlin, Germany. (Nov. 1998, p. 1378)

2-4 **Workshop on the Theory and Practice of Integer Programming in Honor of Ralph E. Gomory on the Occasion of His 70th Birthday**, IBM Watson Research Center, Yorktown Heights, New York. (May 1999, p. 594)

2-13 **IMA Summer Program: IMA Workshop on Codes, Systems and Graphical Models**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

* 2-13 **Workshop on Mathematical Ecology**, University of British Columbia, Vancouver, British Columbia.
**Focus**: Ecology is the study of the distribution and abundance of organisms. Mathematical analysis and methods contribute to this study at a number of different levels.
**Speakers**: F. Adler (Univ. of Utah), G. Dwyer (Univ. of Chicago), S. Ellner (North Carolina State Univ.), S. Gardner (Imperial College at Silwood Park), B. Luttbeg (Yale Univ.), M. Mangel (Univ. of California at Santa Cruz), J. Newman (Univ. of Oxford).
**Information**: http://www.pims.math.ca/sections/activities/eco.html.

* 2-20 **Frontiers of Mathematical Physics, Summer Workshop on Particles, Fields and Strings '99**, University of British Columbia, Vancouver, British Columbia.
**Information**: http://kepler.physics.ubc.ca/~pfs99/.

* 2-20 **Ninth Jyvaskyla Summer School**, University of Jyvaskyla, Jyvaskyla, Finland.
**Aim**: The Jyvaskyla Summer School offers courses in various fields of science for advanced undergraduate students, graduate students, and postdocs, with an aim of encouraging interdisciplinary study.
**Mathematics and Applied Mathematics Courses**: Percolation on Trees and Groups, Aug. 2-13, 20 hours, R. Lyons (Indiana Univ.); Brownian Motion, Fractal Dimension and Trees, Aug. 2-8, 10 hours, Y. Peres (Jerusalem and Berkeley); Stochastic Differential Equations, Aug. 2-6, 10 hours, I. Gyongy (Edinburgh); The Markov Chain Monte Carlo Method—A Rigorous Approach, Aug. 9-13, 10 hours, M. Jerrum (Edinburgh); Evolutionary Computing for Complex Multidisciplinary Design, Aug. 9-13, 10 hours, J. Periaux (Dassault Aviation, France).
**Information**: http://www.jyu.fi/~summerschool/.

* 5-6 **International Conference on the Collatz Problem and Related Topics**, Katholische Universitaet Eichstaett, Germany.
**Focus**: This conference is intended for anyone interested in the $3x + 1$ problem (also known as the Syracuse algorithm, Collatz's, Kakutani's, or Ulam's problem) and related mathematics.
**Organizers**: M. Chamberland, Department of Mathematics, Grinnell College, Grinnell, IA 50112; tel: 515-269-4207; fax: 515-269-4984; e-mail: chamberl@math.grin.edu; G. Wirsching, Mathematisch-Geographische Fakultaet, Katholische Universitaet Eichstaett, Ostenstrasse 26, 85072 Eichstaett, Germany; tel: 08421-93-1456; fax: 08421-93-1789; e-mail: guenther.wirsching@ku-eichstaett.de.
**Invited Speaker**: J. C. Lagarias (AT&T Labs).
**Contributed Talks**: If you are interested in giving a talk, please contact M. Chamberland before May 31.
**Registration**: US$40 or 36 Euro before March 31; US$60 or 54 Euro after April 1. Checks (made out to the "Katholische Universitaet Eichstaett") should be sent to M. Chamberland.
**Information**: http://www.math.grinnell.edu/~chamberl/conf.html.

8-14 **Second International Conference on Boundary Value Problems, Integral Equations and Related Problems**, Chengde, Hebei, and Beijing, China. (Feb. 1999, p. 277)

9-14 **Gyorgy Alexits Memorial Conference**, Budapest, Hungary. (Jun/Jul. 1998, p. 760)

9-20 **Summer School on Empirical Processes**, University of Aarhus, Denmark. (Dec. 1998, p. 1502)

* 10-15 **International Conference on Mathematical Logic**, Novosibirsk, Russia.
**Dedication**: The conference is dedicated to A. I. Malt'sev (1909-1967) 90th birthday anniversary and the 275th anniversary of the Russian Academy of Sciences.
**Program Committee**: S. I. Adyan, B. Cooper, E. Engeler, Yu. L. Ershov (chairman), S. S. Goncharov, A. Macintyre, L. L. Maksimova, Yu. V. Matiyasevich, A. Nerode, H. Ono, E. A. Palyutin, M. G. Peretyat'kin, A. Prestel, A. A. Razborov, H. Schwichtenberg, R. Soare, and M. A. Taitslin.
**Scope**: The conference program is of wide scope, including model theory, computability theory, proof theory, and logic foundation of computer science.
**Invited Speakers**: J. Baldwin, L. Beklemishev, U. Berger, P. Cholak, J. Knight, J. Konigsman, D. Leivant, S. Starchenko, s. Wainer, B. I. Zilber.
**Abstracts**: Abstracts (one-page limit in 12 pt. font) will be published and should be sent by the deadline of June 1, 1999, to: A. N. Ryaskin, Conference on Mathematical Logic, Institute of Mathematics, Novosibirsk, 630090, Russia, e-mail: ryaskin@math.nsc.ru; or can be submitted (using facilities of Atlas Mathematical Conference Abstracts) via http://at.yorku.ca/cgi-bin/amca/submit/cacs-01. Your text will immediately become available to everyone. This will be done automatically and doesn't imply acceptance of the paper. The Program Committee will notify you about acceptance/rejection of your paper not later than June 15, 1999.
**Fee**: Participation fee equivalent to US$50 (this does not include accommodations, subsistence, excursion, banquet) should be paid after arrival. For participants from NIS countries it could be reduced (if you apply).
**Information**: Tel: 7-383-2-356237, fax: 7-383-2-357808, e-mail: ryaskin@math.nsc.ru, http://www.math.nsc.ru/conference/malmeet/99/index.html.

* 11-14 **Workshop on Algorithms and Data Structures**, SFU Harbour Centre, Vancouver, British Columbia.
**Information**: arvind@cs.sfu.ca.

* 15-18 **11th Canadian Conference on Computational Geometry**, University of British Columbia, Vancouver, British Columbia.
**Information**: snoeyink@cs.ubc.ca.

16-18 **Conference in Honor of Daniel J. Kleitman's 65th Birthday**, M.I.T., Cambridge, Massachusetts. (Dec. 1998, p. 1502)

16-20 **International Conference on Analysis and Mathematical Physics in Honor of Lars Gårding on His 80th Birthday**, University of Lund, Sweden. (May 1999, p. 594)

16-21 **International Conference on Differential and Functional Differential Equations**, Moscow, Russia. (Feb. 1999, p. 278)

16-27 **Symposium on Arithmetic Fundamental Groups and Noncommutative Algebra**, Mathematical Sciences Research Institute, Berkeley, California. (Mar. 1999, p. 378)

* 16-27 **Workshop on Mathematical Cellular Biology**, University of British Columbia, Vancouver, British Columbia.
**Aim**: The fields of molecular and cellular

biology have undergone explosive growth over the last decade, with a wealth of biological detail emerging from high-tech experimental techniques. The life of the cell, down to its smallest components, is now the subject of intense scrutiny. We know more about the way that the cell is shaped and controlled, how it moves and divides, how it senses and reacts to its environment, and how it influences other cells than ever before. The way that cell aggregates work together to produce multicellular structures with their own repertoire of behavior is also a fascinating and fervent area of research. Many of the speakers in this list have worked productively at the interface of mathematics and biology. The order of the topics will proceed from the subcellular up the hierarchical scale, highlighting some of the most exciting and productive areas of cross-fertilization of mathematical, theoretical, and experimental work.
**Speakers**: D. Bottino (Univ. of Utah), M. Dembo (Boston Univ.), V. Foe (Univ. of Washington), B. Goldstein (Los Alamos National Laboratory), A. Mogilner (Univ. of California at Davis), G. Odell (Univ. of Washington), L. Segel (Weizmann Institute), C. Wofsy (Univ. of New Mexico).
**Information**: `http://www.pims.math.ca/sections/activities/cell.html`.

*18-20 **Symbolic and Numerical Scientific Computation (SNSC99)**, Linz, Austria.
**Goal**: Further the integration of methods in symbolic and numerical scientific computation.
**Information**: e-mail: `snsc99@risc.uni-linz.ac.at`; `http://www.risc.uni-linz.ac.at/conferences/summer99/snsc99.html`.

19-25 **Topology and Dynamics: Rokhlin Memorial**, Euler International Mathematical Institute, St. Petersburg Mathematical Institute of Russian Academy of Science, St. Petersburg, Russia. (May 1999, p. 594)

*19-27 **International Instructional Workshop on Wavelets and Applications**, Department of Mathematics, University of Delhi, India.
**Purpose**: The purpose of this workshop is: (a) to train a group of young scientists in wavelets, approximation and applications to image analysis, signal processing, informatics, electronics, and biomedical sciences; (b) to acquaint the participants with the recent developments in the area; (c) to bring a few experts in the area together to interact.
**Steering Committee**: P. K. Jain, A. I. Singh, D. Singh, R. Vasudevan.
**Invited Speakers**: H.-P. Blatt (Germany), M. D. Buhmann (Germany), H. P. Dikshit (India), B. Fischer (Lubec), P. E. T. Jorgensen (Iowa), M. Krishna (India), R. Lasser (Germany), H. N. Mhaskar (USA), J. Prestin (Germany), U. B. Tewari (India), M. Vaninathan (India), Y. V. Venkatesh (India).
**Information**: For further details and all correspondence, contact P. K. Jain, Director of the Workshop, Department of Mathematics, Univ. of Delhi, Delhi-110007, India; tel: 11-7256658; fax: 11-7257049; e-mail: `pawankjain@hotmail.com`.

20-26 **Eleventh International Congress of Logic, Methodology and Philosophy of Science**, Krakow, Poland. (Jan. 1999, p. 70)

23-27 **International Conference on Topology and its Applications**, Kanagawa University, Yokohama, Japan. (Aug. 1998, p. 899)

23-29 **International Conference on Nonlinear Partial Differential Equations**, Lviv, Ukraine. (Mar. 1999, p. 379)

23-September 4 **Generalized Dirac Operators and their Geometric Scattering Theory**, Banach Center, Warsaw, Poland. (Jan. 1999, p. 70)

*24-28 **10th International Workshop and Conference in Stochastic Geometry, Stereology & Image Analysis**, University of Calgary, Calgary, Alberta.
**Information**: `enns@math.ucalgary.ca`.

*25-27 **DIMACS Workshop on Diagonal Matrix Scaling and Its Generalizations and Their Applications in Convex Programming over Cones**, DIMACS Center, Rutgers University, Piscataway, New Jersey.
**Sponsors**: DIMACS Center, Rutgers Univ.
**Organizers**: B. Kalantari (Rutgers Univ.), U. Rothblum (Technion-Israel Institute of Technology), and A. Samorodnitsky (DIMACS, Rutgers Univ.).
**Goal**: The goal of the workshop is to bring together researchers working on theoretical and practical aspects of matrix scaling problems, including matrix balancing, and their generalizations. The workshop hopes to provide more convincing evidence on the broad significance of the matrix scaling problems to researchers, as well as those interested in convex programming, self-concordance theory, duality theory, complexity of algorithms, combinatorial optimization, homogeneous inequalities, numerical analysis, etc. This workshop is presented under the auspices of the Special Year on Large Scale Discrete Optimization.
**Contact**: B. Kalantari, Rutgers Univ., `kalantari@cs.rutgers.edu`.
**Local Arrangements**: P. Pravato, DIMACS Center, `pravato@dimacs.rutgers.edu`, 732-445-5929.
**Information**: `http://dimacs.rutgers.edu/Workshops/index.html`.

25-28 **XI International Workshop on Numerical Methods in Viscoelastic Flows**, Vaals, The Netherlands. (Feb. 1999, p. 278)

*25-September 3 **Visions in Mathematics towards 2000**, School of Mathematical Sciences, Tel Aviv University, Tel Aviv, Israel.
**Local Committee**: M. Bialy, D. Ginzburg, M. Gitik, A. Lazar, L. Polterovich, M. Polyak, M. Sodin, D. Soudry, U. Zwick.
**Speakers**: N. Alon, V. Arnold, R. Aumann, A. Beilinson, J. Bernstein, S. Bloch, J. Bourgain, L. Carleson, R. Coifman, A. Connes, M. Douglas, Y. Eliashberg, J. Frohlich, H. Furstenberg, T. Gowers, M. Gromov, H. Hofer, E. Hrushovski, H. Iwaniec. A. Jaffe, V. Kac, D. Kazhdan, S. Kleinerman, M. Kontsevich, A. Kupiainen, E. Lieb, L. Lovasz, R. MacPherson, G. Margoulis, V. Milman, Y. Neeman, S. Novikov, R. Penrose, A. Polyakov, M. Rabin, A. Razborov, P. Sarnak, P. Seymour, P. Shor, Y. Sinai, T. Spencer, R. Stanley, E. Stein, D. Sullivan, J. Tate, V. Voevodsky, A. Wigderson, D. Zagier.
**Information**: `conf2000@math.tau.ac.il`.

27-29 **GAMM-Workshop on Computational Plasticity**, Christian-Albrechts-University of Kiel, Germany. (May 1999, p. 594)

*27-September 1 **4th International Conference on Geometry and Applications**, Varna, Bulgaria.
**Organizers**: The Union of Bulgarian Mathematicians and The Geometry Society of Bulgaria.
**Scientific Committee**: A. Barlotti, W. Benz, R. Fritsch, P. Gilkey, H. Karzel, O. Kowalski, H.-J. Kroll, H. Stachel, G. Stanilov (chairman), H. Zeitler.
**Topics**: Foundation of geometry and incidence geometry; differential geometry; CAD and applications in geometry; geometry in the school.
**Fee**: The conference fee includes a copy of the collection of abstracts, refreshments, social events, and other facilities: regular participants: $125 USD or 210 DM on-site (in cash); accompanying persons: $80 USD or 140 DM on-site (in cash).
**Registration**: Registration forms can be ordered from: G. Stanilov or C. Lozanov, Univ. of Sofia, Faculty of Mathematics and Informatics, 5, James Bourchier Boulevard, 1164 Sofia, Bulgaria; by e-mail to: `stanilov@fmi.uni-sofia.bg` or `lozanov@fmi.uni-sofia.bg`; or R. Fritsch, Mathematisches Institut, Univ. Muenchen, Theresienstrasse 39, D-80333 Muenchen, Germany; e-mail: `fritsch@rz.mathematik.uni-muenchen.de`. Complete registration forms should be received no later than May 1, 1999, by G. Stanilov or C. Lozanov (address above).

30-September 1 **Sixth International Symposium on Generalized Convexity and Monotonicity**, University of the Aegean, Karlovassi, Samos Island, Greece. (Jan. 1999, p. 70)

*30-September 3 **Conference in Honor of Jean Leray**, University of Karlskrona-Ronneby, Sweden.
**Organizers**: M. de Gosson (Karlskrona), J. Vaillant (Paris VI).
**Scientific Committee**: B. Booss-Bavnbek, K. Furutani, B. Gaveau, Y. Hamada, R. Lee, B.-W. Schulze.
**Confirmed Speakers**: A. Bachelot, B. Booss-Bavnbek, A. Bove, S. Cappell, Y. Choquet-Bruhat, P. Ciarlet, F. Colombini, P. Dazord, K. Furutani, B. Gaveau, M. de Gosson, D. Gourdin, O. Gues, Y. Hamada, H. Hedenmalm, C. Houzel, N. H. Ibramigov, S. Illman, K. Kajitani, A. Khrennikov, T. Kobayashi,

R. Lee, J.-L. Lions, C.-M. Marle, V. Nazaykinskiy, J.-P. Nicolas, T. Nishitani, Y. Ohya, B.-W. Schulze, S. Spagnolo, B. Yu. Sternin, G. Taglialatela, G. Tuynman, J. Vaillant, C. Wagschal.
**Information**: C. de Gosson, Charlyne.de Gosson@ihnhk-r.se; conference home page: http://www5.hk-r.se/LERAY.nsf/.

30–September 3 **International Conference on Analysis and Geometry Devoted to the 70th Anniversary of Yu. G. Reshetnyak**, Novosibirsk, Russia. (May 1999, p. 594)

## September 1999

September–May **National Mathematics Honor Society Pi Mu Epsilon's Kansas Gamma Chapter, 50th Anniversary**, Wichita State University, Wichita, Kansas. (May 1999, p. 594)

1–3 **First International Conference on the Integration of Dynamics, Monitoring and Control (DYMAC 99)**, Manchester, United Kingdom. (Sept. 1998, p. 1053)

1–3 **Symposium on Operations Research 1999 (SOR'99)**, Magdeburg, Germany. (May 1999, p. 594)

1–10 **Geometry, Integrability and Quantization**, St. Constantine resort (near Varna), Bulgaria. (May 1999, p. 595)

5–11 **XX International Seminar on Stability Problems for Stochastic Models**, Maria Curie-Sklodowska University, Lublin-Naleczow, Poland. (Jan. 1999, p. 70)

6–10 **Second Meeting on Quaternionic Structures in Mathematics and Physics**, Univ. di Roma "La Sapienza", Univ. Roma Tre, Rome, Italy. (May 1999, p. 595)

*6–10 **Some Trends in Algebra 1999**, Czech Agricultural University, Prague, Czech Republic.
**Topics**: The fourth STA will focus on categorical and homological algebra and model-theoretic and set-theoretic methods in algebra with applications to rings and modules.
**Invited Speakers**: P. C. Eklof (Univ. of California, Irvine), E. Enochs (Univ. of Kentucky), R. Goebel (Univ. Essen), M. Prest (Univ. Manchester), L. Salce (Univ. Padova).
**Information**: Contact J. Trlifaj, trlifaj@karlin.mff.cuni.cz, or R. El Bashir, bashir@karlin.mff.cuni.cz. Postal address is Department of Algebra, MFF UK, Sokolovska 83, Praha 8, 186 75, Czech Republic. More information is available at http://www.karlin.mff.cuni.cz/katedry/ka/.

6–24 **School on Modern Statistical Methods in Medical Research (in conjunction with ICMS, Edinburgh, Scotland, UK)**, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy. (Mar. 1999, p. 379)

6–December 17 **Mathematical Developments in Solid Mechanics and Materials Science**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Mar. 1999, p. 380)

8–15 **European Summer Courses 1999, C.I.M.E.: Direct and Inverse Methods in Solving Nonlinear Evolution Equations**, Cetraro (Cosenza), Italy. (May 1999, p. 595)

9–11 **IX Congress for the learning and teaching of Mathematics (JAEM)**, Lugo (Galicia), Spain. (Mar. 1999, p. 380)

13–18 **International Conference on Arithmetic Algebraic Geometry**, Venice, Italy. (May 1999, p. 595)

14–16 **ElectrIMACS—Conference on Electrical Machines, Converters and Systems**, Lisbon, Portugal. (Apr. 1998, p. 535)

14–18 **International Conference on Analytic Methods of Analysis and Differential Equations (AMADE)**, Minsk, Belarus. (Jan. 1999, p. 70)

15–19 **GD'99 - Seventh International Symposium on Graph Drawing**, Stirin Castle, Prague, Czech Republic. (Jan. 1999, p. 71)

*15–23 **Advanced Course on Integral Geometry**, Centre de Recerca Matemàtica, Barcelona, Spain.
**Speakers**: R. Langevin (Univ. de Bourgogne, Dijon): Introduction to integral geometry; R. Schneider (Albert-Ludwigs-Univ., Freiburg): Integral geometry—measure theoretic approach and stochastic applications.
**Information**: http://crm.es/info/acig/acig.html.

16–22 **The Fourth International Workshop On Differential Geometry and Its Applications**, Brasov, Romania. (Jan. 1999, p. 71)

*17–18 **Illinois Number Theory Conference**, University of Illinois at Urbana-Champaign, Illinois.
**Principal Speakers**: K. Alladi, P. Borwein, A. Pollington, K. S. Williams.
**Organizers**: H. G. Diamond, A. J. Hildebrand.
**Information**: http://www.math.uiuc.edu/nt2000/illinois/.

20–24 **The 10th Biennial Computational Techniques and Applications Conference and Workshops (CTAC99)**, Australian National University, Canberra, Australia. (Feb. 1999, p. 278)

*20–24 **Third Conference on Stochastic Analysis, Random Fields and Applications and Minisymposium on Stochastic Methods in Financial Models III**, Centro Stefano Franscini, Ascona, Switzerland.
**Organizers**: R. Dalang (dalang@math.epfl.ch), M. Dozzi (dozzi@iecn.u-nancy.fr), F. Russo (russo@math.univ-paris13.fr).
**Invited Speakers**: S. Albeverio (Bonn), M. Avellaneda (Columbia), O. Barndorff-Nielsen (Aarhuus), G. Ben Arous (EPFL Lausanne), P. Blanchard (Bielefeld), R. Carmona (Princeton), A. B. Cruzeiro (Lisbon), G. Da Prato (SNS Pisa), F. Delbaen (ETH Zurich), H. Geman (ESSEC), K. Fleischmann (Berlin), N. El Karoui (Polytechnique), F. Moriconi (Perugia), C. Mueller (Rochester), M. Musiela (Sydney), D. Nualart (Barcelona), B. Oksendal (Oslo), G. Pagès (Paris 12), E. Pardoux (Aix-Marseille 1), E. Platen (Canberra), M. Röckner (Bielefeld), B. Rozovski (Southern California), W. J. Runggaldier (Padova), M. Sanz (Barcelona), C. Stricker (Besancon), M. Yor (Paris 6), J. -Cl. Zambrini (Lisbon).
**Information**: E. Gindraux, gindraux@math.epfl.ch; Web site: http://www-math.math.univ-paris13.fr/~russo/Ascona99.html.

*20–26 **International Symposium on Classical Analysis**, Kazimierz Dolny, Poland.
**Organizer**: The Technical University of Radom.
**Topics**: The results and problems in such fields as: several complex variables (especially $L^2$-methods), Riemannian and Hermitian geometry, spectral theory in Hilbert space, probability, mathematical physics. Particular consideration will be given to the interrelation of ideas from different areas and to promoting wider knowledge of some important classical theories.
**Invited Speakers**: K. Goebel, J. Kisyński, J. Ławrynowicz, A. Płoski, P. Rusev, J. Siciak, W. Yin, and Y. Zelinsky.
**Scientific Program**: The scientific program will consist of invited lectures and thirty 45-minute scientific communications in English.
**Information**: Information about registration fee, accommodation costs, and submission of manuscripts for the proceedings of the symposium will be presented in the second announcement. For other information contact T. Mazur, Dept. of Mathematics, Technical Univ., Malczewskiego 29, 26-600 Radom, Poland; fax: 4848-26333 or 4848-23969; e-mail: mazurt@kiux.man.radom.pl or krupa@alpha.sggw.waw.ps.

23–24 **IMA Tutorial: Low-Speed Combustion**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 595)

*26–28 **International Workshop on Analysis of Vibrating Systems**, The Greenwood Inn in Canmore, Alberta, Canada.
**Aim**: An intensive three-day workshop for the discussion of recent advances in the analysis of vibrations (including discrete and distributed systems and symmetry groups) and the identification of developing problem areas in the analysis of vibrations. In particular, there will be an exchange of ideas between those working with linear and nonlinear models, vibrations being the common ground, and dialog between researchers in engineering and the mathematical sciences (including scientists/engineers from industry).
**Invited Speakers**: V. M. Adamjam, S. J. Chern, G. Gladwell, I. Gohberg, P. Hagedorn, N. Leonard, A. Lifschitz, J. Mclaughlin, S. Namachchivaya, J. Woodhouse.
**Sponsors**: The Pacific Institute for the Mathematical Sciences, Univ. of Calgary.

**Scientific Program Committee**: G. Gladwell (Univ. of Waterloo), K. Glover (Cambridge Univ.), P. Lancaster, chair (Univ. of Calgary), H. Langer (Tech. Univ. of Vienna), J. Marsden (Caltech), J. Wickert (Carnegie Mellon).

**Local Organizers**: P. Lancaster, e-mail: lancaste@ucalgary.ca; J. Longworth, e-mail: pims@ucalgary.ca; M. Paulhus, e-mail: paulhusm@math.ucalgary.ca.

**Information**: http://www.math.ucalgary.ca/pims/vibrations/index.html.

27–October 1 **IMA Workshop: Low-Speed Combustion**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 595)

## October 1999

October **National Conference on Issues Related to Doctoral Programs in Mathematics Education**, University of Missouri, Columbia, Missouri. (Jan. 1999, p. 71)

2–3 **AMS Eastern Sectional Meeting**, Providence College, Rhode Island. (Sept. 1997, p. 1031)

**Information**: W. Drady, e-mail: wsd@ams.org.

* 2–3 **24th Cascade Topology Seminar**, University of British Columbia, Vancouver, British Columbia.

**Information**: rolfsen@math.ubc.ca.

4–8 **International Workshop on General Topological Algebras**, Tartu, Estonia. (May 1999, p. 595)

* 4–8 **MSRI Workshop on Constructive Galois Theory**, MSRI, Berkeley, California.

**Topics**: As part of the fall 1999 program in Galois Groups and Fundamental Groups, MSRI will host a one-week workshop in Constructive Galois Theory, October 4–8, 1999. Topics of the workshop include:

• Construction of Galois extensions of function fields using "rigidity" and, more generally, moduli spaces for covers of the Riemann sphere and associated monodromy action of the braid group; realizations of simple groups and classical groups as Galois groups over number fields; constructions of Galois covers of curves over finite fields; computational Galois theory.

• Patching constructions using formal and rigid geometry, deformations (liftings) of given Galois covers. Applications to Galois groups and fundamental groups in characteristic p and for higher-dimensional varieties.

• Galois embedding problems: realizations of composite groups as Galois groups over global fields, realization and structure of profinite Galois extensions, connections to rigid analytic and formal geometric constructions.

• Connections with field arithmetic: constructions over fields with special properties (algebraically closed, complete, henselian, PAC, hilbertian, etc.).

• Invariant theory of finite groups, generic polynomials, and Noether's method.

**Financial Support**: A limited amount of funding is available for partial support of people wishing to attend. Students, recent Ph.D.'s, women, and minorities are particularly encouraged to apply. To apply for funding, send a letter explaining your interest in the workshop together with a vita or bibliography and a budget for travel/living expenses. If you are a student, also solicit a letter from a faculty advisor. All information should be received by July 6, 1999.

**Information**: Send mail to cgt@msri.org, or visit http://www.msri.org/.

4–8 **Workshop on the Complexity of Multivariate Problems**, Hong Kong Baptist University, Hong Kong, China. (Jan. 1999, p. 71)

6–9 **New Trends in the Calculus of Variations**, Centro de Matemática e Aplicações Fundamentais da Universidade de Lisboa, Lisbon, Portugal. (Mar. 1999, p. 380)

8–10 **AMS Central Sectional Meeting**, University of Texas, Austin. (Sept. 1997, p. 1031)

**Information**: W. Drady, e-mail: wsd@ams.org.

10–14 **National Conference on Algebra VII**, Beijing Normal Univ., Beijing, China. (May 1999, p. 595)

11–13 **IMA Workshop: Fires**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 595)

* 11–15 **MSRI Workshop on Galois Actions and Geometry**, MSRI, Berkeley, California.

**Topics**: As part of the fall 1999 program in Galois Groups and Fundamental Groups, MSRI will host a one-week workshop in Galois Actions and Geometry, October 11–15, 1999. The themes of the week-long workshop will include:

• Galois and braid group actions on fundamental groups of marked curves, Galois actions on fundamental groups of moduli spaces of curves, the Grothendieck-Teichmueller group.

• Fundamental groups and geometry of moduli spaces; generalized Hurwitz spaces, modular towers; families of covers.

• Connection with abelian varieties, Iwasawa theory, and modular forms; Galois representations and their images; nilpotent and motivic aspects.

• Grothendieck's anabelian conjectures, fundamental groups of hyperbolic varieties and anabelian neighborhoods of points, conjectures on sections and rational points.

• Galois cohomology; connections to embedding problems; fields of moduli of varieties and covers, descent.

• Arithmetic of covers, related group theory, exceptional covers, special fibers, semistable reduction, p-adic uniformization theory of curves.

**Financial Support**: A limited amount of funding is available for partial support of people wishing to attend. Students, recent Ph.D.'s, women, and minorities are particularly encouraged to apply. To apply for funding, send a letter explaining your interest in the workshop together with a vita or bibliography and a budget for travel/living expenses. If you are a student, also solicit a letter from a faculty advisor. All information should be received by July 12, 1999.

**Information**: Send mail to gactions@msri.org, or visit http://www.msri.org/.

* 12–16 **A Conference in Analysis**, The Ohio State University, Columbus, Ohio.

**Organizing Committee**: V. Bergelson, D. Burghelea, J. Diestel, and P. Nevai.

**Purpose**: The purpose of the conference is to bring together distinguished mathematicians in a number of areas of analysis such as complex analysis, harmonic analysis, operator theory, partial differential equations, Banach spaces, and approximation theory with young researchers and graduate students for a broad discussion of problems, exchange of ideas, and fostering of new collaborations. The conference topics are closely related to the research subjects which our friend and colleague Boris Mityagin has studied during his forty-year-long mathematical career.

**Invited Speakers**: R. A. DeVore, P. Enflo, C. I. Foias, T. W. Gamelin, E. A. Gorin, V. Havin, G. M. Henkin, W. B. Johnson, B. Korenblum, V. Lin, G. G. Lorentz, V. Milman, N. K. Nikolski, S. Novikov, D. Pallaschke, A. Pelczynski, G. Pisier, E. M. Stein, V. M. Tikhomirov, and V. Zahariuta.

**Funding**: Subject to availability of funds, we plan to provide partial financial support for some of the participants. Priority will be given to graduate students and recent Ph.D.'s.

**Information**: Those who wish to be placed on the e-mail list of the conference should send a message to nevai@math.ohio-state.edu. Up-to-date information will be available at http://www.math.ohio-state.edu/.

14–15 **IMA Minisymposium: Mathematical and Computational Strategies for Simplifying Complex Kinetics**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 595)

15–17 **AMS Southeastern Section Meeting**, University of North Carolina, Charlotte, North Carolina. (Nov. 1998, p. 1378)

* 16–17 **West Coast Operator Algebra Symposium**, University of Victoria, Victoria, British Columbia.

**Information**: putnam@math.uvic.ca.

* 21–26 **Workshop on Stochastics and Quantum Physics**, University of Aarhus, Aarhus, Denmark.

**Organizers**: O. E. Barndorff-Nielsen (Aarhus) and K. Molmer (Aarhus).

**Focus**: The workshop will focus on some of the areas where concepts and techniques from stochastics (i.e., probability and mathematical statistics) are or seem likely soon to become of real quantum physical importance. By bringing together leading physicists and mathematicians having an active interest in the themes of the workshop, it is hoped to foster fruitful discussions and collaboration on the role and use of stochastics in quantum physics.

**Topics and Speakers**: Main themes of the workshop are listed below (confirmed keynote speakers are in parentheses): Laser physics/Quantum optics (F. Bardou, H. Carmichael, G. Mahler); Quantum stochastic processes (A. Barchielli, V. P. Belavkin, G. Lindblad); Wick products, white noise analysis and Malliavin calculus (B. Oeksendal); The role of generalized measurements and quantum statistical inference (R. Gill, S. Massar, H. Wiseman); Quantum information (P. Hoeyer, A. S. Holevo, A. Peres, S. Popescu).

**Deadline**: Registration is to be done before September 1, 1999.

**Information**: The workshop Web page can be found at `http://www.maphysto.dk/events/QuantumStoc99/`; from there it is also possible to register.

* 22-23 **19th Annual Southeastern-Atlantic Regional Conference on Differential Equations**, University of Richmond, Richmond, Virginia.

**Scope**: The primary purpose of the conference is to promote research and education in the field of differential equations, i.e., ordinary and partial differential equations and functional differential equations, numerical techniques and their applications to biology, engineering, and physics. These meetings bring together established and new researchers and advanced graduate students for an exchange of ideas and discussions on the diverse aspects of differential equations.

**Topics**: The conference will consist of a series of three plenary one-hour lectures and sessions for contributed papers. Topics presented during these conferences have been diverse and have provided a unique opportunity to see the variety of problems in which differential equations play a critical role. Among subjects presented have been ordinary and partial differential equations, integral and functional equations, numerical methods, and applications to the sciences and engineering.

**Invited Speakers**: M. Cheney (Rensselaer Polytechnic Institute), P. Lax (Courant Institute, New York Univ.), G. Webb (Vanderbilt Univ.).

**Contributed Talks**: There will be sessions of contributed talks. Deadline for submission of abstracts for contributed talks is September 30, 1999.

**Financial Assistance**: Contingent on NSF funding, some financial assistance may be available to offset travel and housing expenses for graduate students and recent Ph.D. recipients. Requests postmarked by September 18, 1999, are guaranteed consideration. Eligible persons who belong to currently underrepresented groups are especially encouraged to apply to the conference for financial assistance.

**Information**: Updated information can be obtained at the conference Web site, `http://www.mathcs.richmond.edu/searcde/searcde.html` or by contacting L. Caudill, SEARCDE Coordinator, Dept. of Mathematics and Computer Science, Univ. of Richmond, Richmond, VA 23173; tel: 804-289-8083; fax: 804-287-6444; e-mail: `lcaudill@richmond.edu`.

* 22-23 **The Twenty-First Midwest Probability Colloquium**, University of Cincinnati, Cincinnati, Ohio.

**Organizing Committee**: A. de Acosta (chair), S. Lalley, V. Wihstutz.

**Invited Speakers**: K. Alexander (Univ. of Southern California), W. Li (Univ. of Delaware), M. Yor (Univ. Pierre et Marie Curie, Paris).

**Support**: Funding has been requested from the National Science Foundation for the support of participants, especially younger investigators and underrepresented groups. We expect to make grants to cover all or part of the hotel charges. To apply for support, please contact the local conference: J. Mitro (`mitroj@math.uc.edu` or 513-556-4055) by October 1, 1999.

22-24 **IMA "Hot Topics" Workshop: Scaling Phenomena in Communication Networks**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 595)

23-24 **Midwest Partial Differential Equations Seminar, Fall 1999**, University of Illinois, Urbana-Champaign, Illinois. (Mar. 1999, p. 380)

* 25-29 **MSRI Workshop on Hopf Algebras**, MSRI, Berkeley, California.

**Topics**: As part of the yearlong program in Noncommutative Algebra, MSRI will host a one-week workshop on Hopf Algebras, October 25-29, 1999.

The last ten years have seen a surge of activity in Hopf algebras. In particular, a number of conjectures of Kaplansky from 1975 on finite-dimensional Hopf algebras have been solved; as a consequence there has been some progress on the classification of semisimple Hopf algebras and on the structure of pointed Hopf algebras. There has also been much progress on actions and coactions of Hopf algebras, in particular on Hopf Galois extensions.

It is striking that many new methods have been used in these results; for example, modular categories and braid theory, representation theory, algebraic geometry, and Lie methods such as Cartan matrices. Thus techniques from quantum groups can now help on these more classical Hopf algebra questions.

**Focus**: The workshop will focus on these new results and methods in hopes of making further progress in describing the structure of Hopf algebras and on their actions and coactions. As Hopf algebras now appear as invariants of a number of other mathematical structures, such progress would be of interest in other areas.

**Financial Support**: A limited amount of funding is available for partial support of people wishing to attend. Students, recent Ph.D.'s, women, and minorities are particularly encouraged to apply. To apply for funding, send a letter explaining your interest in the workshop together with a vita or bibliography and a budget for travel/living expenses. If you are a student, also solicit a letter from a faculty advisor. All information should be received by July 26, 1999.

**Information**: Send mail to `hopfalg@msri.org`, or visit `http://www.msri.org/`.

## November 1999

* 1-5 **MSRI Workshop on The Mathematics of Imaging**, MSRI, Berkeley, California.

**Topics**: Mathematics plays an important role in a variety of imaging problems in the physical and biomedical sciences as well as in many other areas, including remote sensing, computer vision, speech and image compression, and the general area of signal processing. Important contributions have resulted from the interaction between mathematicians working in inverse problems and engineers and other practitioners in these applied fields. New technological advances have opened up a large number of opportunities for increased interaction of this kind. We propose a conference that will bring together mathematicians and scientists with a common interest in these problems and techniques.

**Focus**: This workshop will bring together mathematicians and a number of workers in these various fields. An effort will be made to have lectures of an introductory nature. The program will seek to involve mathematicians with these applications and to explore relevant and emerging mathematical techniques in these areas. The prospective invited speakers are at the forefront of some of the following fields: chemistry, geophysics, medical imaging, nondestructive evaluation, and signal processing.

**Speakers**: J. Berryman (Lawrence Livermore Laboratory), G. Beylkin (Colorado, Boulder), L. Borcea (Rice), T. Budinger (Berkeley), M. Cheney (RPI), J. Claerbout (Stanford), R. Coifman (Yale), D. Colton (Univ. Delaware), I. Daubechies (Princeton), H. Hauptman (Buffalo), G. Herman (Penn), D. Ingerman (MIT), D. Isaacson (RPI), J. Keller (Stanford), J. McLaughlin (RPI), D. Mumford (Brown), F. Natterer (Univ. of Muenster, Germany), C. Nolan (UW), S. Osher (UCLA), G. Papanicolaou (Stanford), S. Patch (GTE), A. Pines (Berkeley), F. Santosa (Minnesota), J. Sethian (Berkeley), W. Symes (Rice), J. Zubelli (IMPA).

**Information**: Send mail to `imaging@msri.org`, or visit `http://www.msri.org/`.

* 2-5 **Workshop on Hilbert's 10th Problem, Relations to Arithmetic and Algebraic Geometry**, University of Gent, Gent, Belgium.

**Scientific Committee**: J. Denef, L. Lipshitz, T. Pheidas, and J. Van Geel.

**Theme**: The main theme of the meeting will be the relation between decidability problems, arithmetic, and algebraic geometry. The scientific committee hopes that bringing together number theorists, algebraic geometers, and logicians will provoke discussions and set directions for future research related to Hilbert's original question.

**Topics**: Apart from selected research lectures presenting recent results in the field, there will be three or four series of lectures of an instructional character selected from among the following topics: Work on Hilbert's 10th problem, for various rings and fields, over the past decades; some model theoretic aspects and related decidability problems; decidability for certain generic diophantine problems and for fragments of arithmetic; the algebraic geometric structure of Diophantine families; Mazur's conjectures on the topology of rational points; computational aspects; work of Rojas on (un)computability of bounds for integral points and the $\exists\exists\forall\exists$ diophantine problem; complexity of diophantine geometry.

**Information**: People interested in the meeting should contact the local organizers by e-mail, `hilbrt10@cage.rug.ac.be`, or by ordinary mail to J. Van Geel or K. Zahidi, Univ. of Gent, Department of Pure Mathematics, Galglaan 2, B-9000 Gent, Belgium; fax: 32-0-9-264-49-93. Although we invite all people who are interested in the topics to apply, the number of participants will be limited in order to maintain the character of the meeting. Further information on the workshop and its location can be found at `http://cage.rug.ac.be/~hilbrt10/hilbert10.html`. There one can also find an updated list of participants.

5 **IMA Tutorial: High-Speed Combustion**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 596)

8–12 **IMA Workshop: High-Speed Combustion in Gaseous and Condensed-Phase Energetic Materials**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 596)

29–December 3 **Group Theory and Computation**, University of Sydney, Sydney, Australia. (May 1999, p. 596)

## December 1999

*2–4 **Computational and Mathematical Methods in Music**, Vienna, Austria.

**Aim**: The aim of this conference is to bring together mathematicians interested in or working on subjects of relevance to music and musicians who make use of computational methods or would like to learn more about possibilities offered by mathematical approaches.

**Topics**: Among the topics to be covered are physical modelling, optimization of instruments, time-frequency analysis methods, the transcription problem, restoration of old musical recordings, or AI methods for studying musical expression. Contributions should emphasize the connections between the two fields. Thus, contributions on computer music per se or describing only efficient implementations are discouraged.

**Organizers**: The Mathematics Department of the Univ. of Vienna, the Austrian Mathematical Society, and the Austrian Academy of Sciences.

**Local Arrangements**: H. G. Feichtinger (`fei@tyche.mat.univie.ac.at`) and C. Krattenthaler (`krat@pap.univie.ac.at`).

**Speakers**: G. DePoli (Padua), W. Fitzgerald (Cambridge), J. C. Risset (Marseille), X. Serra (Barcelona), G. Wakefield (Ann Arbor).

**Deadline**: The deadline for the submission of posters or short talks and other contributions is August 20, 1999, but earlier submission is encouraged.

**Information**: Contact H. G. Feichtinger (`fei@tyche.mat.univie.ac.at`), or visit the Web page `http://tyche.mat.univie.ac.at/~diderot/` for details. This conference is connected with the EMS Diderot Mathematical Forum, to be held Dec. 3–4 in parallel in Lisbon, Paris, and Vienna under the general theme "Mathematics and Music". For general information concerning this forum you may also contact M. Chaleyat-Maurel (`mcm@ccr.jussieu.fr`).

20–22 **Seventh IMA International Conference on Cryptography and Coding**, Royal Agricultural College, Cirencester, United Kingdom. (May 1999, p. 596)

*31–January 3 **Golden Jubilee International Conference on Mathematics (GJICM)**, Lucknow, India.

**Organizers**: B. G. Parishad and Department of Mathematics and Astronomy, Lucknow Univ.

**Aim**: To mark the 50th year of Bharata Ganita Parishad and for ushering in the Year of Mathematics.

**Special Sessions**: Algebra, topology, and analysis; mathematical modelling and computer applications; mathematics through the ages; recent developments in astronomy. Besides invited talks there will be paper reading sessions also.

**Registration**: By October 30, 1999.

**Information**: S. Datta, Dept. of Mathematics and Astronomy, Lucknow Univ., Lucknow 226007, India; e-mail: `bgp11@hotmail.com` or `sdatta@lw1.vsnl.net.in`. For flyer and registration form: `http://www.angelfire.com/ma2/bgp/`.

## January 2000

*3–7 **Fifth International Conference on Difference Equations and Applications**, Univ. de la Frontera, Temuco, Chile.

**Organizers**: Univ. del Bio-Bio., Univ. de Chile, Univ. de La Frontera, Univ. de Los Lagos, Univ. de Oriente (Venezuela).

**Invited Speakers**: (to be confirmed): O. Arino (Pau, France), A. Arneodo (CNRS, France), B. Aulbach (Augsburg, Germany), R. Devaney (Boston), E. Doedel (Montreal, Canada), S. Elaydi (San Antonio), W. Gautschi (West Lafayette, IN.), K. Gopalsamy (Adelaide, Australia), T. Hallam (Tennessee), T. Immink (Groningen, The Netherlands), D. Knuth (Stanford), G. Ladas (Kingston, RI), D. Lubinsky (Johannesburg, South Africa), J. Mallet-Paret (Providence, RI), R. May (Oxford, UK), K. Nishimura (Kyoto, Japan), J. Palis (Rio de Janeiro, Brazil), G. Sell (Minneapolis), A. Sharkovsky (Kiev, Ukraine), D. Siljak (Santa Clara), H. Smith (Tempe, AZ), E. Tirapegui (Santiago, Chile), V. Totik (Szeged, Hungary), W. Van Assche (Leuven, Belgium), A. Vanderbauwhede (Gent, Belgium), F. Van-Diejen (Santiago, Chile), J. Yorke (College Park, MD).

**Special Sessions**: A special session on "Open Problems and Conjectures" (chair: G. Ladas, Kingston, RI) will take place during the conference.

**Topics**: The topics covered in this conference will include, but are not limited to, the following: General theory of difference equations, asymptotic behavior, oscillation theory, stability theory, chaos, discrete dynamical systems, orthogonal polynomials, numerical methods, approximation theory, control theory, stochastic processes, industrial mathematics and mathematical engineering, mathematical biology, mathematical mechanics.

**Registration Fee**: The registration fee is US$180 if paid before September 15, 1999. After this date it will be US$200.

**Information**: Contact: M. Pinto J., Departamento de Matemáticas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile; e-mail: `pintoj@abello.dic.uchile.cl`; J. López Fenner, Departamento de Matemáticas y Estadística, Facultad de Ingeniería, Universidad de La Frontera, Casilla 54-D, Temuco, Chile; e-mail: `jlopez@ufro.cl`; S. Elaydi, Department of Mathematics, Trinity University, San Antonio, Texas 78212; e-mail: `selaydi@trinity.edu`. WWW: `http://www.imat.ufro.cl/ICDEA2T/`.

*10–14 **MSRI Workshop on Combinatorial Algebra**, MSRI, Berkeley, California.

**Topics**: As part of the yearlong program in Noncommutative Algebra, MSRI will host a one-week workshop on Combinatorial Algebra, January 10–14, 2000.

The term "Combinatorial Algebra" comes from Combinatorial Group Theory, which traditionally focuses on such topics as (1) groups presented by generators and relators, (2) growth in groups, (3) The Burnside Problem, and (4) computational and algorithmic aspects. The conference will be concerned with these topics in the context of Lie algebras and related groups. More specifically, we will consider:

- Lie algebras and superalgebras of finite Gelfand-Kirillov dimension and their relations with conformal, vertex, and superconformal algebras;
- pro-p and prounipotent groups of finite width;
- problems related to The Restricted Burnside Problem;

• probabilistic aspects of Group Theory; and
• computational and algorithmic problems. This part of the program will greatly benefit from the presence of specialists in noncommutative algebraic geometry and in Hopf algebras.
**Financial Support**: A limited amount of funding is available for partial support of people wishing to attend. Students, recent Ph.D.'s, women, and minorities are particularly encouraged to apply. To apply for funding, send a letter explaining your interest in the workshop together with a vita or bibliography and a budget for travel/living expenses. If you are a student, also solicit a letter from a faculty advisor. All information should be received by October 11, 1999.
**Information**: Send mail to combalg@msri.org, or visit http://www.msri.org/.

17-21 **International Conference on Mathematical Analysis and its Applications, 2000 (ICMAA2000)**, National Sun Yat-sen University, Kaohsiung 804, Taiwan, R.O.C. (Jan. 1999, p. 71)

*17-22 **Workshop on Computational Stochastics**, University of Aarhus, Denmark.
**Topics**: Computational stochastics is a new and expanding area of stochastics, dealing with computational methods of analyzing complex mathematical and statistical models. The workshop intends to reveal and discuss the potential strength and impact of this new discipline in a variety of applications.
**Organizers**: S. Asmussen (Lund) and E. B. Vedel Jensen (Aarhus).
**Invited Speakers**: A. Baddeley (Perth): Conditional simulation; P. Donnelly (Oxford): Computational inference in genetics; I. Dryden (Leeds): Stochastic deformation; P. Glynn (Stanford): Simulation methodology in applied probability; O. Mouritsen (DTU, Copenhagen): The third science—the computer experiment; W. Stewart (Raleigh, NC): Numerical methods for Markov chains.
**Deadline**: Submission of contributed papers: before October 1, 1999. Registration: before November 15, 1999.
**Information**: The workshop Web page can be found at: http://www.maphysto.dk/events/CompStoc2000/. From there it is also possible to register.

19-22 **Joint Mathematics Meeting**, Sheraton Washington Hotel & Omni Shoreham Hotel, Washington, District of Columbia. (Sept. 1997, p. 1031)

21-22 **1999-2000 ASL Winter Meeting**, Washington, DC. (Jan. 1999, p. 72)

26-30 **IMA Workshop: Confinement and Remediation of Environmental Hazards**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 596)

## February 2000

*7-11 **MSRI Workshop on The Mathematics of Quantum Computation**, MSRI, Berkeley, California.
**Topics**: In the past years, quantum computation has emerged as the "presumptive model" among proposals of new paradigms for computing. Quantum computing seems to provide a model for the computational capacity of any physically plausible finite-dimensional quantum mechanical system, including the modular functors of topological field theories. According to the philosophy of renormalization we might expect BQP to effectively model any computation that could be effected even in an infinite-dimensional field theory. Quantum computing is still a very young field, and our understanding of its power compared to other models of computational complexity is still very preliminary, the most notable success being Shor's factoring algorithm.
**Goal**: The goal of this workshop is to focus on the more mathematical aspects of quantum computation to bring the central challenges of quantum computation to the attention of mathematicians. The workshop will discuss many mathematical and physical topics impinging on quantum computing and quantum information theory, ranging from topology to representation theory to statistical physics. The workshop will be organized around a sequence of expository talks by experts in the area.
**Prospective Speakers**: I. Chuang (IBM Almaden), M. Freedman (Microsoft Research), R. Jozsa (Plymouth Univ., England), P. Shor (Bell Laboratories), U. Vazirani (U.C. Berkeley), N. Wallach (U.C. San Diego), A. Yao (Princeton Univ.).
**Information**: Send email to qcomputing@msri.org, or visit http://www.msri.org/.

9-13 **IMA Workshop: Resource Recovery**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 596)

*14-25 **MSRI Workshop on the Interactions between Algebraic Geometry and Noncommutative Algebra**, MSRI, Berkeley, California.
**Topics**: As part of the yearlong program in Noncommutative Algebra, MSRI will host a two-week workshop on Interactions between Algebraic Geometry and Noncommutative Algebra, February 14-25, 2000. In recent years there have been a number of important applications of techniques and ideas from algebraic geometry to noncommutative algebra, and the aim of this conference will be to examine these applications and their interactions. Among the areas of concentration with which the conference will be concerned are the following topics and their interactions:
• noncommutative projective algebraic geometry and the study of noncommutative graded algebras;
• geometric aspects of algebraic quantum groups, derived categories and quantization;
• geometric aspects of the representation theory of quivers; and
• rings of differential operators and invariant theory.
**Financial Support**: A limited amount of funding is available for partial support of people wishing to attend. Students, recent Ph.D.'s, women, and minorities are particularly encouraged to apply. To apply for funding, send a letter explaining your interest in the workshop together with a vita or bibliography and a budget for travel/living expenses. If you are a student, also solicit a letter from a faculty advisor. All information should be received by November 15, 1999.
**Information**: Send mail to interact@msri.org, or visit http://www.msri.org/.

20-22 **International Conference on Stochastic Optimization: Algorithms and Applications**, University of Florida, Center for Applied Optimization, Gainesville, Florida. (Jan. 1999, p. 72)

## March 2000

6-17 **Homogenization and Effective Media Theories**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 1998, p. 1053)

15-19 **IMA Workshop: Air Quality Engineering**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 596)

16-18 **Seminar on Stochastic Processes, 2000**, The University of Utah, Salt Lake City, Utah. (Feb. 1999, p. 278)

20-31 **Superconvergence in Finite Element Methods**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 1998, p. 1053)

## April 2000

1-2 **AMS Eastern Section Meeting**, University of Massachusetts, Lowell, Massachusetts. (Nov. 1998, p. 1378)

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.

*9-16 **The Klee-Grunbaum Festival of Geometry**, Ein Gev, Israel.
**Focus**: The festival will deal with various aspects of the theory of convexity in Euclidean spaces of a discrete, applied, combinatorial, and computational nature.
**Information**: Information can be obtained from the organizer: J. Zaks, Dept. of Mathematics, Univ. of Haifa, Haifa, Israel 31905; e-mail: jzaks@math.haifa.ac.il.

14-16 **AMS Southeastern Section Meeting**, University of Southwestern Louisiana, Lafayette, Louisiana. (Mar. 1999, p. 380)

16-19 **FRACTAL 2000: "Complexity and Fractals in the Sciences", 6th International Multidisciplinary Conference**, Singapore. (May 1999, p. 596)

17-28 **Elastic Shells: Modeling, Analysis**

**and Numerics**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 1998, p. 1054)

## May 2000

1-5 **IMA Workshop: Dispersive Corrections to Transport Equations**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 596)

*10-12 **ICNPAA-2000, Third International Conference on Nonlinear Problems in Aviation and Aerospace (Methods and Software)**, Daytona Beach, Florida.

**Sponsors**: IFNA, IFIP, IEEE, AAII, AICL.

**Topics**: Conference sponsors seek a spectrum of theoretical, computational, and experimental inquiries concerned with: aeroacoustics, adaptive and smart structures, aerodynamics, computational fluid dynamics, air traffic control design, nonlinear filtering, artificial intelligence, aviation management, atmospheric dynamics, atmospheric sciences, atmospheric flight mechanics, computational structures, propulsion and combustion, human factors modeling, multidisciplinary design, navigation, guidance, stability and control, nonlinear system modeling and chaos, neural networks, neural, fuzzy control, numerical simulation, parallel computing, cryptography and computer security, high-performance computing, pattern recognition, image processing, virtual reality, optimization, reliability, validation and verification. Topics concerned with linear problems are also welcome.

**Advisory Committee**: K. T. Alfriend (USA), A. V. Balakrishnan (USA), P. Borne (France), E. A. Fedosov (Russia), P. Friedman (USA), N. Goto (Japan), L. Gruyitch (France), I. D. Jacobson (USA), S. Joshi (USA), D. Lainiotis (USA), V. Lakshmikantham (USA), J. L. Lions (France), V. Matrosov (Russia), A. Miele (USA), V. Modi (Canada), Y. Y. Nie (China), K. Ninomiya (Japan), S. Sivasundaram (USA), S. Sliwa (USA), K. Tsuchiya (Japan), S. N. Vassilyev (Russia), M. Vidyasagar (India), A. Zelweeger (USA).

**Special Events**: Trips to Kennedy Space Center, Disney World, EPCOT Center, and Universal Studios will be offered, as well as a dinner boat cruise and greyhound racing.

**Deadlines**: For organizing sessions: October 15, 1999; abstracts: January 15, 2000.

**Information**: Conference chairman: S. Sivasundaram, Dept. of Computing and Math., Embry-Riddle Aeronautical Univ., Daytona Beach, FL 32114; e-mail: `siva@db.erau.edu`; fax: 904-226-7050; Web: `http://erau.db.erau.edu/~siva/conference.html`.

17-20 **Trends in Approximation Theory, An International Symposium Celebrating the 60th Birthday of Larry L. Schumaker, held in conjunction with the 15th Annual Shanks Lecture**, Vanderbilt University, Nashville, Tennessee. (May 1999, p. 596)

18-19 **IMA Tutorial: Simulation of Transport in Transition Regimes**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 597)

*18-21 **Year 2000 International Conference on Dynamical Systems and Differential Equations**, Kennesaw State University, Kennesaw, Georgia.

**Program**: The conference will consist of plenary one-hour lectures, 30-minute lectures in special sessions, and 20-minute lectures in contributed sessions.

**Topics**: Papers may address a broad range of research areas of current interest in the fields of differential equations and dynamical systems relevant to theory or applications.

**Invited Plenary Speakers**: (* indicates tentativeness) J. Bona, H. Brezis*, G. Buttazzo, C. Y. Chan*, F. Lin, R. Temam.

**Organizing Committee**: R. Biggers, M. Burke, J. Du, S. Ellermeyer, P. Laval, S. Sims, T. Straley, V. Watson.

**Scientific Committe**: S. Hu (chair).

**Participation**: To present a talk, you need to submit an abstract, full mailing and e-mail addresses, along with phone and fax numbers (if available) before the deadline.

**Proceedings**: The proceedings will be published. All papers will be reviewed for their acceptance.

**Deadlines**: Abstract: February 15, 2000. Pre-registration by March 15, 2000: US$100 (Students: $50); registration after March 15, 2000: US$120 (Students: $60). Banquet will cost US$20, for which payment must be received by May 1, 2000.

**Funding**: A proposal will be submitted to the National Science Foundation for funds to assist graduate students and young researchers.

**Information**: J. Du, Dept. of Math, Kennesaw State Univ., Kennesaw, GA 30144; fax: 770-423-6629; tel: 770-423-6669; e-mail: `jdu@ksumail.kennesaw.edu`; Web address: `http://science.kennesaw.edu/math/y2kdsde/`; or S. Hu at `http://math.smsu.edu/~hu`, e-mail: `shh209f@mail.smsu.edu`.

21-26 **Millennial Conference on Number Theory**, University of Illinois, Urbana, Illinois. (May 1999, p. 597)

22-26 **IMA Workshop: Simulation of Transport in Transition Regimes**, IMA, University of Minnesota, Minneapolis, Minnesota. (May 1999, p. 597)

*23-27 **Summer Symposium in Real Analysis XXIV**, University of North Texas, Denton, Texas.

**Organizers**: P. Humke and D. Mauldin.

**Speakers**: Main speakers to be announced shortly.

*28-June 2 **Nonlinear Analysis, 2000**, Courant Institute, New York, New York.

**Organizing Committee**: Y. Guo (Brown Univ.), B. Jerrard (Univ. of Illinois), T. Kriecherbauer (L. M. Univ. Munich), N. J. Mauser (Univ. Vienna), M. Pugh (Univ. of Pennsylvania).

**Focus**: This conference is dedicated to the state of the art in nonlinear analysis and its applications, with emphasis on differential equations. Applications will include materials science, earth science, biology, finance, and scientific computing.

**Goal**: Our goal is to bring together the rising generation of scientists from all over the world; to let them highlight a sample of their work, meet each other, and talk science. Senior scientists are welcome to attend, space permitting.

**Presentations**: All 60-70 talks will be short presentations by promising junior scientists. In addition there will be open discussion sessions and small working groups to discuss topics and approaches in more detail.

**Information**: N. J. Mauser, e-mail: `mauser@courant.nyu.edu`.

*29-June 9 **Foliations: Geometry and Dynamics Revisited**, Banach Center, Warsaw, Poland.

**Purpose**: Exchange of scientific information among specialists in the theory of foliation and related topics, in particular in the area of relations between this theory, differential geometry, dynamical systems, and ergodic theory.

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

## June 2000

*12-15 **Integral Methods in Science and Engineering (IMSE2000)**, Banff Conference Centre, Banff, Alberta, Canada.

**Topics**: Participation is open to all scientists and engineers whose work makes use of analytic and numerical methods, integral equations, ordinary and partial differential equations, finite element methods, conservation laws, hybrid approaches, vortex methods, etc.

**Hosted By**: Department of Mechanical Engineering, University of Alberta, Edmonton, Alberta, Canada.

**Information**: For further information and/or to be added to a mailing list, contact: P. Schiavone, Department of Mechanical Engineering, University of Alberta, 4-9 Mechanical Engineering Building, Edmonton, Alberta, T6G 2G8 Canada; e-mail: `P.Schiavone@ualberta.ca`; tel: 780-492-3638; fax: 780-492-2200; Web: `http://www.mece.ualberta.ca/IMSE2000/`.

*18-21 **MCS 2000 International Conference on Monte Carlo Simulation**, Monte Carlo, Monaco.

**Organizers**: W. Kliemann (Iowa State Univ., Iowa), G. I. Schuëller (Leopold Franzens Univ., Austria), and P. D. Spanos (Rice Univ., Texas).

**Purpose**: The International Conference on Monte Carlo Simulation will serve as a forum for discussion for engineers, mathematicians, and other professionals who are interested in the theoretical and practical aspects of Monte Carlo Simulation. It will provide a unique opportunity for exchanging ideas on the status of MSC procedures as they are applied to a broad spectrum of problems of a theoretical and applied nature.

**Topics**: The conference theme includes: algorithms for random number generation; methods for solutions (spectral simulation, direct solutions of stochastic differential equations, numerics of partial differential equations, etc.); practical engineering applications.

**Deadlines**: December 15, 1999: Abstracts of about 300 words to be sent via e-mail to mechanik@uibk.ac.at; January 15, 2000: Notification of accepted papers; March 31, 2000: Draft papers due; June 18, 2000: Final papers due. The authors will have the option of requesting review of their papers for publication in the *Journal of Probabilistic Engineering Mechanics.*

**Information**: See the conference Web page at http://www.uibk.ac.at/c/c8/c810/conf/mcs_2000.html.

**Sponsor**: The conference is sponsored by The International Association for Structural Safety and Reliability (IASSAR).

## July 2000

*3-7 **Sixth International Conference on p-Adic Analysis,** Ioannina, Greece.

**Topic**: (Functional) analysis over valued fields other than R or C.

**Scientific Committee**: A. Katsaras (Ioannina, Greece), W. Schikhof (Nijmegen, Netherlands), L. Van Hamme (Brussels, Belgium).

**Participants**: (preliminary) J. Aguayo (Chile), J. Bayod (Spain), E. Beckenstein (USA), J. Araujo (Spain), A. Boutabaa (France), G. Christol (France), S. Caenepeel (Belgium), B. Dragovich (Yugoslavia), B. Diarra (France), M. Endo (Japan), A. Escassut (France), T. Gilsdorf (USA), G. Ren (USA), N. De Grande-de Kimpe (Belgium), L. Haddad (France), A. Katsaras (Greece), A. Kubzdela (Poland), T. Kiyosawa (Japan), A. Khrennikov (Sweden), J. Kakol (Poland), A. Kochubei (Ukraine), N. Mainetti (France), L. Narici (USA), P. N. Natarajan (India), S. Navarro (Chile), H. Ochsenius (Chile), C. Perez-Garcia (Spain), J. Prolla (Brazil), A. M. Robert (Switzerland), G. Rangan (India), H. Reichel (Austria), M. Sarmant (France), S. Yamada (Japan), W. Schikhof (Netherlands), A. van Rooij (Netherlands), S. Vega (Spain), L. Van Hamme (Belgium), F. Woodcock (England), V. Vladimirov (Russia), K. Boussaf (France), V. Srinivasan (USA).

**Information**: A. K. Katsaras, Dept. of Mathematics, Univ. of Ioannina, 45110 Ioannina, Greece; e-mail: akatsar@cc.uoi.gr.

*9-15 **AGRAM Conference on Abelian Groups, Rings and Modules,** The University of Western Australia, Perth, Australia.

**Sponsors**: Aust. Math. Soc. and Dept. of Mathematics, UWA.

**Scientific Committee**: L. Fuchs (Tulane), R. Goebel (Essen), K. Rangaswamy (Univ. of Colorado), C. Vinsonhaler (Univ. of Conn).

**Focus**: The AGRAM Conference is an international conference on Abelian groups, rings, and modules with speakers from Australasia, the USA, Eastern and Western Europe, Central and South America. It will provide an opportunity for young researchers working in those fields to make scholarly contact with internationally renowned experts.

**Information**: Contact P. Schultz, Department of Mathematics, UWA, Nedlands, 6009, Australia; e-mail: schultz@maths.uwa.edu.au; Web: http://WWW/Staff/schultz/AGRAM.html.

*17-22 **I Colloquium on Lie Theory and Applications,** E.T.S.I. Telecomunicaciones, Vigo, Spain.

**Aim**: The colloquium will be devoted to all aspects of Lie theory.

**Scientific Program**: The scientific program includes three courses of 3 hours each, delivered by D. V. Alekseevsky, A. T. Fomenko, and M. Scheunert; eleven invited lectures; and several short communications (of 15 minutes each).

**Invited Speakers**: The remaining invited speakers are the following: S. Benayadi, M. Bordemann, V. Cortes, A. Gonzalez-Lopez, Y. B. Hakimjanov, E. Koelink, M. de Leon, E. Macias-Virgos, A. Medina, C. Moreno, K.-H. Neeb.

**Information**: Further information and a preregistration form may be obtained from the Web page of the colloquium: http://www.dma.uvigo.es/~clieta/index/ or directly from the organizing committee: Organizing Committee, I Colloquium on Lie Theory and Applications, E.T.S.I. Telecomunicaciones, Universidad de Vigo, 36280 Vigo, Spain; e-mail: clieta@dma.uvigo.es.

*31-August 3 **Third Conference of Balkan Society of Geometers,** Univ. Politehnica of Bucharest, Bucharest, Romania.

**Scientific Program**: Includes 30-minute lectures and 15-minute papers. Selected papers will be published in BJGA.

**Topics**: Riemannian geometry, symplectic geometry, submanifolds theory, Chen invariants, harmonic maps, spectral geometry, Finsler-Lagrange-Hamilton geometry, geometry of PDE's, critical point theory and its applications, convexity and optimization on Riemannian manifolds, electromagnetic dynamical systems, numerical integrator of dynamical systems.

**Program Committee**: M. Anastasiei (Romania), D. Andrica (Romania), P. Antonelli (Canada), Gh. Atanasiu (Romania), D. Blair (USA), N. Blazic (Yugoslavia), W. Boskoff (Romania), K. Buchner (Germany), B. Y. Chen (USA), V. Cruceanu (Romania), J. Dorfmeister (USA), D. Hrimiuc (Canada), S. Ianuş (Romania), L. Nicolescu (Romania), D. Opriş (Romania), D. Papuc (Romania), Gh. Pitiş (Romania), P. Popescu (Romania), M. Puta (Romania), H. Shimada (Japan), P. Stavrinos (Greece), L. Tamassy (Hungary), K. Trencevski (Macedonia), I. Vaisman (Israel), L. Vanhecke (Belgium), E. Vassiliou (Greece), L. Verstraelen (Belgium), B. Wegner (Germany).

**Deadline**: May 15, 2000.

**Fee**: $30.

**Organizer**: C. Udriste, Univ. Politehnica of Bucharest, Department Mathematics I, Splaiul Independentei 313, 77206 Bucharest, Romania; fax: 401-411.53.65; e-mail: udriste@mathem.pub.ro.

## August 2000

*22-24 **The Fifth Iranian Statistics Conference,** Isfahan University of Technology, Isfahan, Iran.

**Sponsors**: This conference is jointly sponsored by the Iranian Statistical Society.

**Program**: The program includes invited and contributed talks in the areas of theory and applications of statistics and probability, short introductory sessions on current popular fields in statistics, sessions on promoting statistical culture in the society, and sessions on statistical education.

**Support**: A number of grants are available to those presenting papers from abroad. The grants will cover local hotel and meal expenses.

**Information**: Contact Fifth Iranian Statistics Conference, School of Mathematical Sciences, Isfahan Univ. of Technology, Isfahan 84156, Iran; tel: 98 31 8912600; fax: 98 31 8912602; e-mail: ISC5@cc.iut.ac.ir; Web sites: http://www.iut.ac.ir/math/isc5.htm or http://pegasus.cc.ucf.edu/~iss/.

# New Publications Offered by the AMS

## *New Series from the AMS!*

The AMS is pleased to announce the *Student Mathematical Library*, a new series of undergraduate studies in mathematics. By emphasizing original topics and approaches, the series aims to broaden students' mathematical experiences. We hope the books will spark undergraduates' appreciation for research mathematics by introducing them to interesting, accessible topics of modern mathematics. The books published in the series are suitable for honors courses, upper-division seminars, reading courses or self-study.

Advance Notice

Recommended Text

### An Introduction to the Mathematical Theory of Waves

**Roger A. Knobel**, *University of Texas-Pan American, Edinburg*

This book is based on an undergraduate course taught at the IAS/Park City Mathematics Institute, on linear and nonlinear waves. The first part of the text overviews the concept of a wave, describes one-dimensional waves using functions of two variables, provides an introduction to partial differential equations, and discusses computer-aided visualization techniques.

The second part of the book discusses traveling waves, leading to a description of solitary waves and soliton solutions of the Klein-Gordon and Korteweg-deVries equations. The wave equation is derived to model the small vibrations of a taut string, and solutions are constructed via d'Alembert's formula and Fourier series.

The last part of the book discusses waves arising from conservation laws. After deriving and discussing the scalar conservation law, its solution is described using the method of characteristics, leading to the formation of shock and rarefaction waves. Applications of these concepts are then given for models of traffic flow.

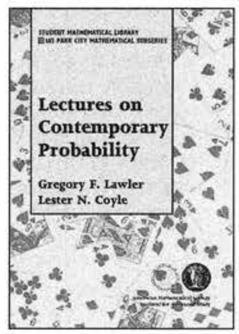
The intent of this book is to create a text suitable for independent study by undergraduate students in mathematics, engineering, and science. The content of the book is meant to be self-contained, requiring no special reference material. Access to computer software such as Mathematica®, MATLAB®, or Maple® is recommended, but not necessary. Scripts for MATLAB applications will be available via a Web site. Exercises are given within the text to allow further practice with selected topics.

® Wolfram Research, Inc., Champaign IL.
® The Math Works, Inc., Natick, MA.
® Waterloo Maple, Inc., Ontario, Canada.

**Student Mathematical Library**

October 1999 (estimated), approximately 200 pages, Softcover, ISBN 0-8218-2039-7, **All AMS members $18**, List $23, Order code STML-KNOBELN

Recommended Text




### Lectures on Contemporary Probability

**Gregory F. Lawler**, *Duke University, Durham, NC*, and **Lester N. Coyle**, *Loyola College, Baltimore, MD*

This volume is based on classes in probability for advanced undergraduates held at the IAS/Park City Mathematics Institute. It is derived from both lectures (Chapters 1-10) and computer simulations (Chapters 11-13) that were held during the program. The material is coordinated so that some of the major computer simulations relate to topics covered in the first ten chapters. The goal is to present topics that are accessible to advanced undergraduates, yet are areas of current research in probability. The combination of the lucid yet informal style of the lectures and the hands-on nature of the simulations allows readers to become familiar with some interesting and active areas of probability.

The first four chapters discuss random walks and the continuous limit of random walks: Brownian motion. Chapters 5 and 6 consider the fascinating mathematics of card shuffles, including the notions of random walks on a symmetric group and the general idea of random permutations.

Chapters 7 and 8 discuss Markov chains, beginning with a standard introduction to the theory. Chapter 8 addresses the recent important application of Markov chains to simulations of random systems on large finite sets: Markov Chain Monte Carlo.

Random walks and electrical networks are covered in Chapter 9. Uniform spanning trees, as connected to probability and random walks, are treated in Chapter 10.

The final three chapters of the book present simulations. Chapter 11 discusses simulations for random walks. Chapter 12 covers simulation topics such as sampling from continuous distributions, random permutations, and estimating the number of matrices with certain conditions using Markov Chain Monte Carlo. Chapter 13 presents simulations of stochastic differential equations for applications in finance.

(The simulations do not require one particular piece of software. They can be done in symbolic computation packages or via programming languages such as C.)

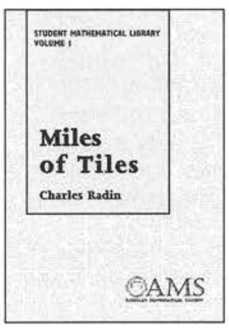
The volume concludes with a number of problems ranging from routine to very difficult. Of particular note are problems that are typical of simulation problems given to students by the authors when teaching undergraduate probability.

**Contents:** Simple random walk and Stirling's formula; Simple ramdon walk in many dimensions; Self-avoiding walk; Brownian motion; Shuffling and random permutations; Seven shuffles are enough (sort of); Markov chains on finite sets; Markov chain Monte Carlo; Random walks and electrical networks; Uniform spanning trees; Random walk simulations; Other simulations; Simulations in finance; Problems; Bibliography.

**Student Mathematical Library**

August 1999, approximately 120 pages, Softcover, ISBN 0-8218-2029-X, 1991 *Mathematics Subject Classification*: 60-02; 60J10, 60J15, 65C05, **All AMS members $14**, List $17, Order code STML-LAWLERN

Supplementary Reading




## Miles of Tiles

**Charles Radin**, *University of Texas, Austin*

*In this book, we try to display the value (and joy!) of starting from a mathematically amorphous problem and combining ideas from diverse sources to produce new and significant mathematics—mathematics unforeseen from the motivating problem...*

***—from the* Preface**

The common thread throughout this book is aperiodic tilings; the best-known example is the "kite and dart" tiling. This tiling has been widely discussed, particularly since 1984 when it was adopted to model quasicrystals. The presentation uses many different areas of mathematics and physics to analyze the new features of such tilings. Although many people are aware of the existence of aperiodic tilings, and maybe even their origin in a question in logic, not everyone is familiar with their subtleties and the underlying rich mathematical theory. For the interested reader, this book fills that gap.

Understanding this new type of tiling requires an unusual variety of specialties, including ergodic theory, functional analysis, group theory and ring theory from mathematics, and statistical mechanics and wave diffraction from physics. This interdisciplinary approach also leads to new mathematics seemingly unrelated to the tilings. Included are many worked examples and a large number of figures. The book's multidisciplinary approach and extensive use of illustrations make it useful for a broad mathematical audience.

**Contents:** Ergodic theory; Physics (for mathematicians); Order; Symmetry; Conclusion; Geometry; Algebra; Analysis; List of symbols; Index; References.

**Student Mathematical Library,** Volume 1

July 1999, approximately 128 pages, Softcover, ISBN 0-8218-1933-X, LC 99-20662, 1991 *Mathematics Subject Classification*: 52C22; 58F11, 47A35, 82D25, 20H15, **All AMS members $13**, List $16, Order code STML/1N

Advance Notice

Independent Study

## Prime Numbers and Their Distribution

**Gérald Tenenbaum**, *Université Henri Poincaré, Nancy I, France*, and **Michel Mendès France**, *Université Bordeaux I, France*

**From a review for the French edition ...**

*This is a short introductory book on analytic number theory. The prerequisites are quite modest, but it still contains an impressive amount of information. A multitude of results is included, some of which were proved just recently ... this book is very well written. It is fun to read and at the same time presents most of the fundamental concepts and ideas in analytic number theory.*

***—Mathematical Reviews***

*The reviewer recommends it to all interested readers.*

***—Zentralblatt für Mathematik***

We have been curious about numbers—and prime numbers—since antiquity. One notable new direction this century in the study of primes has been the influx of ideas from probability. The goal of this book is to provide insights into the prime numbers and to describe how a sequence so tautly determined can incorporate such a striking amount of randomness.

There are two ways in which the book is exceptional. First, some familiar topics are covered with refreshing insight and/or from new points of view. Second, interesting recent developments and ideas are presented that shed new light on the prime numbers and their distribution among the rest of the integers.

The book begins with a chapter covering some classic topics, such as quadratic residues and the Sieve of Eratosthenes. Also discussed are other sieves, primes in cryptography, twin primes, and more.

Two separate chapters address the Riemann zeta function and its connections to number theory. In the first chapter, the familiar link between $\zeta(s)$ and the distribution of primes is covered with remarkable efficiency and intuition. The second chapter presents a walk through an elementary proof of the Prime Number Theorem. To help the novice understand the "'why" of the proof, connections are made along the way with more familiar results such as Stirling's formula.

A most distinctive chapter covers the stochastic properties of prime numbers. The authors present a wonderfully clever interpretation of primes in arithmetic progressions as a phenomenon in probability. They also describe Cramér's model, which provides a probabilistic intuition for formulating conjectures that have a habit of being true. In this context, they address interesting questions about equipartition modulo 1 for sequences involving prime numbers. The final section of the chapter compares geometric visualizations of random sequences with the visualizations for similar sequences derived from the primes. The resulting pictures are striking and illuminating. The book concludes with a chapter on the outstanding big conjectures about prime numbers.

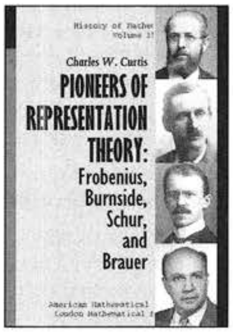
This book is suitable for anyone who has had a little number theory and some advanced calculus involving estimates. Its engaging style and invigorating point of view will make refreshing reading for advanced undergraduates through research mathematicians. This book is the English translation of the French edition.

**Student Mathematical Library**

December 1999 (estimated), approximately 120 pages, Softcover, ISBN 0-8218-1647-0, **All AMS members $14**, List $17, Order code STML-TENENBAUN

# Algebra and Algebraic Geometry

Recommended Text




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

**Charles W. Curtis**, *University of Oregon, Eugene*

The year 1897 was marked by two important mathematical events: the publication of the first paper on representations of finite groups by Ferdinand Georg Frobenius (1849–1917) and the appearance of the first treatise in English on the theory of finite groups by William Burnside (1852–1927). Burnside soon developed his own approach to representations of finite groups. In the next few years, working independently, Frobenius and Burnside explored the new subject and its applications to finite group theory.

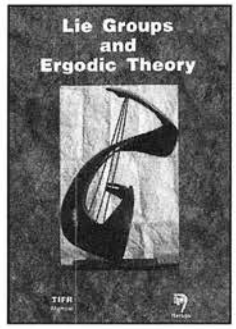
They were soon joined in this enterprise by Issai Schur (1875–1941) and some years later, by Richard Brauer (1901–1977). These mathematicians' pioneering research is the subject of this book. It presents an account of the early history of representation theory through an analysis of the published work of the principals and others with whom the principals' work was interwoven. Also included are biographical sketches and enough mathematics to enable readers to follow the development of the subject. An introductory chapter contains some of the results involving characters of finite abelian groups by Lagrange, Gauss, and Dirichlet, which were part of the mathematical tradition from which Frobenius drew his inspiration.

This book presents the early history of an active branch of mathematics. It includes enough detail to enable readers to learn the mathematics along with the history. The volume would be a suitable text for a course on representations of finite groups, particularly one emphasizing an historical point of view.

**Contents:** Some 19th-century algebra and number theory; Frobenius and the invention of character theory; Burnside: Representations and structure of finite groups; Schur: A new beginning; Polynomial representations of $GL_n(\mathbb{C})$; Richard Brauer and Emmy Noether: 1926-1933; Modular representation theory; Bibliography; Index.

**History of Mathematics,** Volume 15

August 1999, approximately 319 pages, Hardcover, ISBN 0-8218-9002-6, LC 99-14983, 1991 *Mathematics Subject Classification*: 01A55, 01A60, 20C15, 20C20; 01A70, 16G10, 20G05, **All AMS members $39**, List $49, Order code HMATH/15N




## Lie Groups and Ergodic Theory

**S. G. Dani**, *Tata Institute of Fundamental Research, Mumbai, India*, Editor

***A publication of Tata Institute of Fundamental Research.***

This volume presents the proceedings from an international colloquium on Lie groups and ergodic theory held at the Tata Institute of Fundamental Research (TIFR) in Mumbai, India. Designated a *Golden Jubilee* event at the Institute, this was one of the quadrennial colloquia of the School of Mathematics.

There were 24 talks given by participants in Lie groups, ergodic theory and related fields. Leading mathematicians from around the world attended. Recent developments were presented and a session was devoted to discussion and problems for future research.

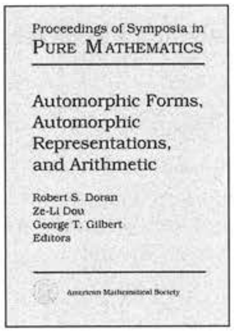
This item will also be of interest to those working in analysis.

Distributed worldwide except in India and neighboring countries.

**Contents: M. Babillot** and **F. Ledrappier**, Geodesic paths and horocycle flow on Abelian covers; **J. R. Choksi** and **M. G. Nadkarni**, On the question of transformations with simple Lebesgue spectrum; **S. G. Dani** and **C. R. E. Raja**, Asymptotics of measures under group automorphisms and an application to factor sets; **A. Eskin** and **B. Farb**, Quasi-flats in $\mathbb{H}^2 \times \mathbb{H}^2$; **H. Furstenberg**, Stiffness of group actions; **D. Y. Kleinbock**, Bounded orbits conjecture and diophantine approximation; **A. Lubotzky** and **R. J. Zimmer**, A canonical arithmetic quotient for simple Lie group actions; **S. Mozes**, On the congruence subgroup problem for tree lattices; **H. Oh**, Arithmetic properties of some Zariski dense discrete subgroups; **M. Ratner**, On the $p$-adic and $S$-arithmetic generalizations of Raghunathan's conjectures; **K. Schmidt**, On the cohomology of algebraic $\mathbb{Z}^d$-actions with values in compact Lie groups; **N. A. Shah**, Invariant measures and orbit closures on homogeneous spaces; **Y. Shalom**, Random ergodic theorems, invariant means and unitary representation; **G. A. Soifer**, Structure of infinite index maximal subgroups of $SL_n(Z)$; **A. N. Starkov**, Dynamics of non-unipotent homogeneous flows; **W. A. Veech**, Geometric realizations of hyperelliptic curves, II; **D. Witte**, Cocycle superrigidity for ergodic actions of non-semisimple Lie groups.

**Tata Institute of Fundamental Research**

December 1998, 386 pages, Hardcover, ISBN 81-7319-235-9, 1991 *Mathematics Subject Classification*: 22-06, 28Dxx; 22D40, 58F11, **All AMS members $32**, List $40, Order code TIFR/1N




## Automorphic Forms, Automorphic Representations, and Arithmetic

**Robert S. Doran, Ze-Li Dou,** and **George T. Gilbert,** *Texas Christian University, Fort Worth,* Editors

Professor Goro Shimura was principal speaker at the conference on "Euler Products and Eisenstein Series" held at Texas Christian University (See *CBMS Regional Conference Series in Mathematics,* Volume 93). The present volume contains articles by leading specialists in the field. Some of these articles are based on talks given at the conference, whereas others were written purposely for this volume. The variety of the work presented reflects the current active state of the topic.

**Contents: D. Blasius** and **M. Borovoi**, On period torsors; **A. W. Bluher**, Near holomorphy, arithmeticity, and the theta correspondence; **R. Coleman**, **B. Kaskel**, and **K. A. Ribet**, Torsion points on $X_0(N)$; **P. Feit**, A fundamental group for symbolic dynamics. I: Definitions; **E. Ghate**, Critical values of twisted tensor $L$-functions over CM-fields; **D. Goldfeld**, Zeta functions formed with modular symbols; **H. Hida**, Non-critical values of adjoint $L$-functions for SL(2); **M. R. Murty**, Bounds for congruence primes; **V. K. Murty**, Frobenius distributions and Galois representations; **K. Rubin** and **A. Silverberg**, Mod 6 representations of elliptic curves; **H. Yoshida**, On absolute CM-periods; **D. Bump** and **S. Friedberg**, Metaplectic generating functions and Shimura integrals; **B. Casselman**, On the Plancherel measure for the continuous spectrum of the modular group; **D. Farmer**, **J. Hoffstein**, and **D. Lieman**, Average values of cubic $L$-series; **P. Garrett**, Euler factorization of global integrals; **M. Harris**, Cohomological automorphic forms on unitary groups. I: Rationality of the theta correspondence; **B. E. Heim**, Pullbacks of Eisenstein series, Hecke-Jacobi theory and automorphic $L$-functions; **J. Hoffstein** and **P. Lockhart**, Omega results for automorphic $L$-functions; **K. Khuri-Makdisi**, Representations of SL(2) x $G$; **J. Levy**, Truncated integrals and the Shintani zeta function for the space of binary quartic forms; **W. Luo**, **Z. Rudnick**, and **P. Sarnak**, On the generalized Ramanujan conjecture for GL($n$); **D. Prasad** and **D. Ramakrishnan**, On the global root numbers of GL(n) x GL(m).

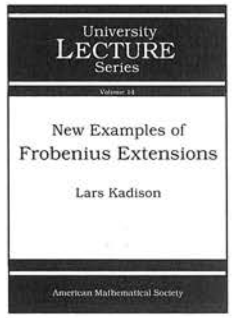
**Proceedings of Symposia in Pure Mathematics**, Volume 66

***Part 1***: July 1999, 278 pages, Hardcover, ISBN 0-8218-1050-2, LC 99-28916, 1991 *Mathematics Subject Classification*: 11Fxx; 14Gxx, 22Exx, **Individual member $38**, List $63, Institutional member $50, Order code PSPUM/66.1N

***Part 2***: July 1999, 330 pages, Hardcover, ISBN 0-8218-1051-0, LC 99-28916, 1991 *Mathematics Subject Classification*: 11Fxx; 14Gxx, 22Exx, **Individual member $38**, List $64, Institutional member $51, Order code PSPUM/66.2N

***Set***: July 1999, 608 pages, Hardcover, ISBN 0-8218-0659-9, LC 99-28916, 1991 *Mathematics Subject Classification*: 11Fxx; 14Gxx, 22Exx, **Individual member $73**, List $121, Institutional member $97, Order code PSPUM/66N

Supplementary Reading




## New Examples of Frobenius Extensions

**Lars Kadison,** *Göteborg University, Sweden*

This volume is based on the author's lecture courses to algebraists at Munich and at Göteborg. He presents, for the first time in book form, a unified approach from the point of view of Frobenius algebras/extensions to diverse topics, such as Jones' subfactor theory, Hopf algebras and Hopf subalgebras, the Yang-Baxter Equation and 2-dimensional topological quantum field theories.

**Other Features:**

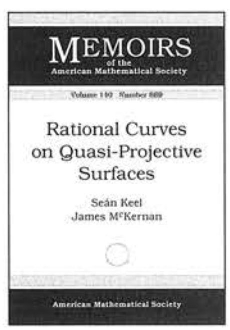
- Initial steps toward a theory of noncommutative ring extensions.
- Self-contained sections on Azumaya algebras and strongly separable algebras.
- Applications and generalizations of Morita theory and Azumaya algebra due to Hirata and Sugano.

Understanding the text requires no prior background in Frobenius algebras or Hopf algebras. An index and a thorough list of further references are included. There is an appendix giving a brief historical guide to the literature.

**Contents:** Introduction to Frobenius extensions; The endomorphism ring theorem; The Jones polynomial; Frobenius algebras; Azumaya algebras; Hopf algebras over commutative rings; Hopf subalgebras; Historical notes; Bibliography; Index.

**University Lecture Series**, Volume 14

June 1999, 84 pages, Softcover, ISBN 0-8218-1962-3, LC 99-25462, 1991 *Mathematics Subject Classification*: 16W30, 16L60, 16H05; 46L37, 57M25, 81R50, 81T40, **All AMS members $18**, List $22, Order code ULECT/14N



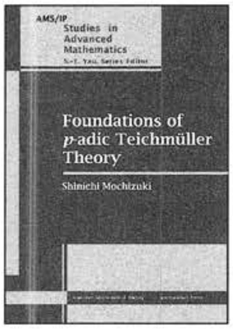

## Rational Curves on Quasi-Projective Surfaces

**Seán Keel,** *University of Texas, Austin,* and **James McKernan,** *University of California, Santa Barbara*

**Contents:** Introduction and statement of results; Glossary of notation and conventions; Gorenstein del Pezzo surfaces; Bug-eyed covers; Log deformation theory; Criteria for log uniruledness; Reduction to $\pi_1^{\mathrm{alg}}(S^0) = \{1\}$; Flushness and preparation for the hunt; Bogomolov bound; Riemann Roch and surfaces with small coefficient; A partial classification of $K_T$-contractions; the linear system $|K_S + A|$; Classification of bananas and fences; $T_1$ a net; $g(A_1) > 1$; $A_1$ has a simple cusp; $A_1$ has a simple node; $A_1$ smooth; The smooth banana; Proof of (1.1) and corollaries; A surface with $\pi_1^{\mathrm{alg}}(S^0) = \{1\}$ but no tiger; Tigers, complements and toric pairs; Classification of almost all rank one log del Pezzos; Appendix: Log terminal surface singularities and adjunction; Appendix: Normalisation of an algebraic space; Index to obscure or unconventional notation; References.

**Memoirs of the American Mathematical Society**, Volume 140, Number 669

May 1999, 153 pages, Softcover, ISBN 0-8218-1096-0, LC 99-14985, 1991 *Mathematics Subject Classification*: 14J26, 14J45, **Individual member $27**, List $45, Institutional member $36, Order code MEMO/140/669N




## Foundations of *p*-adic Teichmüller Theory

**Shinichi Mochizuki**, *Research Institute for the Mathematical Sciences, Kyoto, Japan*

This book lays the foundation for a theory of *uniformization of p-adic hyperbolic curves and their moduli*. On one hand, this theory generalizes the Fuchsian and Bers uniformizations of complex hyperbolic curves and their moduli to nonarchimedian places. That is why in this book, the theory is referred to as *p-adic Teichmüller theory*, for short. On the other hand, the theory may be regarded as a fairly precise hyperbolic analog of the Serre-Tate theory of ordinary abelian varieties and their moduli.

The theory of uniformization of *p*-adic hyperbolic curves and their moduli was initiated in a previous work by Mochizuki. And in some sense, this book is a continuation and generalization of that work. This book aims to bridge the gap between the approach presented and the classical uniformization of a hyperbolic Riemann surface that is studied in undergraduate complex analysis.

**Features:**

- Presents a systematic treatment of the moduli space of curves from the point of view of *p*-adic Galois representations.
- Treats the analog of Serre-Tate theory for hyperbolic curves.
- Develops a *p*-adic analog of Fuchsian and Bers uniformization theories.
- Gives a systematic treatment of a "nonabelian example" of *p*-adic Hodge theory.

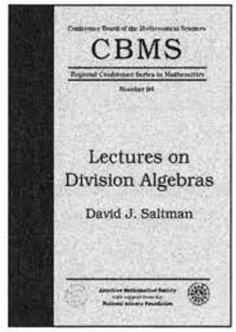
Titles in this series are co-published with International Press, Cambridge, MA.

**Contents:** Introduction; Crys-stable bundles; Torally Crys-stable bundles in positive characteristic; VF-patterns; Construction of examples; Combinatorialization at infinity of the stack of nilcurves; The stack of quasi-analytic self-isogenies; The generalized ordinary theory; The geometrization of binary-ordinary Frobenius liftings; The geometrization of spiked Frobenius liftings; Representations of the fundamental group of the curve; Appendix: Ordinary stable bundles on a curve; Bibliography; Index.

**AMS/IP Studies in Advanced Mathematics**, Volume 11

July 1999, 529 pages, Hardcover, ISBN 0-8218-1190-8, LC 99-26586, 1991 *Mathematics Subject Classification*: 14F30, 14H10, **All AMS members $47**, List $59, Order code AMSIP/11N

Supplementary Reading




## Lectures on Division Algebras

**David J. Saltman**, *University of Texas, Austin*

This volume is based on lectures on division algebras given at a conference held at Colorado State University. Although division algebras are a very classical object, this book presents this "classical" material in a new way, highlighting current approaches and new theorems, and illuminating the connections with a variety of areas in mathematics.

**Contents:** Introduction; A division algebra is a central simple algebra; Azumaya algebras at the generic point; The Brauer group; Form of matrices; Torsion question; Galois extensions; Crossed products and cohomology; Corestriction; Orders and regular domains; Ramification; Specialization and lifting; Lattice methods; Brauer Severi varieties; Generic division algebra; Bibliography.

**CBMS Regional Conference Series in Mathematics**, Number 94

June 1999, 120 pages, Softcover, ISBN 0-8218-0979-2, LC 99-25461, 1991 *Mathematics Subject Classification*: 12E15, 16K20, 13A20; 12G05, 14M99, 13A50, 14D25, **All AMS members $18**, List $22, Order code CBMS/94N

# Analysis


## Function Spaces

**Krzysztof Jarosz**, *Southern Illinois University at Edwardsville*, Editor

This proceedings volume presents 36 papers given by leading experts during the Third Conference on Function Spaces held at Southern Illinois University at Edwardsville. A wide range of topics in the subject area are covered. Most papers are written for nonexperts, so the book can serve as a good introduction to the topic for those interested in this area.

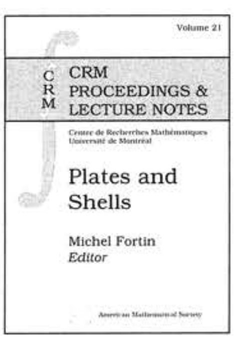
The book presents the following broad range of topics, including spaces and algebras of analytic functions of one and of many variables, $L^p$ spaces, spaces of Banach-valued functions, isometries of function spaces, geometry of Banach spaces and related subjects. Known results, open problems, and new discoveries are featured. At the time of publication, information about the book, the conference, and a list and pictures of contributors are available on the Web at www.siue.edu/MATH/conference.htm.

**Contents:** **M. D. Acosta**, Norm attaining operators in $L_1(\mu)$; **P. Aiena**, The Weyl-Browder spectrum of a multiplier; **J. Akeroyd** and **E. G. Saleeby**, On polynomial approximation in the mean; **J. T. Anderson** and **J. A. Cima**, A uniqueness theorem for normal functions of several complex variables; **J. Araujo** and **K. Jarosz**, Separating maps on spaces of continuous functions; **R. Aron** and **J. Bés**, Hypercyclic differentiation operators; **P. Avramidou** and **F. Jafari**, On norms of composition operators on Hardy spaces; **C. Badea**, Stable ranks, $K$-groups and Witt groups of some Banach and $C^*$-algebras; **A. Bernard** and **G. Muraz**, Locally constant almost everywhere Fourier transform; **S. Bernstein**, The quaternionic Riemann problem; **O. Blasco**, Convolution by means of bilinear maps; **C.-H. Chu**, **A. M. Galindo**, and **A. Rodríguez Palacios**, On prime real $JB^*$-triples; **M. D. Contreras** and **S. Díaz-Madrigal**, Compact-type operators defined on $H^\infty$; **S. J. Dilworth**, On the extensibility of certain homeomorphisms and linear isometries; **P. N. Dowling**, The fixed point property for subsets of $L_1[0,1]$; **J. F. Feinstein** and **D. W. B. Somerset**, Strong regularity for uniform algebras; **R. Gonzalo** and **J. A. Jaramillo**, High order smoothness in sequence spaces and spreading models; **P. Gorkin** and **R. Mortini**, A survey of closed ideals in familiar function algebras; **O. Hatori**, Subalgebras of commutative Banach algebras and Fourier multipliers with natural spectra; **F. Holland** and **R. Rochberg**, Bergman kernels and Hankel forms on generalized Fock spaces; **K. Jarosz**, When is a linear functional multiplicative?; **N. J. Kalton**, A remark on Banach spaces isomorphic to their squares; **S. G. Krantz** and **M. M. Peloso**, Sobolev spaces and projections of holomorphic functions and mappings; **F. León-Saavedra**, Universal functions on the unit ball and the polydisk; **T. Miura**, On commutative $C^*$-algebras in which every element is almost the square of another; **T. Nakazi**, Some special bounded homomorphisms of a uniform algebra; **M. M. Neumann**, Analytic functional models for operators on Banach spaces; **B. Randrianantoanina**, Injective isometries in Orlicz spaces; **A. Rodríguez-Palacios** and **M. V. Velasco**, Continuity of homomorphisms and derivations on Banach algebras with an involution; **A. G. Siskakis** and **R. Zhao**, A Volterra type operator on spaces of analytic functions; **K. Stroethoff**, Algebraic properties of Toeplitz operators on the Hardy space via the Berezin transform; **H. Takagi** and **K. Yokouchi**, Multiplication and composition operators between two $L^p$-spaces; **T. Tonev**, Bourgain algebras and inductive limit algebras; **A. Triki**, A note on averaging operators; **K. Watanabe**, Problems on isometries of non-commutative $L^p$-spaces; **A. Zagorodnyuk**, Multiplicative polynomial operators on topological algebras.

**Contemporary Mathematics**, Volume 232

June 1999, 361 pages, Softcover, ISBN 0-8218-0939-3, LC 99-13038, 1991 *Mathematics Subject Classification*: 46Exx, 46Jxx, 30-02, 32-02, 46-02, **Individual member $49**, List $81, Institutional member $65, Order code CONM/232N

# Applications




## Plates and Shells

**Michel Fortin**, *Université Laval, Ste-Foy, PQ, Canada*, Editor

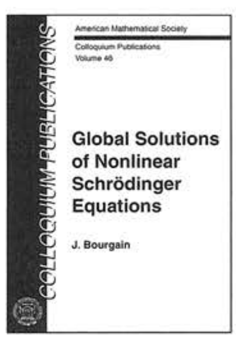
This volume features the proceedings from the Summer Seminar of the Canadian Mathematical Society held at Université Laval. The purpose of the seminar was to gather both mathematicians and engineers interested in the theory or application of plates and shells, or more generally, in the modelisation of thin structures. From this, it was hoped that a better understanding of the problem would emerge for both groups of professionals. New aspects from the mathematical point of view and new applications posing new challenges are reported. This volume offers a snapshot of the state of the art of this rapidly evolving topic.

**Contents:** **S. M. Alessandrini**, **D. N. Arnold**, **R. S. Falk**, and **A. L. Madureira**, Derivation and justification of plate models by variational methods; **J.-L. Batoz**, **Y. Q. Guo**, and **F. Mercier**, Simple triangular shell elements for large strain estimations of sheet metal forming parts; **M. Bernadou**, Some approximation methods for linear thin shell problems; **M. Bernadou** and **C. Haenel**, Numerical analysis of piezoelectric shells; **M. Carrive** and **P. Le Tallec**, Étude intrinsèque d'un problème de coque en grandes déformations; **D. Chapelle** and **R. Stenberg**, Locking-free mixed stabilized finite element methods for bending-dominated shells; **F. Dammak**, **S. Chamlal**, **A. Gakwaya**, and **G. Dhatt**, Un élément de coque simple à trois nœuds en grandes rotations et élastoplasticité; **M. C. Delfour** and **J. Zhao**, Intrinsic nonlinear models of shells; **M. C. Delfour** and **J.-P. Zolésio**, Convergence of the linear $P(1,1)$ and $P(2,1)$ thin shells to asymptotic shells; **Q. Deng** and **X. Feng**, Two-level overlapping Schwarz methods for plate elements on unstructured meshes using non-matching coarse grids; **J.-C. Gelin** and **L. Boubakar**, Large elasto-plastic deformations of thin shells with application to the stamping of anisotropic sheet metal parts; **K. Genevey**, Justification of two-dimensional linear shell models by the use of Γ-convergence theory; **S. F. Golovashchenko** and **N. M. Bessonov**, Numerical simulation of high-rate stamping of tubes and sheets; **A. Ibrahimbegović**, An intrinsic form of the stress resultant geometrically exact shell theory; **A. Iosilevich**, **K.-J. Bathe**, and **F. Brezzi**, Numerical inf-sup analysis of MITC plate bending elements; **E. Pagnacco** and **J. E. Souza de Cursi**, Optimisation des plaques et coques; **M. A. Tournour** and **N. Atalla**, Vibroacoustic behavior of a rectangular box; **G. Yang**, **M. C. Delfour**, and **M. Fortin**, Error analysis of mixed finite elements for cylindrical shells.

**CRM Proceedings & Lecture Notes**, Volume 21

May 1999, 280 pages, Softcover, ISBN 0-8218-0950-4, LC 99-22844, 1991 *Mathematics Subject Classification*: 73Kxx; 65–XX, **Individual member $45**, List $75, Institutional member $60, Order code CRMP/21N

# Differential Equations




## Global Solutions of Nonlinear Schrödinger Equations

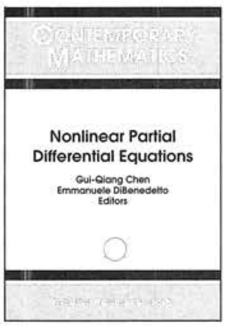
**J. Bourgain**, *Institute for Advanced Study, Princeton, NJ*

This volume presents recent progress in the theory of nonlinear dispersive equations, primarily the nonlinear Schrödinger (NLS) equation. The Cauchy problem for defocusing NLS with critical nonlinearity is discussed. New techniques and results are described on global existence and properties of solutions with Large Cauchy data. Current research in harmonic analysis around Strichartz's inequalities and its relevance to nonlinear PDE is presented. Several topics in NLS theory on bounded domains are reviewed. Using the NLS as an example, the book offers comprehensive insight on current research related to dispersive equations and Hamiltonian PDEs.

**Contents:** Introduction and summary; An overview of results on the Cauchy problem for NLS; Further comments; 3D $H^1$-critical defocusing NLS; Global wellposedness below energy norm; Nonlinear Schrödinger equation with periodic boundary conditions; Appendix 1: Growth of Sobolev norms in linear Schrödinger equations with smooth time dependent potential; Appendix 2: Zakharov systems; References; Index.

**Colloquium Publications**, Volume 46

July 1999, 182 pages, Hardcover, ISBN 0-8218-1919-4, LC 99-13066, 1991 *Mathematics Subject Classification*: 35Q55, **Individual member $21**, List $35, Institutional member $28, Order code COLL/46N




## Nonlinear Partial Differential Equations

**Gui-Qiang Chen** and **Emmanuele DiBenedetto**, *Northwestern University, Evanston, IL*, Editors

This volume is a collection of original research papers and expository articles stemming from the scientific program of the Nonlinear PDE Emphasis Year held at Northwestern University (Evanston, IL). The book offers a cross-section of the most significant recent advances and current trends and directions in nonlinear partial differential equations and related topics.

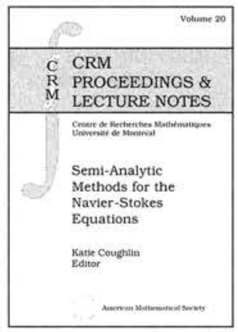
The book's contributions offer two perspectives. There are papers on general analytical treatment of the theory and papers on computational methods and applications originating from significant realistic mathematical models of natural phenomena. Also included are articles that bridge the gap between these two perspectives, seeking synergistic links between theory and modeling and computation. The volume offers direct insight into recent trends in PDEs.

This volume is also available on the Web. Those who purchase the print edition gain free access. Go to www.ams.org/conm/.

**Contents:** **P. Baiti**, **P. G. LeFloch**, and **B. Piccoli**, Nonclassical shocks and the Cauchy problem: General conservation laws; **L. A. Caffarelli**, The Harnack inequality and non-divergence equations; **G.-Q. Chen** and **H. Frid**, Vanishing viscosity limit for initial-boundary value problems for conservation laws; **A. J. Chorin**, **A. P. Kast**, and **R. Kupferman**, On the prediction of large-scale dynamics using unresolved computations; **P. Constantin**, Variational bounds in turbulent convection; **B. Dacorogna** and **P. Marcellini**, On the solvability of implicit nonlinear systems in the vectorial case; **C. M. Dafermos**, Genuinely nonlinear hyperbolic systems of two conservation laws; **I. M. Gamba**, Milne problem for strong force scaling; **J. Glimm**, **J. W. Grove**, **X. L. Li**, and **N. Zhao**, Simple front tracking; **Y. Guo** and **A. S. Tahvildar-Zadeh**, Formation of singularities in relativistic fluid dynamics and in spherically symmetric plasma dynamics; **C. Lattanzio** and **P. Marcati**, Asymptotic stability of plane diffusion waves for the $2$-$D$ quasilinear wave equation; **T.-P. Liu** and **T. Yang**, $L_1$ stability for systems of hyperbolic conservation laws; **T. Ma** and **S. Wang**, The geometry of the stream lines of steady states of the Navier-Stokes equations; **R. Magnanini** and **G. Talenti**, On complex-valued solutions to a 2D eikonal equation. Part one: Qualitative properties; **U. F. Mayer** and **G. Simonett**, On diffusion-induced grain-boundary motion; **M. O'Leary**, Local estimates for solutions to singular and degenerate quasilinear parabolic equations; **D. Peng**, **S. Osher**, **B. Merriman**, and **H.-K. Zhao**, The geometry of Wulff crystal shapes and its relations with Riemann problems.

**Contemporary Mathematics**

August 1999, approximately 320 pages, Softcover, ISBN 0-8218-1196-7, LC 99-30749, 1991 *Mathematics Subject Classification*: 35-06, 35-02; 35J60, 35K55, 35L65, 65Mxx, 76N10, **Individual member $36**, List $60, Institutional member $48, Order code CONM-CHENN
*Electronic only:* ISBN 0-8218-2034-6, **Individual member $32**, List $54, Institutional member $43, Order code CONM-CHEN.EN




## Semi-Analytic Methods for the Navier-Stokes Equations

**Katie Coughlin**, *University of Montreal, PQ, Canada*, Editor

The lectures collected for this volume were given during a workshop entitled "Semi-analytic Methods for the Navier Stokes Equations", held at the CRM in Montréal. The title reflects the current reality in fluid dynamics: the Navier-Stokes equations (NSE) describe the behavior of fluid in a wide range of physical situations, the solutions of these equations are sufficiently complicated, so that another level of analysis is clearly needed. The fundamental problem is not just to solve the NSE, but also to understand what the solutions mean.

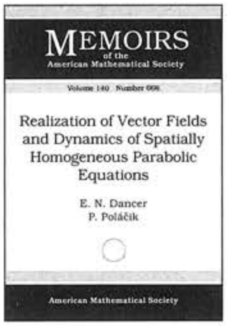
One of the goals of the workshop was to bring together people who, while working in different fields, share a common perspective on the nature of the problem to be solved. The lectures present a diverse set of techniques for modelling, computing, and understanding phenomena such as instabilities, turbulence and spatiotemporal chaos in fluids.

This item will also be of interest to those working in mathematical physics.

**Contents:** **E. S. C. Ching**, Probabilities and conditional averages in turbulence; **H. S. Greenside**, Spatiotemporal chaos in large systems: The scaling of complexity with size; **M. Kirby** and **R. Miranda**, Empirical dynamical system reduction I: Global nonlinear transformations; **D. R. Hundley**, **M. Kirby**, and **R. Miranda**, Empirical dynamical system reduction II: Neural charts; **C. Lee** and **P. S. Marcus**, Asymmetries in eastward and westward jets in a model planetary atmosphere; **C. Meneveau** and **T. S. Lund**, Lagrangian averaging for dynamic Eddy-viscosity subgrid models for filtered Navier-Stokes equation; **J. B. Weiss**, Punctuated Hamiltonian models of structured turbulence.

**CRM Proceedings & Lecture Notes**, Volume 20

April 1999, 119 pages, Softcover, ISBN 0-8218-0878-8, LC 99-14403, 1991 *Mathematics Subject Classification*: 76-06; 76D05, **Individual member $23**, List $39, Institutional member $31, Order code CRMP/20N




## Realization of Vector Fields and Dynamics of Spatially Homogeneous Parabolic Equations

**E. N. Dancer**, *University of Sydney, NSW, Australia*, and **P. Poláčik**, *Comenius University, Bratislava, Slovak Republic*

**Contents:** Introduction; Main results; The center manifold reduction; Center manifolds of (1.1), (1.2); The algebraic independence condition; Perturbation of the domain; A selection of eigenfunctions in high-dimensional eigenspaces; Eigenfunctions with separable variables; Completion of proofs; References.

**Memoirs of the American Mathematical Society**, Volume 140, Number 668

May 1999, 82 pages, Softcover, ISBN 0-8218-1182-7, LC 99-14984, 1991 *Mathematics Subject Classification*: 35K55, 35K57, 35B40; 35J25, 35P05, 58F13, **Individual member $23**, List $39, Institutional member $31, Order code MEMO/140/668N

## An Introduction to the Mathematical Theory of Waves

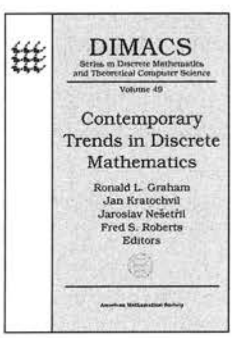
**Roger A. Knobel**, *University of Texas-Pan American, Edinburg*

See page 716 for a full description of this volume.

**Student Mathematical Library**

October 1999 (estimated), approximately 200 pages, Softcover, ISBN 0-8218-2039-7, **All AMS members $18**, List $23, Order code STML-KNOBELN

# Discrete Mathematics and Combinatorics




## Contemporary Trends in Discrete Mathematics

### From DIMACS and DIMATIA to the Future

**Ronald L. Graham**, *AT&T Labs—Research, Florham Park, NJ*, **Jan Kratochvíl** and **Jaroslav Nešetřil**, *DIMATIA, Charles University, Prague, Czech Republic*, and **Fred S. Roberts**, *DIMACS, Rutgers University, Piscataway, NJ*, Editors

Discrete mathematics stands among the leading disciplines of mathematics and theoretical computer science. This is due primarily to its increasing role in university curriculae and its growing importance in applications ranging from optimization to molecular biology. An inaugural conference was held cooperatively by DIMATIA and DIMACS to focus on the versatility, width, and depth of current progress in the subject area.

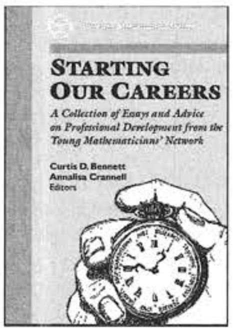
This volume offers a well-balanced blend of research and survey papers reflecting the exciting, attractive topics in contemporary discrete mathematics. Discussed in the book are topics such as graph theory, partially ordered sets, geometrical Ramsey theory, computational complexity issues and applications.

**Contents:** **P. Boiron**, **E. Sopena**, and **L. Vignal**, Acyclic improper colourings of graphs with bounded degree; **P. Ossona de Mendez** and **H. de Fraysseix**, Intersection graphs of Jordan arcs; **J. Díaz**, **M. Serna**, and **P. Spirakis**, Linear and nonlinear systems: A survey; **R. G. Downey**, **M. R. Fellows**, and **U. Stege**, Parameterized complexity: A framework for systematically confronting computational intractability; **G. Elekes**, On the structure of large homothetic subsets; **S. P. Fekete**, **W. Hochstättler**, **S. Kromberg**, and **C. Moll**, The complexity of an inverse shortest paths problem; **A. Frank**, Finding minimum weighted generators of a path system; **J. R. Griggs** and **G. Rote**, On the distribution of sums of vectors in general position; **A. Gupta**, **D. Kaller**, **S. Mahajan**, and **T. Shermer**, The generalized matching problem on partial $k$-trees; **W. Hochstättler** and **M. Loebl**, Bases of cocycle lattices and submatrices of a Hadamard matrix; **M. Klazar**, On the maximum lengths of Davenport-Schinzel sequences; **A. V. Kostochka**, **T. Łuczak**, **G. Simonyi**, and **E. Sopena**, On the minimum number of edges giving maximum oriented chromatic number; **J. Kratochvíl**, **Zs. Tuza**, and **M. Voigt**, New trends in the theory of graph colorings: Choosability and list coloring; **W. Mader**, Topological minors in graphs of minimum degree $n$; **P. Mihók**, Reducible properties and uniquely partitionable graphs; **J. Nešetřil**, **J. Solymosi**, and **P. Valtr**, Induced monochromatic subconfigurations; **J. Nešetřil** and **C. Tardif**, Density; **P. Pančoška**, **V. Janota**, and **J. Nešetřil**, Spectra, graphs, and proteins. Towards understanding of protein folding; **F. S. Roberts**, Meaningless statements; **M. Rosenfeld**, Graceful matchings in finite fields, the factor-difference sets of integers, and integers of the form $a^2 + kb^2$; **M. Simonovits**, How to solve a Turán type extremal graph problem? (Linear decomposition); **A. Sali** and **G. Simonyi**, Oriented list colouring of undirected graphs; **J. Spencer** and **L. Thoma**, On the limit values of probabilities for the first order properties of graphs; **W. T. Trotter**, Ramsey theory and partially ordered sets; **P. Valtr**, Generalizations of Davenport-Schinzel sequences.

**DIMACS: Series in Discrete Mathematics and Theoretical Computer Science**, Volume 49

May 1999, 389 pages, Hardcover, ISBN 0-8218-0963-6, LC 99-19657, 1991 *Mathematics Subject Classification*: 05-06, 05Cxx, 05Dxx, 06A07, 11Bxx, 60C05, 68Rxx, 68Q15, 92C40, **Individual member $54**, List $90, Institutional member $72, Order code DIMACS/49N

# General and Interdisciplinary




## Starting Our Careers

### A Collection of Essays and Advice on Professional Development from the Young Mathematicians' Network

**Curtis D. Bennett**, *Bowling Green State University, OH,* and **Annalisa Crannell**, *Franklin & Marshall College, Lancaster, PA*, Editors

*If you are the reader we envision for this book, you have just passed through the most crucial stage of your career—writing and defending your doctoral thesis in mathematics—only to discover what lies ahead is, yet again, the most crucial stage of your career: making the choice about what job to take ... It is the time when you make the adjustment from studying in a research institution to earning your keep in industry or academia ... It is the time when you will or will not publish your thesis ... when you will decide to leave research behind or to start new mathematics independently ... or when you will struggle to balance time for students and committees with time in the library ... This book was written largely by people like you ...*

**—*from the* Introduction**

This "how-to" book addresses all aspects of a young mathematician's early career development: How do I get good letters of recommendation? How do I apply for a grant? How do I do research in a small department that has no one in my field? How do I do anything meaningful if all I can get is a series of one-year jobs?

These articles paint a broad portrait of current professional development issues of interest from the Young Mathematicians' Network—from finding jobs to organizing special sessions. There are chapters on applying for positions, working in industry and in academia, starting and publishing research, writing grant proposals, applying for tenure, and becoming involved in the academic community. The book offers timely and sound advice offered by recent doctorates through experienced mathematicians. The material originally appeared in the electronic pages of *Concerns of Young Mathematicians.* The book is devoted exclusively to the early stages of a mathematical career.

**Contents:** Applying for jobs; Industrial mathematics; Life in small schools; Doing research; What to do with your research once you've done it; Getting grants; Tenure; The active mathematical community; Epilogue: A pep-talk; List of authors; Index.

June 1999, 116 pages, Softcover, ISBN 0-8218-1543-1, LC 99-14350, 1991 *Mathematics Subject Classification:* 00A35; 00A06, **Individual member $14**, List $24, Institutional member $19, Order code SOCN

Back in print from the AMS

A Classic

## Geometry and the Imagination

**D. Hilbert** and **S. Cohn-Vossen**

*A fascinating tour of the 20th century mathematical zoo ... Anyone who would like to see proof of the fact that a sphere with a hole can always be bent (no matter how small the hole), learn the theorems about Klein's bottle—a bottle with no edges, no inside, and no outside—and meet other strange creatures of modern geometry will be delighted with Hilbert and Cohn-Vossen's book.*

***—Scientific American***

*Should provide stimulus and inspiration to every student and teacher of geometry.*

***—Nature***

*A mathematical classic ... The purpose is to make the reader* see *and* feel *the proofs ... readers can penetrate into higher mathematics with ... pleasure instead of the usual laborious study.*

***—Scientific American***

*Students, particularly, would benefit very much by reading this book ... they will experience the sensation of being taken into the friendly confidence of a great mathematician and being shown the real significance of things.*

***—Science Progress***

*A person with a mininum of formal training can follow the reasoning ... an important [book].*

***—Mathematics Teacher***

This remarkable book has endured as a true masterpiece of mathematical expostion. There are few mathematics books that are still so widely read and continue to have so much to offer—even after more than half a century has passed! The book is overflowing with mathematical ideas, which are always explained clearly and elegantly, and above all, with penetrating insight. It is a joy to read, both for beginners and experienced mathematicians.

"Hilbert and Cohn-Vossen" is full of interesting facts, many of which you wish you had known before. It's also likely that you have heard those facts before, but surely wondered *where* they could be found. The book begins with examples of the simplest curves and surfaces, including thread constructions of certain quadrics and other surfaces. The chapter on regular systems of points leads to the crystallographic groups and the regular polyhedra in $\mathbb{R}^3$. In this chapter, they also discuss plane lattices. By considering unit lattices, and throwing in a small amount of number theory when necessary, they effortlessly derive Leibniz's series: $\pi/4 = 1 - 1/3 + 1/5 - 1/7 + - \ldots$. In the section on lattices in three and more dimensions, the authors consider sphere-packing problems, including the famous Kepler problem.

One of the most remarkable chapters is "Projective Configurations". In a short introductory section, Hilbert and Cohn-Vossen give perhaps the most concise and lucid description of *why* a general geometer would care about projective geometry and why such an ostensibly plain setup is truly rich in structure and ideas. Here, we see regular polyhedra again, from a different perspective. One of the high points of the chapter is the discussion of Schlafli's Double-Six, which leads to the description of the 27 lines on the general smooth cubic surface. As is true throughout the book, the magnificent drawings in this chapter immeasurably help the reader.

A particularly intriguing section in the chapter on differential geometry is *Eleven Properties of the Sphere*. Which eleven properties of such a ubiquitous mathematical object caught their discerning eye and why? Many mathematicians are familiar with the plaster models of surfaces found in many mathematics departments. The book includes pictures of some of the models that are found in the Göttingen collection. Furthermore, the mysterious lines that mark these surfaces are finally explained!

The chapter on kinematics includes a nice discussion of linkages and the geometry of configurations of points and rods that are connected and, perhaps, constrained in some way. This topic in geometry has become increasingly important in recent times, especially in applications to robotics. This is another example of a simple situation that leads to a rich geometry.

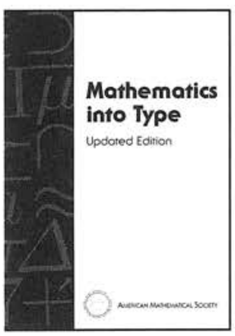
It would be hard to overestimate the continuing influence Hilbert-Cohn-Vossen's book has had on mathematicians of this century. It surely belongs in the "pantheon" of great mathematics books.

This item will also be of interest to those working in geometry and topology.

**Contents:** The simplest curves and surfaces; Regular systems of points; Projective configurations; Differential geometry; Kinematics; Topology; Index.

**AMS Chelsea Publishing**

May 1999, 357 pages, Hardcover, ISBN 0-8218-1998-4, LC 52-2894, 1991 *Mathematics Subject Classification*: 00A05, 01A75, **All AMS members $26**, List $29, Order code CHEL/87.HN




## Mathematics into Type

### Updated Edition

**Ellen Swanson**, *Director of AMS Editorial Services (Retired)*

This edition, updated by Arlene O'Sean and Antoinette Schleyer of the American Mathematical Society, brings Ms. Swanson's work up to date, reflecting the more technical reality of publishing today. While it includes information for copy editors, proofreaders, and production staff to do a thorough, traditional copyediting and proofreading of a manuscript and proof copy, it is increasingly more useful to authors, who have become intricately involved with the typesetting of their manuscripts.

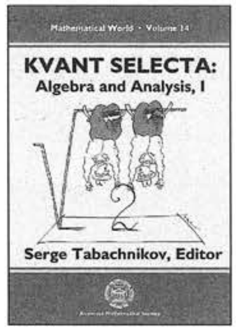
**Features:**

- Maintains the same user-friendly presentation as the original work.
- Serves as a training tool for newcomers to mathematical publishing.
- Includes a glossary.

**Contents:** Especially for authors; How to mark mathematical manuscripts; Mathematics in print; Techniques of handling manuscript and proof; Processing a publication in mathematics; Publication style; Trends; Appendixes; Glossary; Bibliography; Index.

May 1999, 102 pages, Softcover, ISBN 0-8218-1961-5, LC 99-25448, 1991 *Mathematics Subject Classification*: 00A20; 00A99, **Individual member $14**, List $24, Institutional member $19, Order code MIT/2N

Supplementary Reading





## Kvant Selecta

### Algebra and Analysis, I and II

**Serge Tabachnikov**, *University of Arkansas at Fayetteville*, Editor

These volumes are the first volumes of articles published from 1970 to 1990 in the Russian journal, *Kvant*. The influence of this magazine on mathematics and physics education in Russia is unmatched. This collection represents the Russian tradition of expository mathematical writing at its best.

Articles selected for these two volumes are written by leading Russian mathematicians and expositors. Some articles contain classical mathematical gems still used in university curriculae today. Others feature cutting-edge research from the 20th Century.

The articles in these books are written so as to present genuine mathematics in a conceptual, entertaining, and accessible way. The volumes are designed to be used by students and teachers who love mathematics and want to study its various aspects, thus deepening and expanding the school curriculum.

The articles in the first volume are mainly devoted to various topics in number theory, whereas the second volume treats diverse aspects of analysis and algebra.

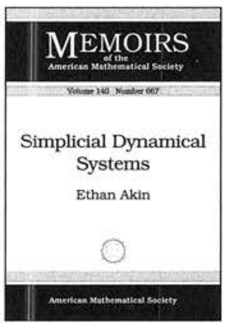
Cover art created by Sergei Ivanov. Used with permission.

**Contents** *(Preliminary)*. ***Volume I:*** **D. B. Fuchs** and **M. B. Fuchs**, The arithmetic of binomial coefficients; **M. I. Bashmakov**, Do you like messing around with integers?; **M. I. Bashmakov**, On Bertrand's conjecture; **D. B. Fuchs** and **M. B. Fuchs**, On best approximations. I; **D. B. Fuchs** and **M. B. Fuchs**, On best approximations. II; **A. I. Shirshov**, On a certain property of binomial coefficients; **L. G. Limanov**, On $n!$ and the number $e$ (Several approaches to a certain problem); **D. B. Fuchs** and **M. B. Fuchs**, Rational approximations and transcendence; **V. N. Vaguten**, Close fractions; **A. I. Shirshov**, On the equation $\binom{n}{m} = \binom{n+1}{m-1}$; **A. Kirillov**, On regular polygons, Euler's function, and Fermat numbers; **B. Bekker**, **S. Vostokov**, and **Yu. Ionin**, 2-adic numbers; **E. Kuzmin** and **A. Shirshov**, On the number $e$; **M. G. Krein**, Markov's Diophantine equation; **A. B. Goncharov**, The arithmetic of Gaussian integers; **V. S. Shevelev**, Three formulas of Ramanujan; **V. G. Stolyar**, **E. A. Kuraev**, **Z. K. Silogadze**, **G. A. Galperin**, and **A. V. Korlyukov**, Amazing adventures in the land of repeating decimals. ***Volume II:*** **V. N. Vaguten**, Binomial coefficients, polynomials, and sequences (Several approaches to a certain problem); **Yu. V. Matiyasevich**, Formulas for prime numbers; **B. Martynov**, Fermat's theorem for polynomials; **I. Yantarov**, Commuting polynomials; **D. B. Fuchs**, On the removal of parentheses, on Euler, Gauss, and Macdonald, and on missed opportunities; **N. Vassiliev** and **A. Zelevinskii**, Chebyshev polynomials and recurrence relations; **O. V. Lyashko**, Why resistance does not decrease; **V. I. Arnold**, Evolution processes and ordinary differential equations; **V. A. Oleinikov**, Irrationality and irreducibility; **V. A. Oleinikov**, Irreducibility and irrationality; **Yu. P. Solov'ev**, The arithmetic of elliptic curves; **N. B. Vassiliev**, Pascal's hexagrams and cubic curves; **V. I. Arnold**, Kepler's second law and the topology of abelian integrals (According to Newton); **F. V. Vainstein**, Partitions of integers; **V. Yu. Ovsienko**, On the Denogardus great number and Hooke's law; **S. Tabachnikov**, Polynomials having least deviation from zero.

**Mathematical World,** Volume 14 and Volume 15

*I*: August 1999, 155 pages, Softcover, ISBN 0-8218-1002-2, 1991 *Mathematics Subject Classification*: 00-01, 00A08, **All AMS members $19**, List $24, Order code MAWRLD/14N
*II*: August 1999, approximately 159 pages, Softcover, ISBN 0-8218-1915-1, 1991 *Mathematics Subject Classification*: 00-01, 00A08, **All AMS members $19**, List $24, Order code MAWRLD/15N

# Geometry and Topology



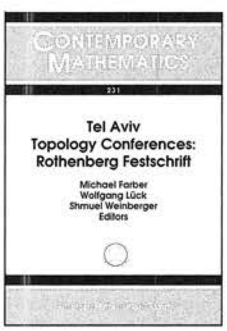

## Simplicial Dynamical Systems

**Ethan Akin**, *City College (CUNY), New York*

**Contents:** Introduction; Chain recurrence and basic sets; Simplicial maps and their local inverses; The shift factor maps for a simplicial dynamical system; Recurrence and basic set images; Invariant measures; Generalized simplicial dynamical systems; Examples; PL roundoffs of a continuous map; Nondegenerate maps on manifolds; Appendix: Stellar and lunar subdivisions; Appendix: Hyperbolicity for relations; References; Index.

**Memoirs of the American Mathematical Society**, Volume 140, Number 667

May 1999, 197 pages, Softcover, ISBN 0-8218-1383-8, LC 99-14982, 1991 *Mathematics Subject Classification*: 54H20, 58F10, 34C35, **Individual member $29**, List $49, Institutional member $39, Order code MEMO/140/667N




## Tel Aviv Topology Conference: Rothenberg Festschrift

**Michael Farber**, *Tel Aviv University, Israel*, **Wolfgang Lück**, *Westfalische Wilhelms University, Munster, Germany*, and **Shmuel Weinberger**, *University of Chicago, IL*, Editors

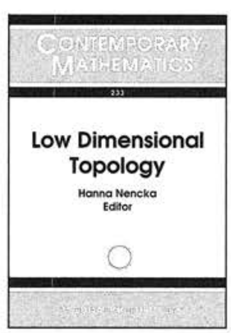
This volume presents the proceedings of the Tel Aviv International Topology Conference held during the Special Topology Program at Tel Aviv University. The book is dedicated to Professor Mel Rothenberg on the occasion of his 65th birthday. His contributions to topology are well known—from the early work on triangulations to numerous papers on transformation groups and on geometric and analytic aspects of torsion theory. Current research related to those contributions are reported in this book.

Coverage is included on the following topics: vanishing theorems for the Dirac operator, the theory of Reidemeister torsion (including infinite dimensional flat bundles), Nobikov-Shubin invariants of manifolds, topology of group actions, Lusternik-Schnirelman theory for closed 1-forms, finite type invariants of links and 3-manifolds, equivariant cobordisms, equivariant orientations and Thom isomorphisms, and more.

**Contents:** **M. Braverman**, Vanishing theorems on covering manifolds; **R. Brooks**, The Sunada method; **D. Burghelea**, **L. Friedlander**, and **T. Kappeler**, Relative torsion for homotopy triangulations; **S. Cappell** and **J. Shaneson**, Nonlinear similarity and linear similarity are equivariant below dimension 6; **M. Farber**, Massey products and critical points; **M. Farber** and **V. Turaev**, Absolute torsion; **S. Garoufalidis**, Signatures of links and finite type invariants of cyclic branched covers; **V. L. Ginzburg**, **V. L. Guillemin**, and **Y. Karshon**, The relation between compact and non-compact equivariant cobordisms; **M. G. Katz** and **A. I. Suciu**, Volume of Riemannian manifolds, geometric inequalities, and homotopy theory; **J. Levine**, Pure braids, a new subgroup of the mapping class group and finite-type invariants of 3-manifolds; **W. Lück**, **H. Reich**, and **T. Schick**, Novikov-Shubin invariants for arbitrary group actions and their positivity; **M. Markl** and **S. Shnider**, Differential operator endomorphisms of an Euler-Lagrange complex; **V. Mathai**, $K$-theory of twisted group $C*$-algebras and positive scalar curvature; **J. P. May**, Equivariant orientations and Thom isomorphisms; **A. Nabutovsky** and **S. Weinberger**, Algorithmic aspects of homeomorphism problems; **J. Rosenberg**, The $G$-signature theorem revisited; **M. Shubin**, A sequence of connections and a characterization of Kähler manifolds; **M. Teicher**, New invariants for surfaces; **G. Triantafillou**, The arithmeticity of groups of automorphisms of spaces; **S. Weinberger**, Nonlinear averaging, embeddings, and group actions; **S. Weinberger**, Higher $\rho$-invariants.

**Contemporary Mathematics**, Volume 231

June 1999, 320 pages, Softcover, ISBN 0-8218-1362-5, LC 99-13037, 1991 *Mathematics Subject Classification*: 55-XX, 57-XX, **Individual member $43**, List $71, Institutional member $57, Order code CONM/231N




## Low Dimensional Topology

**Hanna Nencka**, *University of Madeira, Funchal, Madeira, Portugal*, Editor

This volume presents the proceedings from the conference on low dimensional topology held at the University of Madeira (Portugal). The event was attended by leading scientists in the field from the U.S., Asia, and Europe.

The book has two main parts. The first is devoted to the Poincaré conjecture, characterizations of $PL$-manifolds, covering quadratic forms of links and to categories in low dimensional topology that appear in connection with conformal and quantum field theory. The second part of the volume covers topological quantum field theory and polynomial invariants for rational homology 3-spheres, derived from the quantum $SU(2)$-

invariants associated with the first cohomology class modulo two, knot theory, and braid groups. This collection reflects development and progress in the field and presents interesting and new results.

**Contents: V. Poénaru**, $\pi_1^\infty$ and infinite simple homotopy type in dimension 3; **L. Funar**, Cubulations mod bubble moves; **I. Bobtcheva** and **F. Quinn**, Numerical presentations of tortile categories; **I. Bobtcheva**, On Quinn's invariants of 2-dimensional CW-complexes; **A. Kawauchi**, The quadratic form of a link; **H. Murakami**, Quantum $SU(2)$-invariants of three-manifolds associated with the trivial first cohomology class modulo two; **G. Masbaum**, An element of infinite order in TQFT-representations of mapping class groups; **T. Ohtsuki**, The perturbative $SO(3)$ invariant of homology circles; **A. S. Cattaneo**, Configuration space integrals and invariants for 3-manifolds and knots; **H. R. Morton**, The multivariable Alexander polynomial for a closed braid; **K. Kobayashi**, Boundary links and h-split links; **K. Habiro**, **T. Kanenobu**, and **A. Shima**, Finite type invariants of ribbon 2-knots; **S. Kamada**, Arrangement of Markov moves for 2-dimensional braids; **P. Traczyk**, A criterion for signed unknotting number; **H. Nencka**, On some extensions of Artin's braid relations; **J. O'Hara**, Asymptotic behavior of energy of polygonal knots.

**Contemporary Mathematics**, Volume 233

June 1999, 251 pages, Softcover, ISBN 0-8218-0884-2, LC 99-14986, 1991 *Mathematics Subject Classification*: 57Mxx, 57Nxx, 57Pxx, 57Qxx, 57Rxx, 57Sxx, 57Txx, **Individual member $34**, List $56, Institutional member $45, Order code CONM/233N

Supplementary Reading

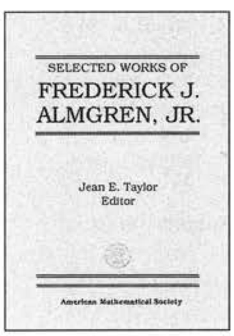
# Miles of Tiles

**Charles Radin**, *University of Texas, Austin*

See page 717 for a full description of this volume.

**Student Mathematical Library**, Volume 1

July 1999, approximately 128 pages, Softcover, ISBN 0-8218-1933-X, LC 99-20662, 1991 *Mathematics Subject Classification*: 52C22; 58F11, 47A35, 82D25, 20H15, **All AMS members $13**, List $16, Order code STML/1N




# Selected Works of Frederick J. Almgren, Jr.

**Jean E. Taylor**, *Rutgers University, New Brunswick, NJ*, Editor

This volume offers a unique collection of some of the work of Frederick J. Almgren, Jr., the man most noted for defining the shape of geometric variational problems and for his role in founding The Geometry Center. Included in the volume are the following: a summary by Sheldon Chang of the famous 1700 page paper on singular sets of area-minimizing $m$-dimensional surfaces in $R^n$, a detailed summary by Brian White of Almgren's contributions to mathematics, his own announcements of several longer papers, important shorter papers, and memorable expository papers.

Almgren's enthusiasm for the subject and his ability to locate mathematically beautiful problems that were "ready to be solved" attracted many students who further expanded the subject into new areas. Many of these former students are now known for the clarity of their expositions and for the beauty of the problems that they work on. As Almgren's former graduate student, wife, and colleague, Professor Taylor has compiled an important volume on an extraordinary mathematician. This collection presents a fine comprehensive view of the man's mathematical legacy.

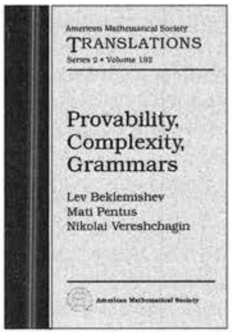
This item will also be of interest to those working in analysis.

**Contents: B. White**, The mathematics of F. J. Almgren, Jr.; **S. X. Chang**, On Almgren's regularity result; The homotopy groups of the integral cycle groups; An isoperimetric inequality; Three theorems on manifolds with bounded mean curvature; Existence and regularity almost everywhere of solutions to elliptic variational problems among surfaces of varying topological type and singularity structure; Measure theoretic geometry and elliptic variational problems; The structure of limit varifolds associated with minimizing sequences of mappings; Existence and regularity almost everywhere of solutions to elliptic variational problems with constraints; (with **W. K. Allard**), The structure of stationary one dimensional varifolds with positive density; (with **J. E. Taylor**), The geometry of soap films and soap bubbles; (with **W. P. Thurston**), Examples of unknotted curves which bound only surfaces of high genus within their convex hulls; (with **R. Schoen** and **L. Simon**), Regularity and singularity estimates on hypersurfaces minimizing parametric elliptic variational integrals; Dirichlet's problem for multiple valued functions and the regularity of mass minimizing integral currents; (with **R. N. Thurston**), Liquid crystals and geodesics; Q valued functions minimizing Dirichlet's integral and the regularity of area minimizing rectifiable currents up to codimension two; Optimal isoperimetric inequalities; (with **W. Browder** and **E. Lieb**), Co-area, liquid crystals, and minimal surfaces; (with **E. H. Lieb**), Singularities of energy minimizing maps from the ball to the sphere: Examples, counterexamples, and bounds; (with **E. H. Lieb**), Symmetric decreasing rearrangement is sometimes continuous; Questions and answers about area-minimizing surfaces and geometric measure theory; (with **J. E. Taylor** and **L. Wang**), Curvature-driven flows: A variational approach; Questions and answers about geometric evolution processes and crystal growth.

**Collected Works**, Volume 13

August 1999, 586 pages, Hardcover, ISBN 0-8218-1067-7, LC 99-13039, 1991 *Mathematics Subject Classification*: 49F20, 49F22, **Individual member $63**, List $105, Institutional member $84, Order code CWORKS/13N

# Logic and Foundations




## Provability, Complexity, Grammars

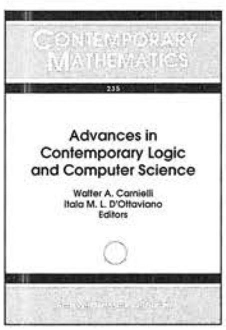
**Lev Beklemishev**, *Steklov Institute of Mathematics, Moscow, Russia*, and **Mati Pentus** and **Nikolai Vereshchagin**, *Moscow State University, Russia*

The book contains English translations of three outstanding dissertations in mathematical logic and complexity theory. L. Beklemishev proves that all provability logics must belong to one of the four previously known classes. The dissertation of M. Pentus proves the Chomsky conjecture about the equivalence of two approaches to formal languages: the Chomsky hierarchy and the Lambek calculus. The dissertation of N. Vereshchagin describes a general framework for criteria of reversability in complexity theory.

**Contents:** **L. D. Beklemishev**, Classification of propositional provability logics; **M. Pentus**, Lambek calculus and formal grammars; **N. K. Vereshchagin**, Relativizability in complexity theory.

**American Mathematical Society Translations—Series 2**, Volume 192

May 1999, 172 pages, Hardcover, ISBN 0-8218-1078-2, LC 99-20177, 1991 *Mathematics Subject Classification*: 68Q15, 68S05, 03B45; 03B65, 03F40, **Individual member $53**, List $89, Institutional member $71, Order code TRANS2/192N




## Advances in Contemporary Logic and Computer Science

**Walter A. Carnielli** and **Itala M. L. D'Ottaviano**, *State University of Campinas, São Paolo, Brazil*, Editors

This volume presents the proceedings from the Eleventh Brazilian Logic Conference on Mathematical Logic held by the Brazilian Logic Society (co-sponsored by the Centre for Logic, Epistemology and the History of Science, State University of Campinas, São Paolo) in Salvador, Bahia, Brazil. The conference and the volume are dedicated to the memory of Professor Mário Tourasse Teixeira, an educator and researcher who contributed to the formation of several generations of Brazilian logicians.

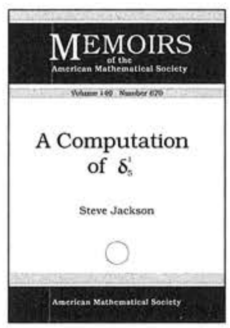
Contributions were made from leading Brazilian logicians and their Latin-American and European colleagues. All papers were selected by a careful refereeing processs and were revised and updated by their authors for publication in this volume.

There are three sections: Advances in Logic, Advances in Theoretical Computer Science, and Advances in Philosophical Logic. Well-known specialists present original research on several aspects of model theory, proof theory, algebraic logic, category theory, connections between logic and computer science, and topics of philosophical logic of current interest. Topics interweave proof-theoretical, semantical, foundational, and philosophical aspects with algorithmic and algebraic views, offering lively high-level research results.

**Contents:** *Part I. Advances in Logic:* **J.-Y. Béziau**, The mathematical structure of logical syntax; **X. Caicedo** and **M. Krynicki**, Quantifiers for reasonizing with imperfect information and $\Sigma_1^1$-logic; **W. A. Carnielli** and **M. Lima-Marques**, Society semantics and multiple-valued logics; **J. C. Cifuentes**, A topological approach to the logic underlying fuzzy subset theory; **M. E. Coniglio**, Categorical logic with partial elements; **M. Dickmann** and **F. Miraglia**, Algebraic K-theory of fields and special groups; **A. Di Nola**, **G. Georgescu**, and **S. Sessa**, Closed ideals of $MV$-algebras; **K. Došen**, Definitions of adjunction; **N. G. Martínez**, A reduced spectrum for $MV$-algebras; *Part II. Advances in Theoretical Computer Science:* **A. Avellone**, **M. Ferrari**, **P. Miglioli**, and **U. Moscato**, A tableau calculus for Dummett predicate logic; **J. M. Turull Torres**, A hierarchy of unbounded almost rigid classes of finite structures; **P. A. S. Veloso**, Some connections between logic and computer science; *Part III. Advances in Philosophical Logic:* **D. Krause** and **S. French**, Opaque predicates, veiled sets and their logic; **O. Bueno**, Truth, quasi-truth and paraconsistency; **G. E. Rosado Haddock**, To be a Fregean or to be a Husserlian: That is the question for Platonists; **C. Pizzi**, A modal framework for consequential implication and the factor law.

**Contemporary Mathematics**, Volume 235

August 1999, 326 pages, Softcover, ISBN 0-8218-1364-1, LC 99-23309, 1991 *Mathematics Subject Classification*: 03-XX, 03-06; 00B25, 03A05, **Individual member $36**, List $60, Institutional member $48, Order code CONM/235N




## A Computation of $\delta_5^1$

**Steve Jackson**, *University of North Texas, Denton*

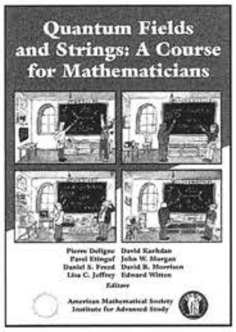
**Contents:** Introduction; Embedding theorems; Martin's Theorem; The upper bound for $\delta_5^1$; Results on uniform cofinalities; Analysis of measures on $\delta_3^1$; The strong partition relation on $\delta_3^1$; The lower bound for $\delta_5^1$; Analysis of measures on $(\delta_5^1)^-$; The weak partition relation on $\delta_5^1$; Bibliography.

**Memoirs of the American Mathematical Society**, Volume 140, Number 670

May 1999, 94 pages, Softcover, ISBN 0-8218-1091-X, LC 99-26354, 1991 *Mathematics Subject Classification*: 03E15, **Individual member $24**, List $40, Institutional member $32, Order code MEMO/140/670N

# Mathematical Physics

Supplementary Reading




## Quantum Fields and Strings: A Course for Mathematicians

**Pierre Deligne**, *Institute for Advanced Study, Princeton, NJ*, **Pavel Etingof**, *Massachusetts Institute of Technology, Cambridge*, **Daniel S. Freed**, *University of Texas, Austin*, **Lisa C. Jeffrey**, *University of Toronto, ON, Canada*, **David Kazhdan**, *Harvard University, Cambridge, MA*, **John W. Morgan**, *Columbia University, New York*, **David R. Morrison**, *Duke University, Durham, NC*, and **Edward Witten**, *Institute for Advanced Study, Princeton, NJ*, Editors

Ideas from quantum field theory and string theory have had considerable impact on mathematics over the past 20 years. Advances in many different areas have been inspired by insights from physics.

In 1996–97 the Institute for Advanced Study (Princeton, NJ) organized a special year-long program designed to teach mathematicians the basic physical ideas which underlie the mathematical applications. The purpose is eloquently stated in a letter written by Robert MacPherson: "The goal is to create and convey an understanding, in terms congenial to mathematicians, of some fundamental notions of physics ... [and to] develop the sort of intuition common among physicists for those who are used to thought processes stemming from geometry and algebra."

These volumes are a written record of the program. They contain notes from several long and many short courses covering various aspects of quantum field theory and perturbative string theory. The courses were given by leading physicists and the notes were written either by the speakers or by mathematicians who participated in the program. The book also includes problems and solutions worked out by the editors and other leading participants. Interspersed are mathematical texts with background material and commentary on some topics covered in the lectures.

These two volumes present the first truly comprehensive introduction to this field aimed at a mathematics audience. They offer a unique opportunity for mathematicians and mathematical physicists to learn about the beautiful and difficult subjects of quantum field theory and string theory.

Cover artwork was created and provided by Robbert Dijkgraaf. The seal for the Institute for Advanced Study is used with the permission of the Institute.

**Contents:** *Volume 1, Part 1. Classical Fields and Supersymmetry:* **P. Deligne** and **J. W. Morgan**, Notes on supersymmetry (following Joseph Bernstein); **P. Deligne**, Notes on spinors; **P. Deligne** and **D. S. Freed**, Classical field theory; **P. Deligne** and **D. S. Freed**, Supersolutions; **P. Deligne** and **D. S. Freed**, Sign manifesto; *Volume 1, Part 2. Formal Aspects of QFT:* **P. Deligne**, Note on quantization; **D. Kazhdan**, Introduction to QFT; **E. Witten**, Perturbative quantum field theory; **E. Witten**, Index of Dirac operators; **L. Faddeev**, Elementary introduction to quantum field theory; **D. Gross**, Renormalization groups; **P. Etingof**, Note on dimensional regularization; **E. Witten**, Homework; Index; *Volume 2, Part 3. Conformal Field Theory and Strings:* **K. Gawędzki**, Lectures on conformal field theory; **E. D'Hoker**, Perturbative string theory; **P. Deligne**, Super space descriptions of super gravity; **D. Gaitsgory**, Notes on *2d* conformal field theory and string theory; **A. Strominger**, Kaluza-Klein compactifications, supersymmetry, and Calabi-Yau spaces; *Volume 2, Part 4. Dynamical Aspects of QFT:* **E. Witten**, Dynamics of Quantum Field Theory; **N. Sieberg**, $N = 1$ supersymmetric field theories in four dimensions; Index.

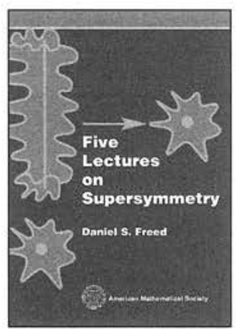
July 1999, 1991 *Mathematics Subject Classification*: 81TXX, LC 99-20755.

***Volume 1***: 752 pages. *Hardcover:* ISBN 0-8218-1987-9, **All AMS members $32**, List $40, Order code QFT/1N; *Softcover:* ISBN 0-8218-2012-5, **All AMS members $20**, List $25, Order code QFT/1.SN

***Volume 2***: 800 pages. *Hardcover:* ISBN 0-8218-1988-7, **All AMS members $32**, List $40, Order code QFT/2N; *Softcover:* ISBN 0-8218-2013-3, **All AMS members $20**, List $25, Order code QFT/2.SN

***Set***: 1552 pages. *Hardcover:* ISBN 0-8218-1198-3, **All AMS members $60**, List $75, Order code QFT/1/2N; *Softcover:* ISBN 0-8218-2014-1, **All AMS members $32**, List $40, Order code QFT/1/2.SN

Supplementary Reading




## Five Lectures on Supersymmetry

**Daniel S. Freed**, *University of Texas, Austin*

Since physicists introduced supersymmetry in the mid 1970s, there have been great advances in the understanding of supersymmetric quantum field theories and string theories. These advances have had important mathematical consequences as well.

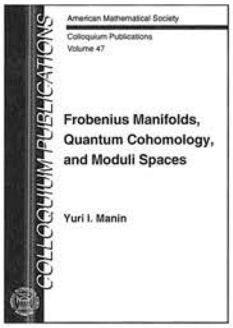
The lectures featured in this book treat fundamental concepts necessary for understanding the physics behind these mathematical applications. Freed approaches the topic with the assumption that the basic notions of supersymmetric field theory are unfamiliar to most mathematicians. He presents the material intending to impart a firm grounding in the elementary ideas.

The first half of the book offers expository introductions to superalgebras, supermanifolds, classical field theory, free quantum theories, and super Poincaré groups. The second half covers specific models and describes some of their geometric features. The overall aim is to explain the classical supersymmetric field theories that are basic for applications in quantum mechanics and quantum field theory, thereby providing readers with sufficient background to explore the quantum ideas.

**Contents:** What are fermions?; Lagrangians and symmetries; Supersymmetry in various dimensions; Theories with two supersymmetries; Theories with more supersymmetry; References; Index.

May 1999, 119 pages, Softcover, ISBN 0-8218-1953-4, LC 99-14915, 1991 *Mathematics Subject Classification*: 70G50, 81T60, 70H99, 70-02, **All AMS members $19**, List $24, Order code FLSN

Recommended Text




## Frobenius Manifolds, Quantum Cohomology, and Moduli Spaces

**Yuri I. Manin**, *Director, Max-Planck-Institut für Mathematik, Bonn, Germany*

This is the first monograph dedicated to the systematic exposition of the whole variety of topics related to quantum cohomology. The subject first originated in theoretical physics (quantum string theory) and has continued to develop extensively over the last decade.

The author's approach to quantum cohomology is based on the notion of the Frobenius manifold. The first part of the book is devoted to this notion and its extensive interconnections with algebraic formalism of operads, differential equations, perturbations, and geometry. In the second part of the book, the author describes the construction of quantum cohomology and reviews the algebraic geometry mechanisms involved in this construction (intersection and deformation theory of Deligne-Artin and Mumford stacks).

Yuri Manin is currently the director of the Max-Planck-Institut für Mathematik in Bonn, Germany. He has authored and coauthored 10 monographs and almost 200 research articles in algebraic geometry, number theory, mathematical physics, history of culture, and psycholinguistics. Manin's books, such as *Cubic Forms: Algebra, Geometry, and Arithmetic* (1974), *A Course in Mathematical Logic* (1977), *Gauge Field Theory and Complex Geometry* (1988), *Elementary Particles: Mathematics, Physics and Philosophy* (1989, with I. Yu. Kobzarev), *Topics in Non-commutative Geometry* (1991), and *Methods of Homological Algebra* (1996, with S. I. Gelfand), secured for him solid recognition as an excellent expositor. Undoubtedly the present book will serve mathematicians for many years to come.

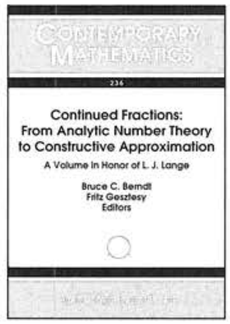
This item will also be of interest to those working in algebra and algebraic geometry.

**Contents:** Introduction: What is quantum cohomology?; Introduction to Frobenius manifolds; Frobenius manifolds and isomonodromic deformations; Frobenius manifolds and moduli spaces of curves; Operads, graphs, and perturbation series; Stable maps, stacks, and Chow groups; Algebraic geometric introduction to the gravitational quantum cohomology; Bibliography; Subject index.

**Colloquium Publications,** Volume 47

July 1999, 297 pages, Hardcover, ISBN 0-8218-1917-8, LC 99-18035, 1991 *Mathematics Subject Classification*: 14H10, 14N10, 58D29; 58D10, **All AMS members $44**, List $55, Order code COLL/47N

# Number Theory




## Continued Fractions: From Analytic Number Theory to Constructive Approximation

### A Volume in Honor of L. J. Lange

**Bruce C. Berndt**, *University of Illinois, Urbana*, and **Fritz Gesztesy**, *University of Missouri, Columbia*, Editors

This volume presents the contributions from the international conference held at the University of Missouri at Columbia, marking Professor Lange's 70th birthday and his retirement from the university. The principal purpose of the conference was to focus on continued fractions as a common interdisciplinary theme bridging gaps between a large number of fields—from pure mathematics to mathematical physics and approximation theory.

Evident in this work is the widespread influence of continued fractions in a broad range of areas of mathematics and physics, including number theory, elliptic functions, Padé approximations, orthogonal polynomials, moment problems, frequency analysis, and regularity properties of evolution equations. Different areas of current research are represented. The lectures at the conference and the contributions to this volume reflect the wide range of applicability of continued fractions in mathematics and the applied sciences.

**Contents:** **R. Askey**, Continued fractions and orthogonal polynomials; **B. C. Berndt**, **Y.-S. Choi**, and **S.-Y. Kang**, The problems submitted by Ramanujan to the Journal of the Indian Mathematical Society; **B. Bojanov** and **A. S. Ranga**, Some examples of moment preserving approximation; **C. F. Bracciali**, Relations between certain symmetric strong Stieltjes distributions; **A. Bultheel**, **C. Díaz-Mendoza**, **P. González-Vera**, and **R. Orive**, Estimates of the rate of convergence for certain quadrature formulas on the half-line; **A. Bultheel** and **P. González-Vera**, Wavelets by orthogonal rational kernels; **H. H. Chan** and **V. Tan**, On the explicit evaluations of the Rogers-Ramanujan continued fraction; **D. Chelst**, Absence of phase transitions in modified two-component plasmas: The analytic theory of continued fractions in statistical mechanics; **M. E. H. Ismail** and **D. R. Masson**, Some continued fractions related to elliptic functions; **W. B. Jones** and **G. Shen**, Asymptotics of Stieltjes continued fraction coefficients and applications to Whittaker functions; **L. J. Lange**, A generalization of Van Vleck's theorem and more on complex continued fractions; **X. Li**, Convergence of interpolating Laurent polynomials on an annulus; **L. Lorentzen**, Convergence criteria for continued fractions $K(a_n/1)$ based on value sets; **O. Njåstad**, Strong Stieltjes moment problems; **F. Peherstorfer** and **R. Steinbauer**, Weak asymptotics of orthogonal polynomials on the support of the measure of orthogonality and considerations on functions of the second kind; **S. Perrine**, Trees of approximation constants; **I. Rodnianski**, Continued fractions and Schrödinger evolution; **W. Van Assche**, Multiple orthogonal polynomials, irrationality and transcendence; **A. J. van der Poorten**, Reduction of continued fractions of formal power series; **H. Waadeland**, Some observations in frequency analysis; **F. Wielonsky**, Some properties of Hermite-Padé approximants to $e^z$.

**Contemporary Mathematics,** Volume 236

August 1999, 379 pages, Softcover, ISBN 0-8218-1200-9, LC 99-30750, 1991 *Mathematics Subject Classification*: 42C05, 30B70, 30E05, 40A15; 11-XX, 33-XX, 41-XX, **Individual member $47**, List $78, Institutional member $62, Order code CONM/236N

Back in print from the AMS

# History of the Theory of Numbers

## Leonard Eugene Dickson

Dickson's *History* is truly a monumental account of the development of one of the oldest and most important areas of mathematics. It is remarkable today to think that such a complete history could even be conceived. That Dickson was able to accomplish such a feat is attested to by the fact that his *History* has become *the* standard reference for number theory up to that time. One need only look at later classics, such as Hardy and Wright, where Dickson's *History* is frequently cited, to see its importance.

The book is divided into three volumes by topic. In scope, the coverage is encyclopedic, leaving very little out. It is interesting to see the topics being resuscitated today that are treated in detail in Dickson.

The first volume of Dickson's *History* covers the related topics of divisibility and primality. It begins with a description of the development of our understanding of perfect numbers. Other standard topics, such as Fermat's theorem, primitive roots, counting divisors, the Möbius function, and prime numbers themselves are treated. Dickson, in this thoroughness, also includes less workhorse subjects, such as methods of factoring, divisibility of factorials and properties of the digits of numbers. Concepts, results and citations are numerous.

The second volume is a comprehensive treatment of Diophantine analysis. Besides the familiar cases of Diophantine equations, this rubric also covers partitions, representations as a sum of two, three, four or $n$ squares, Waring's problem in general and Hilbert's solution of it, and perfect squares in artihmetical and geometrical progressions. Of course, many important Diophantine equations, such as Pell's equation, and classes of equations, such as quadratic, cubic and quartic equations, are treated in detail. As usual with Dickson, the account is encyclopedic and the references are numerous.

The last volume of Dickson's *History* is the most modern, covering quadratic and higher forms. The treatment here is more general than in Volume II, which, in a sense, is more concerned with special cases. Indeed, this volume chiefly presents methods of attacking whole classes of problems. Again, Dickson is exhaustive with references and citations.

This item will also be of interest to those working in general and interdisciplinary areas.

**Contents:** *Part 1:* Perfect, multiply perfect, and amicable numbers; Formulas for the number and sum of divisors, problems of Fermat and Wallis; Fermat's and Wilson's theorems, generalizations and converses; symmetric functions of $1, 2, \ldots, p-1$, modulo $p$; Residue of $(u^{p-1}-1)/p$ modulo $p$; Euler's $\phi$-function, generalizations; Farey series; Periodic decimal fractions; periodic fractions; factors of $10^n \pm 1$; Primitive roots, exponents, indices, binomial congruences; Higher congruences; Divisibility of factorials and multinomial coefficients; Sum and number of divisors; Miscellaneous theorems on divisibility, greatest common divisor, least common multiple; Criteria for divisibility by a given number; Factor tables, lists of primes; Methods of factoring; Fermat numbers $F_n = 2^{2^n}+1$; Factors of $a^n \pm b^n$; Recurring series; Lucas' $u_n, v_n$; Theory of prime numbers; Inversion of functions; Möbius' function $\mu(n)$; numerical integrals and derivatives; Properties of the digits of numbers; Author index; Subject index; *Part 2:* Polygonal, pyramidal and figurate numbers; Linear diophantine equations and congruences; Partitions; Rational right triangles; Triangles, quadrilaterals, and tetrahedra; Sum of two squares; Sum of three squares; Sum of four squares; Sum of $n$ squares; Number of solutions of quadratic congruences in $n$ unknowns; Liouville's series of eighteen articles; Pell equation; $ax^2+bx+c$ made a square; Further single equations of the second degree; Squares in arithmetical or geometrical progression; Two or more linear functions made squares; Two quadratic functions of one or two unknowns made squares; Systems of two equations of degree two; Three or more quadratic functions of one or two unknowns made squares; Systems of three or more equations of degree two in three or more unknowns; Quadratic form made an $n$th power; Equations of degree three; Equations of degree four; Equations of degree $n$; Sets of integers with equal sums of like powers; Waring's problem and related results; Fermat's last theorem, $ax^r+by^s=cz^t$, and the congruence $x^n+y^n \equiv z^n \pmod{p}$; Author index; Subject index; *Part 3:* Reduction and equivalence of binary quadratic forms, representation of integers; Explicit values of $x, y$ in $x^2+\Delta y^2=g$; Composition of binary quadratic forms; Orders and genera; their composition; Irregular determinants; Number of classes of binary quadratic forms with integral coefficients; Binary quadratic forms whose coefficients are complex integers or integers of a field; Number of classes of binary quadratic forms with complex integral coefficients; Ternary quadratic forms; Quaternary quadratic forms; Quadratic forms in $n$ variables; Binary cubic forms; Cubic forms in three or more variables; Forms of degree $n \geqq 4$; Binary Hermitian forms; Hermitian forms in $n$ variables and their conjugates; Bilinear forms, matrices, linear substitutions; Representation by polynomials modulo $p$; Congruencial theory of forms; Author index; Subject index.

**AMS Chelsea Publishing**

***Part 1***: May 1999, 486 pages, Hardcover, ISBN 0-8218-1934-8, LC 66-26932, 1991 *Mathematics Subject Classification*: 11-03, 01A05, **All AMS members $41**, List $45, Order code CHEL/86.1.HN;
***Part 2***: May 1999, 803 pages, Hardcover, ISBN 0-8218-1935-6, LC 66-26932, 1991 *Mathematics Subject Classification*: 11-03, 01A05, **All AMS members $53**, List $59, Order code CHEL/86.2.HN;
***Part 3***: May 1999, 313 pages, Hardcover, ISBN 0-8218-1936-4, LC 66-26932, 1991 *Mathematics Subject Classification*: 11-03, 01A05, **All AMS members $32**, List $35, Order code CHEL/86.3.HN
***Set***: May 1999, 1602 pages, Hardcover, ISBN 0-8218-1938-0, LC 66-26932, 1991 *Mathematics Subject Classification*: 11-03, 01A05, **All AMS members $119**, List $132, Order code CHEL/86.HN

# Prime Numbers and Their Distribution

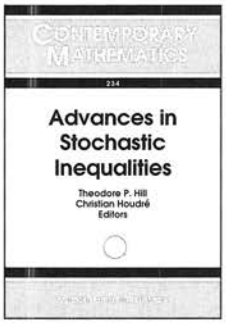
**Gérald Tenenbaum**, *Université Henri Poincaré, Nancy I, France*, and **Michel Mendès France**, *Université Bordeaux I, France*

See page 717 for a full description of this volume.

**Student Mathematical Library**

December 1999 (estimated), approximately 120 pages, Softcover, ISBN 0-8218-1647-0, **All AMS members $14**, List $17, Order code STML-TENENBAUN

# Probability




## Advances in Stochastic Inequalities

**Theodore P. Hill** and **Christian Houdré**, *Georgia Institute of Technology, Atlanta*, Editors

This volume contains 15 articles based on invited talks given at an AMS Special Session on "Stochastic Inequalities and Their Applications" held at Georgia Institute of Technology (Atlanta). The session drew international experts who exchanged ideas and presented state-of-the-art results and techniques in the field. Together, the articles in the book give a comprehensive picture of this area of mathematical probability and statistics.

The book includes new results on the following: convexity inequalities for ranges of vector measures; inequalities for tails of Gaussian chaos and for independent symmetric random variables; Bonferroni-type inequalities for sums of stationary sequences; Rosenthal-type second moment inequalities; variance inequalities for functions of multivariate random variables; correlation inequalities for stable random vectors; maximal inequalities for VC classes; deviation inequalities for martingale polynomials; and expectation equalities for bounded mean-zero Gaussian processes. Various articles in the book emphasize applications of stochastic inequalities to hypothesis testing, mathematical finance, statistics, and mathematical physics.

**Contents: P. C. Allaart**, Bounds on the non-convexity of ranges of vector measures with atoms; **M. A. Arcones**, The class of Gaussian chaos of order two is closed by taking limits in distribution; **R. C. Bradley**, Two inequalities and some applications in connection with $\rho*$-mixing, a survey; **W.-Y. Chang** and **D. St. P. Richards**, Variance inequalities for functions of multivariate random variables; **P. Hitczenko** and **S. Montgomery-Smith**, A note on sums of independent random variables; **Y. Hu**, Exponential integrability of diffusion processes; **A. Jakubowski** and **J. Rosiński**, Local dependencies in random fields via a Bonferroni-type inequality; **R. P. Kertz**, Pricing-differentials and bounds for lookback options, and prophet problems in probability; **A. Koldobsky**, A correlation inequality for stable random vectors; **R. Latala**, A note on the maximal inequalities for VC classes; **K. Oleszkiewicz**, Comparison of moments via Poincaré-type inequality; **I. Pinelis**, Fractional sums and integrals of $r$-concave tails and applications to comparison probability inequalities; **J. Rosiński** and **G. Samorodnitsky**, Product formula, tails and independence of multiple stable integrals; **J. Szulga**, A domination inequality for martingale polynomials; **R. A. Vitale**, A log-concavity proof for a Gaussian exponential bound.

**Contemporary Mathematics**, Volume 234

June 1999, 212 pages, Softcover, ISBN 0-8218-1086-3, LC 99-22875, 1991 *Mathematics Subject Classification*: 60E15; 62F15, **Individual member $27**, List $45, Institutional member $36, Order code CONM/234N

## Lectures on Contemporary Probability

**Gregory F. Lawler**, *Duke University, Durham, NC*, and **Lester N. Coyle**, *Loyola College, Baltimore, MD*

See page 716 for a full description of this volume.

**Student Mathematical Library**

August 1999, approximately 120 pages, Softcover, ISBN 0-8218-2029-X, 1991 *Mathematics Subject Classification*: 60-02; 60J10, 60J15, 65C05, **All AMS members $14**, List $17, Order code STML-LAWLERN

# Previously Announced Publications

The following selection of titles were previously announced in "New Publications Offered by the AMS". They are listed alphabetically by author. For information on additional recent publications, visit the AMS Bookstore at www.ams.org/bookstore/.

Supplementary Reading

## Nonlinear Functional Analysis

**Rajendra Akerkar**, *Chh. Shahu Central Institute of Business Education and Research, Kolhapur, India*

***A publication of Narosa Publishing House.***

This book presents background for the solution of nonlinear equations in Banach spaces. It contains basic techniques in nonlinear analysis and also touches upon today's research. The book deals with recent topics, such as measures on noncompactness, topological degree, and bifurcation theory. It can be used as a text and as a reference source for students and researchers.

Distributed by the AMS exclusively in North America and Europe and non-exclusively elsewhere.

**Narosa Publishing House**

January 1999, 157 pages, Softcover, ISBN 81-7319-230-8, 1991 *Mathematics Subject Classification*: 46-01, **All AMS members $22**, List $27, Order code NAR/4RT96

Supplementary Reading

## Symplectic Geometry and Topology

**Yakov Eliashberg**, *Stanford University, CA*, and **Lisa Traynor**, *Bryn Mawr College, PA*, Editors

Symplectic geometry has its origins as a geometric language for classical mechanics. But it has recently exploded into an independent field interconnected with many other areas of mathematics and physics. The goal of the IAS/Park City Mathematics Institute Graduate Summer School on Symplectic Geometry and Topology was to give an intensive introduction to these exciting areas of current research. Included in this proceedings are lecture notes from the following courses: *Introduction to Symplectic Topology* by D. McDuff; *Holomorphic Curves and Dynamics in Dimension Three* by H. Hofer; *An Introduction to the Seiberg-Witten Equations on Symplectic Manifolds* by C. Taubes; *Lectures on Floer Homology* by D. Salamon; *A Tutorial on Quantum Cohomology* by A. Givental; *Euler*

*Characteristics and Lagrangian Intersections* by R. MacPherson; *Hamiltonian Group Actions and Symplectic Reduction* by L. Jeffrey; and *Mechanics: Symmetry and Dynamics* by J. Marsden.

Members of the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM) receive a 20% discount from list price.

**IAS/Park City Mathematics Series**, Volume 7

May 1999, 431 pages, Hardcover, ISBN 0-8218-0838-9, LC 99-17909, 1991 *Mathematics Subject Classification*: 14-XX, 22-XX, 34-XX, 49-XX, 53-XX, 57-XX, 58-XX, 70-XX, **All AMS members $55**, List $69, Order code PCMS/7RT96

## Algebra and Geometry

**Ming-chang Kang**, *National Taiwan University, Taipei, Taiwan*, Editor

***A publication of International Press.***

This volume presents the proceedings from a conference held at the National Taiwan University. The conference brought together specialists in mathematical physics, algebraic geometry, differential geometry, algebra and number theory from five Pacific Rim countries. Included are articles by S.-T. Yau, V. Kac, M. P. Murthy, Shing-Tung Yau, and other leading specialists.

This item will also be of interest to those working in algebra and algebraic geometry and mathematical physics.

Distributed worldwide, except in Japan, by the American Mathematical Society.

**Contributors include:** C.-L. Chai, J.-M. Hwang, N. Mok, T. Jiang, S. S.-T. Yau, V. Kac, W.-C. W. Li, T. T. Moh, M. P. Murthy, R. G. Swan, I.-H. Tsai, B. H. Lian, and S.-T. Yau.

**International Press**

August 1998, 227 pages, Hardcover, ISBN 1-57146-058-6, 1991 *Mathematics Subject Classification*: 00B25, **All AMS members $34**, List $42, Order code INPR/32RT96

## Understanding the Genome: Technological and Mathematical Challenges, May 21–23, 1998

***A publication of MSRI.***

This CD-ROM presents video selections from the workshop held at MSRI (Berkeley, CA) for mathematical scientists and scientists in the biotech/pharmaceutical industry.

Featured speakers include D. Botstein, E. Branscomb, G. Churchill, P. Green, D. Haussler, L. Hood, R. Lipshutz, P. Pevzner, D. Siegmund, D. Slonim, G. Stormo, and E. Wijsman.

The purpose of the workshop was to acquaint the audience with the contributions made by mathematics, statistics, and computation to the acquisition and interpretation of genomic data and related areas of functional genomics. Invited speakers gave surveys of the challenges ahead, descriptions of key new technological developments, applications of mathematics and computation to specific related problems in genomics, and analysis of biological systems at the cellular level.

The CD requires Real®Video Player, which can be downloaded for free from the RealNetworks Internet home page. RealVideo Player is available for Windows95/Windows NT, Windows 3.1, MacOS, IRIX 6.2/6.3, Solaris 2.5 and Linux 2.0.

Distributed worldwide by the American Mathematical Society.

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**Contributors include:** D. Botstein, E. Branscomb, P. Green, D. Haussler, L. Hood, P. Pevzner, D. Siegmund, D. Slonim, G. Stormo, and E. Wijsman.

**Selections From MSRI's Video Archive**

December 1998, CD-ROM, 1991 *Mathematics Subject Classification*: 92Dxx, List $15, Order code MSRICD/3RT96

A Classic

## Surgery on Compact Manifolds

### Second Edition

**C. T. C. Wall**, *University of Liverpool, England*, and
**A. A. Ranicki (Editor)**, *University of Edinburgh, Scotland*

The publication of this book in 1970 marked the culmination of a particularly exciting period in the history of the topology of manifolds. The world of high-dimensional manifolds had been opened up to the classification methods of algebraic topology by Thom's work in 1952 on transversality and cobordism, the signature theorem of Hirzebruch in 1954, and by the discovery of exotic spheres by Milnor in 1956.

In the 1960s, there had been an explosive growth of interest in the surgery method of understanding the homotopy types of manifolds (initially in the differentiable category), including results such as the $h$-cobordism theory of Smale (1960), the classification of exotic spheres by Kervaire and Milnor (1962), Browder's converse to the Hirzebruch signature theorem for the existence of a manifold in a simply connected homotopy type (1962), the $s$-cobordism theorem of Barden, Mazur, and Stallings (1964), Novikov's proof of the topological invariance of the rational Pontrjagin classes of differentiable manifolds (1965), the fibering theorems of Browder and Levine (1966) and Farrell (1967), Sullivan's exact sequence for the set of manifold structures within a simply connected homotopy type (1966), Casson and Sullivan's disproof of the Hauptvermutung for piecewise linear manifolds (1967), Wall's classification of homotopy tori (1969), and Kirby and Siebenmann's classification theory of topological manifolds (1970).

The original edition of the book fulfilled five purposes by providing:

- a coherent framework for relating the homotopy theory of manifolds to the algebraic theory of quadratic forms, unifying many of the previous results;
- a surgery obstruction theory for manifolds with arbitrary fundamental group, including the exact sequence for the set of manifold structures within a homotopy type, and many computations;
- the extension of surgery theory from the differentiable and piecewise linear categories to the topological category;
- a survey of most of the activity in surgery up to 1970;
- a setting for the subsequent development and applications of the surgery classification of manifolds.

This new edition of this classic book is supplemented by notes on subsequent developments. References have been updated and numerous commentaries have been added. The volume remains the single most important book on surgery theory.

**Mathematical Surveys and Monographs**, Volume 69

April 1999, 302 pages, Hardcover, ISBN 0-8218-0942-3, LC 99-12274, 1991 *Mathematics Subject Classification*: 57-02, 57R57; 18F25, 19J25, 11E39, **All AMS members $47**, List $59, Order code SURV/69RT96

# AMERICAN MATHEMATICAL SOCIETY

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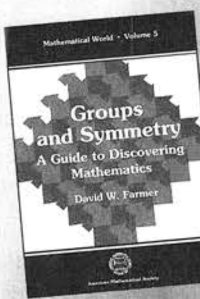
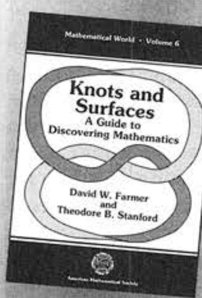
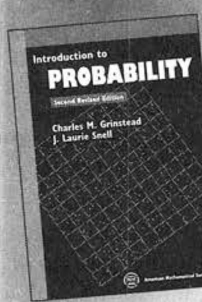
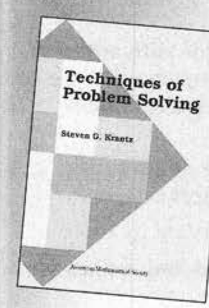
## Recommended Undergraduate Texts

The AMS offers an extensive selection of titles that are suitable for many levels of course study. The titles below are among those in high demand for course adoption by undergraduate mathematics teachers. For more recommended texts at the undergraduate level, visit the AMS Bookstore at www.ams.org/bookstore/.

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**George David Birkhoff** † and **Ralph Beatley**

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***—The Mathematics Teacher***

*Should be required reading for every teacher of geometry.*
***—Mathematical Gazette***

**AMS Chelsea Publishing**; 1959; ISBN 0-8284-0120-9; 294 pages; Hardcover; **All AMS members $18**, List $20, Order Code CHEL/120CT96

### Groups and Symmetry: A Guide to Discovering Mathematics

**David W. Farmer**, *Bucknell University, Lewisburg, PA*

*Nicely produced and concentrates on the informal analysis of geometrical patterns with the emphasis on informality ... could serve as a useful collection of activities to precede a formal course and would provide a range of intuitive experiences to which the more formal treatment could refer.*
***—The Mathematical Gazette***

*On the basis of this book it is possible to tailor a good course for high school students to really discover mathematics ... for anyone who is working with high school students in an advanced level the book is really recommended.*
***—Zentralblatt für Mathematik***

**Mathematical World**, Volume 5; 1996; ISBN 0-8218-0450-2; 102 pages; Softcover; **All AMS members $15**, List $19, Order Code MAWRLD/5CT96

### Knots and Surfaces: A Guide to Discovering Mathematics

**David W. Farmer**, *Bucknell University, Lewisburg, PA*, and **Theodore B. Stanford**, *University of Nevada, Reno*

*The book is perfectly suited to a course for non-science majors in need of fulfilling a math requirement. All the sections have worked well at sparking student interest and convincing them that math is much more interesting than mere number-crunching and graphing.*
***—Professor William Bloch, Wheaton College***

*Would serve well as the basis of an independent study course in which the student would work through the tasks in a journal subject to periodic review by the instructor ...*
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**Mathematical World**, Volume 6; 1996; ISBN 0-8218-0451-0; 101 pages; Softcover; **All AMS members $15**, List $19, Order Code MAWRLD/6CT96

### Introduction to Probability
**Second Revised Edition**

**Charles M. Grinstead**, *Swarthmore College, PA*, and **J. Laurie Snell**, *Dartmouth College, Hanover, NH*

1997; ISBN 0-8218-0749-8; 510 pages; Hardcover; **All AMS members $39**, List $49, Order Code IPROBCT96

### Techniques of Problem Solving

**Steven G. Krantz**, *Washington University, St. Louis, MO*

*Krantz has collected a thoroughly engaging arsenal of problems and problem-solving techniques. Most scientists will want to have a copy for personal reference and for the mental stimulation that it provides. It is well written in a style that encourages the reader to become actively involved ... a myriad of fascinating related problems are provided. After a delightful introductory chapter, the chapters are primarily organized around specific techniques and their applicability in areas such as geometry, logic, recreational math, and counting.*
***—CHOICE***

*Steven Krantz is a teacher, scholar, and artist. How else could he have written a book that not only introduces students to many of the great problems of mathematics, but also informs them about the process of solving these problems? Although many books include collections of intriguing problems,* Techniques of Problem Solving *uses clear development and lucid explanations to guide students through the process of problem solving. The text gives compelling examples that capture students' interest and encourages them to work problems at the end of the chapter ... Although the book would be excellent for a senior-level capstone course in mathematics, it would also appeal to advanced lower-division or strong high school students as well. [T]his superb book connects the worlds of great mathematical problems with effective classroom instruction.*
***—The Mathematics Teacher***

1997; ISBN 0-8218-0619-X; 465 pages; Softcover; **All AMS members $23**, List $29, Order Code TPSCT96

### Solutions Manual for Techniques of Problem Solving

**Luis Fernández** and **Haedeh Gooransarab**, *Washington University, St. Louis, MO*, with assistance from Steven G. Krantz

1997; ISBN 0-8218-0628-9; 188 pages; Softcover; **All AMS members $10**, List $12, Order Code SMTPSCT96

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*Nearly any ten years there seems to arrive a new edition of this now classical book the review of which (1st edition 1967, Zbl. 153,324; 2nd edition 1979, Zbl. 428.00002) the reviewer hardly can improve. The main advantage of the authors had been the introduction of thoroughly categorical concepts into algebra.*
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**AMS Chelsea Publishing**; 1988; ISBN 0-8218-1646-2; 626 pages; Hardcover; **All AMS members $35**, List $39, Order Code CHEL/330.HCT96

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The AMS is pleased to invite authors to submit manuscripts to be considered for publication in the ***Student Mathematical Library***, a new series of undergraduate studies in mathematics.

This developing series is intended to spark undergraduates' appreciation for research by introducing them to interesting topics of modern mathematics. By emphasizing original topics and approaches, the series aims to broaden students' mathematical experiences. Books to be published in the series should be suitable for honors courses, upper-division seminars, reading courses, or self-study.

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Volumes in the *Student Mathematical Library* series that would be suitable as continuations from standard undergraduate courses might cover topics such as: coding theory following on from number theory and/or algebra, Fourier series from analysis or ODEs, elementary PDEs from analysis and ODEs. Volumes that are related to topics normally seen in graduate school might cover: introductory differential geometry, minimal surfaces, introductory algebraic geometry, topics in representation theory, complex analysis, or probability. Other volumes might cover topics that are not standard elements of the curriculum, such as mathematical physics, game theory, or mathematics of finance.

These works should contain problems, either within the body of the text or at the end of each chapter or section. Connections to current research are encouraged; this may take the form of reports on recent results and, when appropriate, lists of open problems of continuing interest.

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

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# Classified Advertisements

*Positions available, items for sale, services available, and more*

## OHIO

### CASE WESTERN RESERVE UNIVERSITY
### Faculty Positions in Mathematics

The Department of Mathematics anticipates openings at the senior and junior levels beginning January 2000, with additional tenure-track and visiting positions beginning August 2000.

Case Western Reserve University is a private research university, with, in addition to a College of Arts and Sciences, schools of medicine, business, engineering, and other areas which interact with the Department. Current research interests of the Department include both core and applied mathematics in the areas of algebra, analysis, differential equations/dynamical systems, geometry, probability, numerical and computational mathematics, imaging reconstruction and analysis, theoretical computer science, and certain areas of modeling.

A person appointed to a senior position will be a midcareer individual with a proven record of attracting research funding who will enhance the Department's interaction with other units at CWRU. A person appointed to a junior position will have potential in these areas. For the positions beginning in August 2000, candidates in all fields of mathematics will be considered, with particular interest in those fields that fit in well with the current state of mathematics at CWRU.

Required: Ph.D. in mathematics; exceptional promise, with accomplishments commensurate with experience in research and teaching. A complete application should contain AMS Cover Sheet, letter of application (including e-mail address and fax number), curriculum vitae, and relevant (p)reprints. Candidates should also have three letters of recommendation sent.

Mail all materials to: James Alexander, Chair, Department of Mathematics, Case Western Reserve University, Cleveland, OH 44106-7058. No e-mail or fax applications will be accepted. Screening and processing applications will begin September 15; however, applications will be accepted until positions are filled.

CWRU is an Affirmative Action/Equal Opportunity Employer.

## TEXAS

### UNIVERSITY OF HOUSTON-CLEAR LAKE
### Mathematics Education

The University of Houston-Clear Lake School of Natural and Applied Sciences invites applications for a position in mathematics education beginning August 1999. The position is, pending funding approval, a tenure-track position. The position requires a doctorate in mathematics education or a doctorate in mathematics with extensive experience teaching university mathematics education courses. Preference will be given to candidates with extensive public school teaching experience.

Duties will include teaching, research, and service. Responsibilities will include acting as director of the recently created Math Center and teaching 3 courses per academic year. The mathematical sciences program at UHCL includes faculty in pure and applied mathematics, statistics, and mathematics education. Degrees are granted at the bachelor's and master's levels. Send the completed AMS Standard Cover Sheet, a letter of interest, vita, transcripts, and three letters of recommendation to: Marty Spears, Chair, Search Committee, University of Houston-Clear Lake, Houston, TX 77058.

UHCL is an AA/EO Institution.

## VIRGINIA

### NATIONAL SCIENCE FOUNDATION

NSF's Division of Ocean Science is seeking qualified applicants for the position of Associate Program Director (AD-3, salary range $58,027 to $91,410 per annum) or Program Director (AD-4, salary range $68,570 to $106,868 per annum) in the Physical Oceanography Program.

This position is excepted from the competitive civil service and will be filled about winter 1999 on a 1- or 2-year visiting scientist/temporary basis.

Alternatively, the position may be filled under the Intergovernmental Personnel Act (IPA). Individuals eligible for an IPA assignment include employees of state

**Suggested uses** for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

**The 1999 rate is** $100 per inch or fraction thereof on a single column (one-inch minimum), calculated from top of headline. Any fractional text of $1/2$ inch or more will be charged at the next inch rate. No discounts for multiple ads or the same ad in consecutive issues. For an additional $10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Headlines will be centered in boldface at no extra charge. Ads will appear in the language in which they are submitted.

There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified advertising.

**Upcoming deadlines** for classified advertising are as follows: August issue–May 21, 1999; September issue–June 21, 1999; October issue–July 23, 1999; November issue–August 23, 1999; December issue–September 24, 1999; January 2000 issue–October 25, 1999.

**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.

and local government agencies, institutions of higher education, Indian tribal governments, federally funded research and development centers, and qualified nonprofit organizations involved in public management. IPA applicants must be permanent career employees of their current employer for at least 90 days prior to entering into a mobility assignment agreement. The individual remains an employee of the home institution, and cost-sharing arrangements are negotiated between NSF and the individual's institution.

Primary responsibilities involve proposal evaluation, project development and support, program planning and budgeting, and related administrative duties.

Qualifications Required: For the AD-3 level, applicants must have a Ph.D. or equivalent experience in physical oceanography or related disciplinary fields and four or more years of successful research and research administration experience pertinent to the position. For the AD-4 level, applicants must have a Ph.D. or equivalent experience in physical oceanography or related disciplinary fields and six or more years of successful research and research administration experience pertinent to the position.

Interested applicants should submit a letter of recommendation and vita to: National Science Foundation, Division of Human Resources Management, 4201 Wilson Blvd., Room 315, Arlington, VA 22230 USA; Attn.: Myra Loyd and reference vacancy announcement EX99-46. For further information call 703-306-1185 x3090. For technical information call Dr. Reece, Ocean Science Research, 703-306-1582. Hearing-impaired individuals should call TDD 703-306-0189.

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## AUSTRIA

### Chair in Mathematical Finance

The Faculty for Science and Engineering of the Johannes Kepler University in Linz, Austria, invites applications for a newly created position at the level of full professor in mathematical finance, to commence as soon after the first of March 2000 as possible. We are looking for a mathematician with a Ph.D., scientific qualifications equivalent to a European habilitation, and a distinguished research reputation in the field of mathematical finance. The appointee should be willing to establish collaboration with the financial industry in joint research projects (for example, in the fields of derivative products or risk management).

The Johannes Kepler University specifically encourages female candidates to apply, with a view to increasing the proportion of female professors.

Applications should be accompanied by a curriculum vitae, list of publications, teaching record, a brief research prospectus, and copies of three of the candidate's most important and relevant publications. These should be submitted to Dean Prof. Dr. Heinz W. Engl, Dekanat der TNF, Johannes Kepler Universität Linz, Altenbergerstrasze 69, A-4040 Linz, Austria, no later than Sept. 30, 1999.

## ENGLAND

### UNIVERSITY OF SUSSEX, BRIGHTON

**Chair in Pure Mathematics**
**(Ref. 090)**

The University of Sussex invites applications for a chair in pure mathematics. The appointed full professor will be active in a research area appropriate to the Centre for Mathematical Analysis and Its Applications, one of two research centres in the School of Mathematical Sciences. The chair is tenable from September 1, 1999, or a later date to be arranged. Pure mathematics at Sussex was very highly rated in the last national Research Assessment Exercise. The professor will be expected to provide enthusiastic leadership of the pure mathematics group in both teaching and research. Associated with this chair is a permanent lectureship in pure mathematics, which the professor will be involved in filling.

Salary will be within the professorial range.

Informal enquiries may be made to the dean of the School of Mathematical Sciences, Professor Charles Goldie (e-mail `C.M.Goldie@sussex.ac.uk`, tel (+44) 1273 678311, or fax (+44) 1273 678097).

**Lectureship in Applied Mathematics**
**(Ref. 091)**

The University of Sussex invites applications for a permanent lectureship in applied mathematics. The lectureship is associated with the Centre for Mathematical Analysis and Its Applications in the School of Mathematical Sciences and, in particular, with the applied mathematics group led by Professor C. M. Elliott, whose focus for research is the analysis and numerical analysis of partial differential equations and their applications. The successful candidate will have expertise in one or more of modelling, numerical and applied analysis, and scientific computation and will be willing to collaborate with other members of the Centre. The post is tenable from September 1, 1999, or a later date to be arranged.

Salary will be on either the Lecturer Grade A (16,655–21,815 pounds) or Grade B (22,726–29,048 pounds) scales per annum according to qualifications and relevant experience.

Informal enquiries about the post may be made to Professor C. M. Elliott (`c.m.elliott@sussex.ac.uk`).

Further details of both posts and of the School's activities can be found at `http://www.maths.sussex.ac.uk/Posts/`.

Applications should include a full curriculum vitae and the names and addresses of three referees and are needed by June 30, 1999, or as soon as possible thereafter.

Further particulars may be obtained from Sandra Jenks, Staffing Services Office, Sussex House, University of Sussex, Brighton BN1 9RH, England; tel (+44) 1273 678201; fax (+44) 1273 678335; e-mail: `S.Jenks@sussex.ac.uk`.

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## GERMANY

### UNIVERSITY OF PADERBORN
### Professor of Mathematics

The Department of Mathematics and Computer Science invites applications for a tenured professorship in a field which supplements the Center of Scientific Computation in the Department. The salary will be on the C3 level. Preference will be given to candidates working in the areas of stochastics and/or its applications. Applicants are expected to have an excellent record of research and a strong commitment to teaching. Postdoctoral experience is required. Requirements include the habilitation or equivalent qualifications (§49 Abs. 1 Ziff. 4 a Universitätsgesetz NRW).

Teaching duties will include stochastics. Additionally, all applicants are also expected to teach, mostly in German, courses across the mathematics curriculum.

Applications should be sent within 4 weeks of this publication by quoting reference number 190 to: Dekan Fachbereich 17, Universität Paderborn, D-33095 Paderborn, Germany.

Applicants must submit a curriculum vitae, including a list of publications, and the names, addresses, fax, and phone numbers of at least three referees.

The University is interested in increasing the number of female faculty and particularly invites women to apply for the position.

Information about the Center of Scientific Computation can be obtained at the above address or through `http://math-www.uni-paderborn.de/`.

## KOREA

### KOREA INSTITUTE FOR ADVANCED STUDY SCHOOL OF MATHEMATICS
### Postdoctoral Research Fellowships

The School of Mathematics at the Korea Institute for Advanced Study (KIAS) invites applications for positions at the level of postdoctoral research fellows in the mainstream areas of pure and applied mathematics. Priority will be given to the area of differential geometry and topology. KIAS, incepted in 1996, is committed to the excellence of research in basic sciences. Applicants are expected to have demonstrated exceptional research potential, including major contributions beyond or through the doctoral dissertation. Salary for 12 months is up to $25,000 (30,000,000 Korean Won) with additional funds of $5,000 (W6,000,000) to defray expenses related to research activities. The initial appointment for the position is two years and is renewable up to two additional years, depending on research performance. Applications can be considered all year round, but those wishing to be appointed this year are encouraged to apply as soon as possible. Applications must include a complete vita, with a list of publications, a research plan, and three letters of recommendation, and should be mailed to: Korea Institute for Advanced Study (KIAS), 207-43, Chungryangri-dong, Dongdaemun-ku, Seoul 130-012, Korea; tel: (011)-82-2-958-3775; fax: (011)-82-2-958-3770; e-mail: fellow@kias.re.kr.

## SOUTH AFRICA

### UNIVERSITY OF CAPE TOWN
### Professor in Mathematics

The Department of Mathematics and Applied Mathematics wishes to appoint a mathematician with an outstanding research record to a chair. Preference will be given to applicants able to lead research and teaching in one of the fields of topology and formal aspects of computing, two of the strong areas of research within the Department. However, applications are also welcome from researchers with strength in areas such as functional analysis, algebra, logic, algebraic geometry, differential geometry, number theory, and dynamical systems.

The Department is a large and dynamic organization with some 47 full-time members of academic, administration, technical, and support staff. The headship of the Department becomes vacant in mid-2000, and the successful candidate for this chair will, if so desired, be eligible for appointment as head.

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Send your CV (including the names, postal/e-mail addresses, tel/fax numbers of 3 referees) to: The Staff Recruitment Office, University of Cape Town, Rondebosch 7701, Cape Town, South Africa, by June 30, 1999 (however, late applications will be accepted until an appointment is made); tel: +27-21-650-2196; fax: +27-21-686-2565; e-mail: samuel@bremner.uct.ac.za; Web site: http://www.uct.ac.za/.

## PUBLICATIONS WANTED

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* USA/Canada: M.S. degree or equivalent in Math. Candidates having adequate teaching experience at college level will be given preference.
* UK/Ireland: First degree in Maths with appropriate post-graduate qualification (M.Sc., M.Ed. or P.G.C.E.). A-level or college teaching experience is essential.
* Candidates must be native speakers of English.

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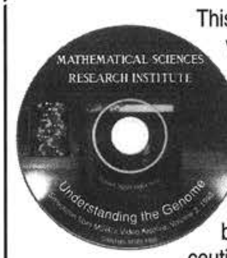
## Understanding the Genome: Technological and Mathematical Challenges, May 21–23, 1998

***A publication of MSRI.***




This CD-ROM presents video selections from the workshop held at MSRI (Berkeley, CA) for mathematical scientists and scientists in the biotech/pharmaceutical industry.

Featured speakers include D. Botstein, E. Branscomb, G. Churchill, P. Green, D. Haussler, L. Hood, R. Lipshutz, P. Pevzner, D. Siegmund, D. Slonim, G. Stormo, and E. Wijsman.

The purpose of the workshop was to acquaint the audience with the contributions made by mathematics, statistics, and computation to the acquisition and interpretation of genomic data and related areas of functional genomics. Invited speakers gave surveys of the challenges ahead, descriptions of key new technological developments, applications of mathematics and computation to specific related problems in genomics, and analysis of biological systems at the cellular level.

The CD requires Real®Video Player, which can be downloaded for free from the RealNetworks Internet home page. RealVideo Player is available for Windows95/Windows NT, Windows 3.1, MacOS, IRIX 6.2/6.3, Solaris 2.5 and Linux 2.0.

Distributed worldwide by the American Mathematical Society.

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**Selections From MSRI's Video Archive**; 1998; CD-ROM; List $15; Order code MSRICD/3NA

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# MATHEMATICAL SCIENCES RESEARCH INSTITUTE

1000 Centennial Drive, Berkeley, California 94720-5070

## The Institute solicits applications for membership during the 2000-2001 year.

## MSRI will feature three programs in 2000-2001:

**OPERATOR ALGEBRAS (Fall 2000 - Spring 2001)** 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. The following topics will be emphasized : Noncommutative dynamical systems; Simple C*-algebras; Subfactors; Algebraic quantum field theory; Free probability theory; Noncommutative Banach spaces; Quantization; Noncommutative Geometry . These topics will be sequenced as above in overlapping segments.
*Program committee:* C. Anantharaman-Delaroche, H. Araki, A. Connes, J. Cuntz, E.G. Effros, U. Haagerup, V.F.R. Jones, M.A. Rieffel, D.V. Voiculescu.

**ALGORITHMIC NUMBER THEORY (Fall 2000)** Throughout history, number theorists have tended to enjoy making computations. This predilection has been greatly reinforced in the last 20 years by faster computers and better software, and also by an explosion of interest from algebraic geometry, cryptography, and areas of computer science. The MSRI program will cover algorithmic number theory broadly, with an eye to fostering new developments, and to covering both the theoretical and practical sides of this field. Specific topics will include elliptic curves, factoring, combinatorial number theory, analytic number theory, algebraic number fields, lattice basis reduction, finite fields, higher genus curves, higher dimensional varieties, and many others. There will be an introductory workshop in August, a workshop on cryptography in October, and a workshop on arithmetic algebraic geometry in December. We hope that the a diverse collection of participants will include number theorists of all stripes as well as people from other fields interested in number theory and its applications.
*Program committee:* J. Buhler, C. Dwork, H. Lenstra, A. Odlyzko, B. Poonen, N. Yui.

**SPECTRAL INVARIANTS: Analytic and Geometric Aspects (Spring 2001)** The past few decades have witnessed many new developments in the broad area of spectral theory of geometric operators, centered around the study of new spectral invariants and their application to problems in conformal geometry, classification of 4-manifolds, index theory, relationship with scattering theory and other topics. This program will bring together people working on different problems in these areas, to appraise the current status of development, encourage interactions among these different points of view, and to assess future directions. Some specific topics are: new developments originating in the zeta-regularized determinant of Ray and Singer, leading to the introduction of extremal conformal metrics on 4-manifolds, sharp inequalities arising from the variational characterization of eigenvalues for conformally invariant operators, including scalar curvature equations, and subtle nonlinear phenomena in these equations, the $\eta$ invariant and spectral flow of Dirac-type operators, and gluing formulae for these invariants, leading to a better understanding of their existence and nature on singular spaces, new generalizations of the index theorem, noncommutative residues on spaces of Lagrangian distributions and wave invariants, and new advances in geometric scattering theory. Of particular interest are the new insights into linear and nonlinear PDEs arising from the geometric connections among these topics.
*Program committee*: Tom Branson, S.-Y. Alice Chang, Rafe Mazzeo, Kate Okikiolu.

In addition to these programs, MSRI also continues the **COMPLEMENTARY PROGRAM**, in which applications from candidates working in any field of mathematics are welcome. Candidates should specify why a fellowship at MSRI at this time is particularly relevant for their research, for example, by describing potential interactions with one of the above fields, or indicating interest in one or more of MSRI's joint industrial fellow/internships.

### MSRI has available three award categories available to applicants:

**Research Professorships.** These awards, which provide partial salary support for at least three months, are intended for mathematicians with Ph.D.s awarded in 1994 or earlier. **Application Deadline: September 25, 1999.**

**Postdoctoral Fellowships.** These awards, which provide support for five to ten months, are intended for mathematicians with Ph.D.s awarded in 1995 or later. There will be several one-semester awards for participants in half-year programs; this could be extended to a full year in special cases. In addition, together with **Hewlett-Packard** and **Microsoft Research**, MSRI will make several fellowship/intern awards. **Application Deadline: November 25, 1999.**

**General Memberships.** These awards may provide partial support toward living and travel expenses. It is expected that general members will come with partial or full support from other sources. **Application Deadline: November 25, 1999.**

**Further information and application forms are available from http://www.msri.org or by writing to MSRI, 1000 Centennial Drive, Berkeley CA 94720-5070.**

# IMPORTANT PUBLICATIONS FROM World Scientific

World Scientific Series in 20th Century Mathematics - Vol. 5

## FIELDS MEDALLISTS' LECTURES

edited by **Sir Michael Atiyah** *(Trinity College, Cambridge)* & **Daniel Iagolnitzer** *(CE-Saclay)*

A list of Fields Medallists and their contributions provides a bird's eye view of mathematics over the past 60 years. It highlights the areas in which, at various times, greatest progress has been made. This volume does not pretend to be comprehensive, nor is it a historical document. On the other hand, it presents contributions from 22 Fields Medallists and so provides a highly interesting and varied picture.

**Readership:** Mathematicians and mathematical physicists.

**644pp • Oct 1997 • 981-02-3102-4 • US$86 • 981-02-3117-2(pbk) • US$48**

***Co-published with Singapore University Press***

## WOLF PRIZES IN MATHEMATICS

(In 2 Volumes)

edited by **S S Chern** *(Univ. of California, Berkeley)* & **F Hirzebruch** *(Universität Bonn & Max-Planck-Institut für Mathematik, Germany)*

This invaluable book features Bibliographies, important papers, and speeches (for example at international congresses) of Wolf Prize winners, such as S S Chern, F Hirzebruch, J Leray, I Piatestski-Shapiro, etc. This is the first time that lectures by several Wolf Prize winners have been published together. Since the work of the Wolf laureates covers a wide spectrum, much of the mathematics of the twentieth century comes to life in this books.

**Readership:** Mathematicians.

**1200pp (~) • Autumn 2000 • 981-02-3928-9 (set) • US$90**

## SEIBERG-WITTEN THEORY AND INTEGRABLE SYSTEMS

by **Andrei Marshakov** *(P N Lebedev Physics Institute and Institute of Theoretical and Experimental Physics, Russia)*

This book presents in a clear form the main ideas of the relation between the exact solutions to the supersymmetric (SUSY) Yang-Mills theories and integrable systems. This relation is a beautiful example of reformulation of close-to-realistic physical theory in terms widely known in mathematical physics – systems of integrable nonlinear differential equations and their algebro-geometric solutions.

**Readership:** Research students in mathematics and theoretical physics, and professionals in quantum field theory, string theory and integrable systems.

**260pp • Mar 1999 • 981-02-3636-0 • US$48 • 981-02-3637-9(pbk) • US$24**

## WITTEN'S LECTURES ON THREE-DIMENSIONAL TOPOLOGICAL QUANTUM FIELD THEORY

by **Sen Hu** *(Princeton Univ.)*

This invaluable book is based on E Witten's lectures on topological quantum field theory which were presented in the spring of 1989 at Fine Hall, Princeton. At that time Witten unified several important mathematical works in terms of quantum field theory, most notably the Donaldson polynomial, Gromov/Floer homology and Jones polynomials.

**Readership:** Undergraduates in mathematics.

**200pp (~) • Autumn 1999 • 981-02-3908-4 • US$48 • 981-02-3909-2(pbk) • US$24**

World Scientific Series in 20th Century Mathematics - Vol. 6

## SELECTED LOGIC PAPERS

by **G E Sacks** *(Harvard Univ.)*

**Contents:** Recursive Enumerability and the Jump Operator; On the Degrees Less Than **0'**; A Simple Set Which Is Not Effectively Simple; The Recursively Enumerable Degrees Are Dense; Metarecursive Sets (with *G Kreisel*); Post's Problem, Admissible Ordinals and Regularity; and other papers.

**Readership:** Mathematical logicians and computer scientists.

**400pp (~) • Summer 1999 • 981-02-3267-5 • US$78**

### NEW JOURNAL FOR 1999

## COMMUNICATIONS IN CONTEMPORARY MATHEMATICS

Editors-in-Chief: **Haïm Brezis** *(Universite. Paris VI, France)* & **Xiao-Song Lin** *(Univ. of California, Riverside, USA)*

Editors: **Jerry Bona** *(Univ. of Texas, Austin)*, **Felix Browder** *(Rutgers Univ.)*, **Luis Cafferelli** *(Univ. of Texas, Austin)*, **Thierry Cazenave** *(CNRS)*, **Sun-Yung A Chang** *(UCLA)*, **Kung-Ching Chang** *(Peking Univ.)*, **Weinan E** *(Courant, NYU)*, **Yakov Eliashberg** *(Stanford Univ.)*, **Ron Fintushel** *(Michigan State Univ.)*, **Dan Freed** *(Univ. of Texas, Austin)*, **Michael Freedman** *(UC San Diego & Microsoft)*, **Hillel Furstenberg** *(Jerusalem)*, **David Kinderlehrer** *(Carnegie Mellon)*, **Sergiu Klainerman** *(Princeton Univ.)*, **Joel Lebowitz** *(Rutgers Univ.)*, **Jim Lepowsky** *(Rutgers Univ.)*, **Jian-Shu Li** *(Univ. of Maryland , College Park)*, **Fanghua Lin** *(Courant, NYU)*, **John Mather** *(Princeton Univ.)*, **Jean Mawhin** *(Louvain, Belgium)*, **Jocab Palis** *(IMPA, Brasil)*, **Richard Schoen** *(Stanford Univ.)*, **Gang Tian** *(MIT)*, **Zhihong Xia** *(Northwestern)*, **Edward Zehnder** *(ETH)*.

It intends to communicate the research in the fields of : Algebra, Analysis, Applied Mathematics, Dynamical Systems, Geometry, Mathematical Physics, Number Theory, Partial Differential Equations, and Topology, among others. It hopes to provide a forum to stimulate interactions between different areas.

**ISSN: 0219-1997 • Vol. 1/1999 • 4 Issues**

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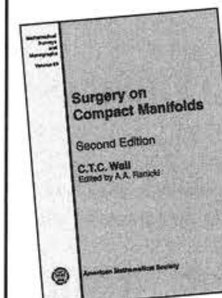
**A Classic**

## Surgery on Compact Manifolds

### Second Edition




**C. T. C. Wall,** *University of Liverpool, England,* and **A. A. Ranicki (Editor),** *University of Edinburgh, Scotland*

The publication of this book in 1970 marked the culmination of a particularly exciting period in the history of the topology of manifolds. The world of high-dimensional manifolds had been opened up to the classification methods of algebraic topology by Thom's work in 1952 on transversality and cobordism, the signature theorem of Hirzebruch in 1954, and by the discovery of exotic spheres by Milnor in 1956.

The original edition of the book fulfilled five purposes by providing:

- a coherent framework for relating the homotopy theory of manifolds to the algebraic theory of quadratic forms, unifying many of the previous results;
- a surgery obstruction theory for manifolds with arbitrary fundamental group, including the exact sequence for the set of manifold structures within a homotopy type, and many computations;
- the extension of surgery theory from the differentiable and piecewise linear categories to the topological category;
- a survey of most of the activity in surgery up to 1970;
- a setting for the subsequent development and applications of the surgery classification of manifolds.

This new edition of this classic book is supplemented by notes on subsequent developments. References have been updated and numerous commentaries have been added. The volume remains the single most important book on surgery theory.

**Mathematical Surveys and Monographs,**
Volume 69; 1999; 302 pages; Hardcover;
ISBN 0-8218-0942-3; List $59; All AMS members $47;
Order code SURV/69NA

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# AMS APPLICATION FOR MEMBERSHIP 1999

AMERICAN MATHEMATICAL SOCIETY

JANUARY—DECEMBER

*Please read the "Membership Categories" section of this form to determine the membership category for which you are eligible. Then fill out this application and return it as soon as possible.*

**Date** ____________ **19**____________

Family Name ____ First ____ Middle ____

*Place of Birth* 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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Telephone number(s) ____________

Electronic address ____________

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**Signature**

## 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

## Prepayment Methods and Mailing Addresses

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## 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.

***Introductory ordinary member rate applies*** to the first five ***consecutive*** years of ordinary membership. Eligibility begins with the first year of membership in any category other than student and nominee. Dues are $50.

For ***ordinary members*** whose annual professional income is below $55,000, the dues are $99; for those whose annual professional income is $55,000 or more, the dues are $132.

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 $198. 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 $33, and annual verification is required.

The annual dues for ***reciprocity members*** who reside outside the U.S. are $66. To be eligible for this classification, members must belong to one of those foreign societies with which the AMS has established a reciprocity agreement, and annual verification is required. Reciprocity members who reside in the U.S. must pay ordinary member dues ($99 or $132).

The annual dues for ***category-S members,*** those who reside in developing countries, are $16. Members can 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.

## 1999 Dues Schedule (January through December)

| | | | |
|---|---|---|---|
| Introductory ordinary member rate | | | ☐$50 |
| Ordinary member | | ☐$99 | ☐$132 |
| Joint family member (full rate) | | ☐$99 | ☐$132 |
| Joint family member (reduced rate) | | ☐$79 | ☐$112 |
| Contributing member (minimum $192) | | | ☐ |
| Student member (please verify)[1] | | | ☐$33 |
| Unemployed member (please verify)[2] | | | ☐$33 |
| Reciprocity member (please verify)[3] | ☐$66 | ☐$99 | ☐$132 |
| 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
- ☐ Canadian 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
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- ☐ Mongolian Mathematical Society
- ☐ Nepal Mathematical Society
- ☐ New Zealand Mathematical Society
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- ☐ Norsk Matematisk Forening
- ☐ Österreichische Mathematische Gesellschaft
- ☐ Palestine Society for Mathematical Sciences
- ☐ Polskie Towarzystwo Matematyczne
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- ☐ Ramanujan Mathematical Society
- ☐ Real Sociedad Matemática Española
- ☐ Saudi Association for Mathematical Sciences
- ☐ Singapore Mathematical Society
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- ☐ 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
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- ☐ 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
- ☐ Svenska Matematikersamfundet
- ☐ Ukrainian Mathematical Society
- ☐ Union Mathemática Argentina
- ☐ Union of Bulgarian Mathematicians
- ☐ Union of Czech Mathematicians and Physicists
- ☐ Union of Slovak Mathematicians and Physicists
- ☐ Unione Matematica Italiana
- ☐ Vijnana Parishad of India
- ☐ Wiskundig Genootschap

# Meetings & Conferences of the AMS

**IMPORTANT NEW PROGRAM INFORMATION:** In order that AMS meeting programs include the most timely information for each speaker, abstract deadlines have been moved to dates much closer to the meeting. As a result, Sectional Meeting programs have been appearing in the *Notices* ***after*** the meeting takes place. The Secretariat of the AMS has observed that this arrangement does not provide an adequate service to the reader. So, beginning with the Gainesville meeting (March 12-13, 1999), AMS Sectional Meeting programs will no longer appear in the print version of the *Notices*. However, prior to the meeting date, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on e-MATH. See `http://www.ams.org/meetings/`. Programs and abstracts will continue to be displayed on e-MATH in the Meetings and Conferences section until about three weeks after the meeting is over. Final programs for Sectional Meetings will be archived on e-MATH in the next electronic issue of the *Notices* which follows the meeting. See the entry "Program issue of electronic *Notices*" listed below for each meeting to identify the specific issue.

## Las Vegas, Nevada

*University of Nevada-Las Vegas*

**April 10–11, 1999**

**Meeting #942**

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: February 1999
Program first available on eMATH: March 5, 1999
Program issue of electronic *Notices*: June/July 1999
Issue of *Abstracts*: Volume 20, Issue 2

## 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*: February 1999
Program first available on eMATH: March 17, 1999
Program issue of electronic *Notices*: June/July 1999
Issue of *Abstracts*: Volume 20, Issue 3

## 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*: February 1999
Program first available on eMATH: April 8, 1999
Program issue of electronic *Notices*: June/July 1999
Issue of *Abstracts*: Volume 20, Issue 3

## 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*: April 1999
Program first available on eMATH: N/A
Program issue of electronic *Notices*: N/A
Issue of *Abstracts*: N/A

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

### Invited Addresses

**Jennifer Chayes**, Microsoft, *Title to be announced.*

**Michael Eastwood**, University of Adelaide, *Title to be announced.*

**Roger Grimshaw**, Monash University, *Title to be announced.*

**Gerhard Huisken**, University of Tuebingen, *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

*Algebraic Groups and Related Topics*, **Eric Friedlander**, Northwestern University, and **Gustav Lehrer**, University of Sydney.

*Computability and Complexity*, **Rod Downey**, Victoria University.

*Differential Geometry and Partial Differential Equations*, **Benjamin H. Andrews**, Australian National University, **Michael G. Eastwood**, University of Adelaide, **Klaus Ecker**, Monash University, and **Gerhard Huisken**, Princeton University and University of Tuebingen.

*Fluid Dynamics*, **Susan Friedlander**, Northwestern University, and **Roger H. J. Grimshaw**, Monash University.

*General Relativity*, **Robert Bartnik**, University of Canberra, **Gregory Galloway**, University of Miami, and **Anthony Lun**, Monash University.

*Geometric Group Theory*, **Swarup Gadde** and **Walter Neumann**, University of Melbourne.

*Geometric Themes in Group Theory*, **Gustav I. Lehrer**, University of Sydney, **Cheryl E. Praeger**, University of Western Australia, and **Stephen D. Smith**, University of Illinois at Chicago.

*Group Actions*, **Marston Conder**, **Gaven Martin**, and **Eamonn O'Brien**, University of Auckland.

*Low-Dimensional Topology*, **William H. Jaco**, Oklahoma State University, and **Hyam Rubinstein**, Melbourne University.

*Mathematical Physics: Many Body Systems*, **Alan L. Carey**, University of Adelaide, **Paul A. Pearce**, University of Melbourne, and **Mary Beth Ruskai**, University of Massachusetts, Lowell.

*Mathematics Learning Centers*, **Judith Baxter**, University of Illinois, Chicago, **Marian Kemp**, Murdoch University, **Jackie Nicholas**, University of Sidney, and **Jeanne Wald**, Michigan State University.

*Moduli Spaces of Riemann Surfaces, Mapping Class Groups and Invariants of 3-manifolds*, **Ezra Getzler**, Northwestern University, and **Richard Hain**, Duke University.

*Nonlinear Dynamics and Optimization*, **A. F. Ivanov**, Penn State University and University of Ballarat, **A. Mees**, University of Western Australia, and **A. Rubinov**, University of Ballarat.

*Operations Research Methods and Applications*, **Adi Ben-Israel**, Rutgers University, and **Moshe Sniedovich**, University of Melbourne.

*Probability Theory and Its Applications*, **Timothy Brown**, University of Melbourne, **Phil Pollett**, University of Queensland, and **Ruth J. Williams**, University of California, San Diego.

*Recent Trends in Operator Theory and Harmonic Analysis*, **Michael T. Lacey**, Georgia Institute of Technology, and **Alan G. R. McIntosh**, Macquarie University.

*Solitons, Integrable Systems and Singular Limits*, **Jared Bronski**, University of Illinois, Urbana, **Nalini Joshi**, University of Adelaide, **Peter Miller**, Monash University, and **Colin Rogers**, University of New South Wales.

# Salt Lake City, Utah

*University of Utah*

### September 25–26, 1999

### Meeting #946

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: June/July 1999
Program first available on eMATH: August 19, 1999
Program issue of electronic *Notices*: December 1999
Issue of *Abstracts*: Volume 20, Issue 4

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: August 3, 1999

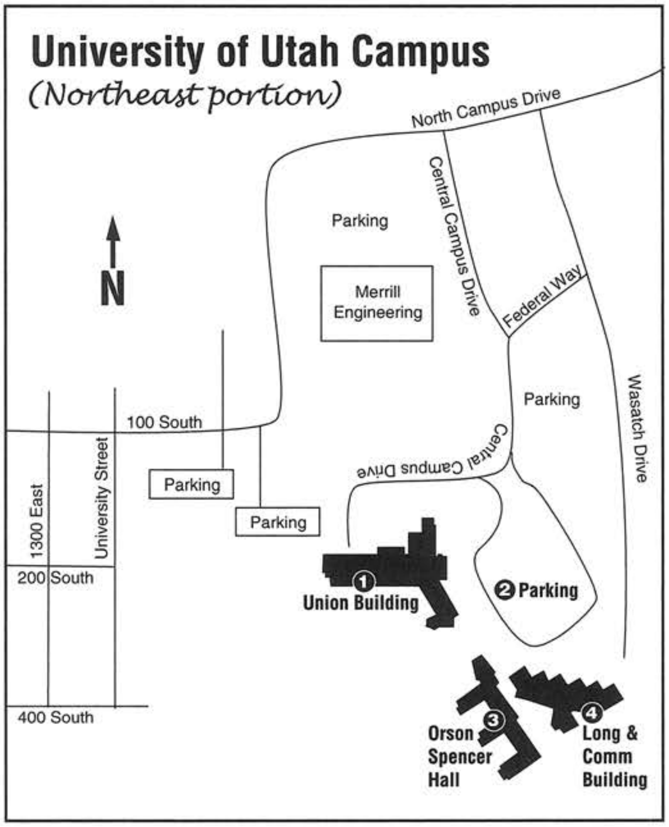
### Invited Addresses

**Robert Burton**, Oregon State University, *Title to be announced.*

**Michael Kapovich**, University of Utah, *Title to be announced.*

**Richard Wentworth**, University of California, Irvine, *Title to be announced.*

**Maciej Zworski**, University of California, Berkeley, *Title to be announced.*




## Special Sessions

*Arithmetical Algebraic Geometry* (Code: AMS SS B1), **Minhyong Kim**, University of Arizona, and **Wieslawa Niziol**, University of Utah.

*Commutative Algebra* (Code: AMS SS C1), **Paul Roberts**, University of Utah, and **Roger Wiegand**, University of Nebraska.

*Complex Variables and Operator Theory* (Code: AMS SS A1), **Siqi Fu**, **Farhad Jafari**, and **Peter Polyakov**, University of Wyoming.

*Ergodic Theory of Stochastic Processes* (Code: AMS SS D1), **Stewart N. Ethier** and **Davar Khoshnevisan**, University of Utah.

*Microlocal Analysis and Applications* (Code: AMS SS E1), **Gunther Uhlmann**, University of Washington, and **Maciej Zworski**, University of California, Berkeley.

*Numerical Methods for Partial Differential Equations* (Code: AMS SS F1), **Benito Chen** and **Junping Wang**, Institute for Scientific Study, University of Wyoming.

## 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. **Deadline for reservations is August 24.**

**Doubletree Hotel,** 255 South West Temple, Salt Lake City, UT; 801-328-2000; $89/single or double.

**Marriott Residence Inn-Trolley Square**, 765 East 400 South, Salt Lake City, UT; 801-532-5511 or 800-331-3131; $69/single or double and $10/for 3rd guest.

**Quality Inn City Center,**154 West 600 South, Salt Lake City, UT; 800-521-9997 or 801-521-2930; $58/single or double.

## Food Service

There are a number of restaurants adjacent to the campus. A list of restaurants will be available at the registration desk. Food service will also be available in the Olpin Union Building.

## Local Information

Please visit the Web site maintained by the Department of Mathematics at www.math.utah.edu/, the University of Utah Web site www.utah.edu/, or Salt Lake Convention and Visitors Bureau site at www.visitsaltlake.com/.

## 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 in the lot adjacent to the Oplin Union Building.

## Registration and Meeting Information

The registration desk will be located in the Saltair Room of the Oplin Union Building, and will be open 8:00 a.m. to 4:30 p.m. on Saturday, and 8:00 a.m. to noon on Sunday. Talks will take place in the following buildings: Long and Comm Hall and Orson Spencer Hall.

**Registration fees**: (payable on-site only) $30/AMS or CMS 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 Salt Lake City International Airport is served by most major airlines and is located ten minutes from downtown Salt Lake City. Taxi fare is approximately $13.

**Driving:** Interstate 15 (I-15), the freeway that links Salt Lake City to Idaho and Southern Utah, is currently undergoing renovation. The 16.5 miles of freeway closest to Salt Lake City are being rebuilt. For more information, check the I-15 Web site at www.I-15.com/. For daily updates, call 888-INFO-I15 (888-463-6415).

## Weather

Temperatures vary from 80˚F to 50˚F in September. Fall is the favorite season of many who visit and live in Utah. Vibrant colors splash across the mountains and canyons as the cooler temperatures turn the leaves all shades of gold, purple, red, green, and brown. For up-to-date forecasts: http://www.visitsaltlake.com/.

# Providence, Rhode Island

*Providence College*

### October 2–3, 1999

### Meeting #947

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 1999
Program first available on eMATH: August 25, 1999
Program issue of electronic *Notices*: December 1999
Issue of *Abstracts*: Volume 20, Issue 4

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 16, 1999
For abstracts: August 11, 1999

### Invited Addresses

**Dan M. Barbasch**, Cornell University, *Title to be announced.*

**Henri Berestycki**, Université Paris VI and École Normale Superieure, *Title to be announced.*

**David Mumford**, Brown University, *Title to be announced.*

**Guoliang Yu**, University of Colorado, *Title to be announced.*

### Special Sessions

*Algebraic Dynamics* (Code: AMS SS G1), **Jonathan Lubin** and **Joseph H. Silverman**, Brown University.

*Algebraic and Geometric Combinatorics* (Code: AMS SS A1), **Vesselin N. Gasharov**, Cornell University, and **Ira M. Gessel**, Brandeis University.

*Difference Equations and Applications* (Code: AMS SS E1), **Gerasimos Ladas**, University of Rhode Island, and **Jeffrey T. Hoag**, Providence College.

*Geometric Properties of Nonlinear Elliptic PDEs* (Code: AMS SS K1), **Henri Berestycki**, Université Paris VI and École Normale Superieure, and **Yanyan Li**, Rutgers University.

*Geometry and Representation Theory of Algebraic Groups* (Code: AMS SS C1), **James E. Humphreys** and **Ivan Mirkovic**, University of Massachusetts.

*Mathematical and Statistical Aspects of Vision* (Code: AMS SS H1), **David Mumford**, **Donald E. McClure**, and **Stuart A. Geman**, Brown University.

*Number Theory* (Code: AMS SS J1), **Michael I. Rosen** and **Siman Wong**, Brown University.

*Operator K-Theory and its Applications to Geometry and Topology* (Code: AMS SS D1), **Guoliang Yu**, **Carla E. Farsi**, and **Jeffrey S. Fox**, University of Colorado, Boulder.

*Representation Theory of Reductive Groups* (Code: AMS SS B1), **Dan M. Barbasch** and **Birgit Speh**, Cornell University.

*The History of Mathematics* (Code: AMS SS F1), **Daniel Otero**, Xavier University, and **C. Edward Sandifer**, Western Connecticut State University.

# Austin, Texas

*University of Texas-Austin*

### October 8–10, 1999

### Meeting #948

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: June/July 1999
Program first available on eMATH: August 25, 1999
Program issue of electronic *Notices*: December 1999
Issue of *Abstracts*: Volume 20, Issue 4

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 16, 1999
For abstracts: August 11, 1999

### Invited Addresses

**Mikhail Kapranov**, Northwestern University, *Title to be announced.*

**John Roe**, Oxford and Pennsylvania State University, *Large scale geometric invariants of elliptic operators.*

**Catherine Sulem**, University of Toronto, *The nonlinear Schrodinger equation: Self-focusing and wave collapse.*

**Tatiana Toro**, University of Washington, *Characterization of non-smooth domains via potential theory.*

### Special Sessions

*Aperiodic Tiling* (Code: AMS SS D1), **Charles Radin** and **Lorenzo Sadun**, University of Texas, Austin.

*Banach and Operator Spaces: Isomorphic and Geometric Structure* (Code: AMS SS E1), **Edward Odell** and **Haskell P. Rosenthal**, University of Texas, Austin.

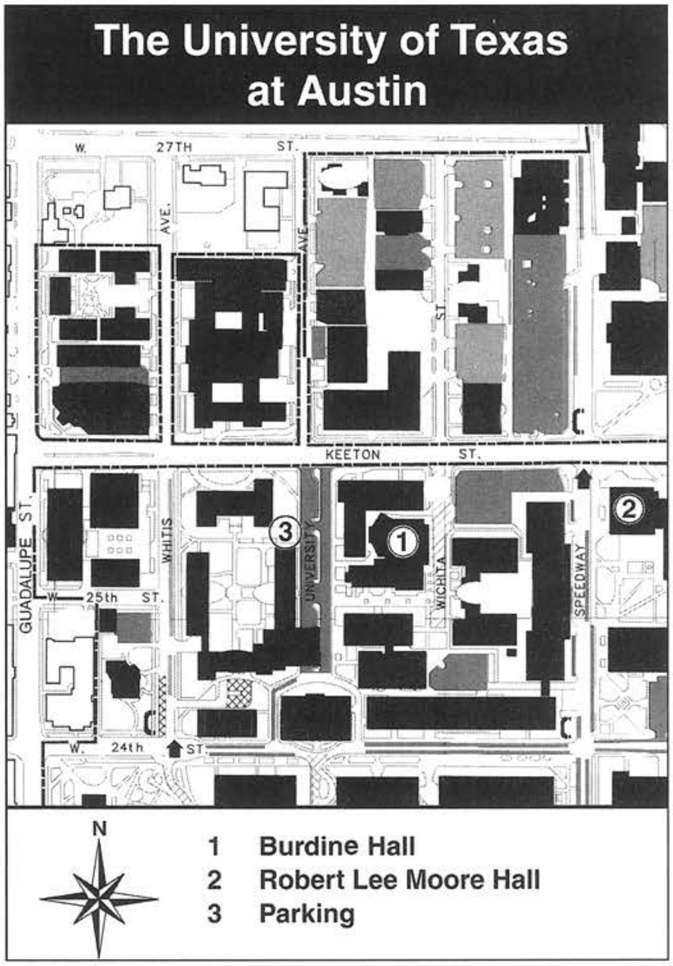
*DNA Topology* (Code: AMS SS J1), **Isabel K. Darcy**, University of Texas, Austin, and **Makkuni Jayaram**, University of Texas, Austin.

*Dehn Surgery and Kleinian Groups* (Code: AMS SS L1), **John Luecke** and **Alan Reid**, University of Texas, Austin.

*Dynamical Systems* (Code: AMS SS S1), **David Delatte**, **R. Daniel Mauldin**, **Mariusz Urbanski**, and **Luca Quardo Zamboni**, University of North Texas.

*Free Surface Interfaces and PDEs* (Code: AMS SS K1), **Kirk Lancaster**, Wichita State University, and **Thomas Vogel**, Texas A&M University.

*Harmonic Analysis and PDEs* (Code: AMS SS C1), **William Beckner** and **Luis A. Caffarelli**, University of Texas at Austin, **Toti Daskalopoulos**, University of California, Irvine, and **Tatiana Toro**, University of Washington.




*Interconnections Among Diophantine Geometry, Algebraic Geometry, and Value Distribution Theory* (Code: AMS SS Q1), **William Cherry**, University of North Texas, **Min Ru**, University of Houston, and **Felipe Voloch**, University of Texas, Austin.

*Mathematical Problems in Transport Phenomena* (Code: AMS SS M1), **Jose Antonio Carrillo** and **Irene M. Gamba**, University of Texas, Austin.

*Mathematical and Computational Finance* (Code: AMS SS H1), **Stathis Tompaidis**, University of Texas, Austin.

*Nonlinear Dynamics* (Code: AMS SS G1), **Robert J. McCann** and **Catherine Sulem**, University of Toronto.

*Recent Developments in Index Theory* (Code: AMS SS F1), **Daniel S. Freed**, University of Texas, Austin, and **John Roe**, Pennsylvania State University.

*The Development of Topology in the Americas* (Code: AMS SS A1), **Cameron Gordon**, University of Texas, Austin, and **Ioan Mackenzie James**, University of Oxford.

*The Diverse Mathematical Legacy of Jean Leray* (Code: AMS SS N1), **Eric M. Friedlander**, Northwestern University, and **Susan J. Friedlander**, University of Illinois, Chicago.

*Theoretical, Computational and Experimental Aspects of Mechanics* (Code: AMS SS P1), **Jerry Bona**, **Steven Levandosky**, and **Jiahong Wu**, University of Texas, Austin.

*Topology of Continua* (Code: AMS SS R1), **Wayne Lewis** and **Carl Seaquist**, Texas Tech University.

*Wavelets and Approximation Theory* (Code: AMS SS B1), **Don Hong**, Eastern Tennessee State University, and **Michael Prophet**, Murray State University.

## 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. Particpants will be exempt from city tax on hotel rooms. The AMS is not responsible for rate changes or for the quality of the accommodations.

**Days Inn**,3105 N. IH 35, Austin, TX: 800-725-7666 or 512-478-1631; $64/single and $68/double; 3/4 mile to campus.

**Doubletree Guest Suites**, 303 W 15th Street, Austin TX; 800-222-8733 or 512-478-3562 or 512-478-7000; $119 per suite; 3/4 mile to campus.

**La Quinta Inn Capitol**, 300 E. 11th Street; 800-531-5900 or 512-476-1166 or 512-476-6044; $89/1-4 persons; 1 mile to campus.

**Rodeway Inn**, 29 N. IH 35, Austin, TX; 888-792-9466; $54/single and $58.50 double double; 1/2 mile to campus.

## 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.ma.utexas.edu/`, and the site maintained by the city of Austin `www.ci.austin.tx.us/`. Other useful sites are: `http://www.austin360.com/acvb/`. maintained by the Convention Bureau; `http://www.capmetro.austin.tx.us/`, maintained by Capital Metro, the transport authority, as well as: `http://www.austinlinks.com/`, `http://austin.citysearch.com/`, `http://www.auschron.com/`. Maps of the University, pictures of the buildings, schedules and maps for the University buses can be obtained from `http://www.utexas.edu/maps/main/`.

## 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 in the lot across from Burdine Hall and is available at no charge **after 4:00 p.m. on Friday and all day Saturday and Sunday**. Participants may also pay to park at any meter or in Parking Garage 1 located on San Jacinto.

## Registration and Meeting Information

The registration desk will be located in Robert Lee Moore Hall, and will be open 1:00 p.m. to 5:00 p.m. on Friday and 8:00 a.m. to 4:30 p.m. on Saturday. Talks will take place in the following buildings: Robert Lee Moore Hall (Special Sessions) and Burdine Hall (Invited Addresses).

**Registration fees**: (payable on-site only) \$30/AMS or CMS members; \$45/nonmembers; \$10/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

### Travel

Austin will be served by the Austin-Bergstrom International Airport which is scheduled to begin passenger service on Sunday, May 23, 1999. It is not far from the University and taxi rides should be reasonably priced.

**Driving**: If you are driving, the best way to reach the University is to take IH-35 and take the LBJ Library exit. Take 26th Street (a.k.a. Dean Keeton) west until you reach Speedway. RLM is on the corner of 26th Street and Speedway. The hotels with reservations are in the same general area. For convenient planning of driving routes please visit `http://www.mapblast.com/mapblast/`, which gives detailed driving directions in many cities, including Austin.

### Weather

The weather in central Texas is notoriously unstable (especially in the fall), but it is not very extreme. Normally, it should be between 60˚F and 80˚F. Up-to-date information about the weather in Austin can be obtained from `http://www.accuweather.com/`. Some local TV stations carry online weather broadcasts. `http://www.kvue24.com/` and `http://www.keye42.com/`.

# Charlotte, North Carolina

*University of North Carolina, Charlotte*

### October 15–17, 1999

### Meeting #949

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: August 1999
Program first available on eMATH: September 1, 1999
Program issue of electronic *Notices*: December 1999
Issue of *Abstracts*: Volume 20, Issue 4

### Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 23, 1999
For abstracts: August 18, 1999

### Invited Addresses

**Valery Alexeev**, University of Georgia, *Title to be announced.*

**Béla Bollobás**, University of Memphis and Cambridge University, *Title to be announced.*

**Konstantin M. Mischaikow**, Georgia Institute of Technology, *Title to be announced.*

**Yakov Sinai**, Princeton University, *Title to be announced.*

### Special Sessions

*Algebraic Geometry* (Code: AMS SS K1), **Valery Aleexev**, **William Graham**, **Roy C. Smith**, and **Robert Varley**, University of Georgia.

*Commutative Algebra* (Code: AMS SS B1), **Sarah Glaz**, University of Connecticut, and **Evan G. Houston** and **Thomas G. Lucas**, University of North Carolina at Charlotte.

*Contemporary Methods in Dynamics and Differential Equations* (Code: AMS SS J1), **Robert W. Ghrist** and **Konstantin M. Mischaikow**, Georgia Institute of Technology.

*Gauge Theory and Low-Dimensional Topology* (Code: AMS SS L1), **Eric P. Klassen**, Florida State University, and **Paul A. Kirk**, Indiana University.

*Geometric Function Theory* (Code: AMS SS H1), **David A. Herron**, University of Cincinnati, and **Shanshuang Yang**, Emory University.

*Knot Theory and Its Applications* (Code: AMS SS A1), **Yuanan Diao**, University of North Carolina at Charlotte.

*Operator Theory, including Applications in Operator Algebras and Wavelets* (Code: AMS SS F1), **Alan L. Lambert** and **Xingde Dai**, University of North Carolina at Charlotte.

*Optimal Control and Computational Optimization* (Code: AMS SS D1), **Mohammed A. Kazemi**, University of North Carolina at Charlotte, and **Gamal N. Elnagar**, University of South Carolina Spartanburg.

*Set-Theoretic Topology* (Code: AMS SS G1), **Ronald F. Levy**.

*Spectral Theory of Differential Operators and Applications* (Code: AMS SS C1), **Boris R. Vainberg** and **Stanislav Molchanov**, University of North Carolina at Charlotte.

*Stochastic PDEs and Turbulence* (Code: AMS SS E1), **Weinan E**, Courant Institute, New York University.

*Stochastic Processs and Control* (Code: AMS SS M1), **Volker Wihstutz** and **Alexander A. Yushkevich**, University of North Carolina at Charlotte.

# Washington, District of Columbia

*Marriott Wardman Park Hotel and Omni Shoreham Hotel*

### January 19–22, 2000

*Note: This is a World Math Year 2000 (WMY2000) event.*

### Meeting #950

*Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM), the annual meetings of the As-*

*sociation for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).*

Associate secretary: Bernard Russo
Announcement issue of *Notices*: October 1999
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: January 2000
Issue of *Abstracts*: Volume 21, Issue 1

## Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: August 10, 1999
For abstracts: October 5, 1999
For summaries of papers to MAA organizers: September 9, 1999



## Joint Special Sessions

*Innovative Development Programs for Teaching Assistants and Part-Time Instructors* (Code: AMS SS D1), **Suzanne M. Lenhart**, University of Tennessee. (AMS-MAA)

*Linear Algebra and Optimization* (Code: AMS SS C1), **Dianne P. O'Leary**, University of Maryland, College Park, and **Margaret H. Wright**, Bell Laboratories. (AMS-AWM-SIAM)

*The History of Mathematics* (Code: AMS SS E1), **Karen H. Parshall**, University of Virginia, and **David E. Zitarelli**, Temple University. (AMS-MAA)

## AMS Invited Addresses

**Sun-Yung Alice Chang**, UCLA, *Title to be announced.*

**Thomas C. Hales**, University of Michigan, Ann Arbor, *Title to be announced.*

**Alexander R. Its**, Indiana University-Purdue University Indianapolis, *Title to be announced.*

**Arthur M. Jaffe**, Harvard University, *Title to be announced* (AMS Retiring Presidential Address).

**M. Lyubich**, SUNY at Stony Brook, *Title to be announced.*

**Roger Penrose**, Oxford University, *Title to be announced* (AMS Josiah Willard Gibbs Lecture).

## AMS Special Sessions

*Mathematical Aspects of Concensus Theory* (Code: AMS SS B1), **Melvin F. Janowitz**, University of Massachusetts, Amherst.

*Mathematical Reviews* (Code: AMS SS F1), **Jane E. Kister**, *Mathematical Reviews.*

*The Feynman Integral and Applications* (Code: AMS SS A1), **Michel L. Lapidus**, University of California, Riverside, and **Gerald W. Johnson**, University of Nebraska.

## MAA Contributed Papers in Washington, D.C.

This preliminary announcement is designed to alert participants about the MAA's Contributed Paper Sessions and their deadlines. Please note that the dates scheduled for these sessions remain tentative. The organizers listed below solicit contributed papers pertinent to their sessions; proposals should be directed to the organizer whose name is followed by an asterisk (*). Sessions generally limit presentations to ten minutes, but selected participants may extend their contributions up to twenty minutes. For additional instructions, see the "Submission Procedures" at the end of the list.

Each session room contains an overhead projector and screen; blackboards will not be available. Persons needing additional equipment should contact, as soon as possible, and prior to October 5, 1999: the session organizer and Jim Tattersall, Department of Mathematics and Computer Science, Providence College, Providence, RI 02918, e-mail: `tat@providence.edu`.

*The Use of History in the Teaching of Mathematics*, Wednesday and Thursday mornings. This session invites contributions from individuals describing how they have used the history of mathematics in innovative ways in the classroom to motivate students or to support changes in curriculum and pedagogy. Ideas about the use of history to prepare future teachers are especially encouraged. Also invited are contributions discussing new and interesting ways of teaching history of mathematics classes. Ideas about how to get students actively involved are especially encouraged. **Florence Fasanelli** (*), College-University Resource Institute, Inc., 4711 Davenport St. NW, Washington, DC 29916, phone: 202-966-5591, e-mail: `ffasanelli@juno.com`; **V. Frederick Rickey**, U.S. Military AcademyM.A. at West Point; and **Victor J. Katz**, University of the District of Columbia.

*Integrating Mathematics and Other Disciplines*, Wednesday and Thursday mornings. The session will present: discussions of the content of current mathematics courses in the first two years in the light of the way other disciplines use mathematics and the expectations they have of our students, discussions of how applications of mathematics in other disciplines can be incorporated into mathematics courses in a way that enhances mathematical understanding, and presentations of exemplary courses or course modules. Submissions are encouraged from teachers in engineering, the physical and social sciences, and management and public policy, showing examples of how mathematics is used in their courses. Submissions are also encouraged from mathematicians who have successfully incorporated such material into their courses. **William G. McCallum** (*), Department of Mathematics, University of Arizona, Tucson, AZ 85721, phone: 520-621-6886, fax: 520-621-8322, e-mail: `wmc@math.arizona.edu`; **Duff G. Campbell**, U.S.M.A. at West Point; **Deborah Hughes Hallett**, University of Arizona; **David C. Lay**, University of Maryland; **Nicholas Losito**, SUNY Farmingdale; **Jim Rolf**, U.S.M.A. at West Point; and **Yajun Yang**, SUNY Farmingdale.

*Innovative Uses of the World Wide Web in Teaching Mathematics*, Wednesday and Thursday mornings. This contributed paper session will focus on creative uses of the World Wide Web in mathematics instruction. Proposals are solicited on original uses of Web resources in the classroom. We are looking for presentations involving the use of real data sets, instructional materials, interactive simulations, videoconferencing, or other topics of interest for educators who are currently using, or planning to use, the Web in their classes. **Brian E. Smith** (*), Department of Statistics, Faculty of Management, McGill University, 1001 Sherbrooke St. West, Montreal QC, Canada H3A 1G5, phone: 514-398-4038, fax: 514-398-3876, e-mail: `smithb@management.mcgill.ca`; and **Marcelle Bessman**, Jacksonville University.

*Environmental Mathematics in the Classroom*, Wednesday and Thursday mornings. Presentations are invited that apply mathematics to problems of the environment and that are suitable for classroom use. Also invited are papers that address the issue of infusing environmental awareness into the teaching community. This session is sponsored by the Committee for Mathematics in the Environment. **Ben Fusaro** (*), Department of Mathematics, Florida State University, Tallahassee, FL 32306, phone: 850-644-9717, fax: 850-644-4053, e-mail: `fusaro@math.fsu.edu`; and **Pat Kenschaft**, Montclair State University.

*Interdisciplinary Applications for College Algebra*, Wednesday and Thursday afternoons. The College Algebra Reform Movement has grown exponentially over the past few years. New courses have been developed featuring data analysis, discrete dynamical systems, real life applications, and modeling. Students are expected to use graphing calculators or computers in these courses. Pedagogical changes include small group work, out-of-class projects, and writing assignments. Interdisciplinary aspects appear in these reform courses through applications and group projects. The reformed courses are changing the role of college algebra from being a remedial course to being the core course in the noncalculus curriculum. Papers are invited on all aspects of reforming college algebra. **Donald B. Small** (*), Department of Mathematical Sciences, U.S. Military Academy, West Point, NY 10996, phone: 914-938-2227, fax: 914-938-2409, e-mail: `don-small@usma.edu`; **Della D. Bell**, Texas Southern University, and **Ahmad Kamalvand**, Houston-Tillotson College.

*Interdisciplinary Collaborations to Improve Service Courses in Mathematics and Statistics*, Wednesday and Thursday afternoons. We invite descriptions of collaborations with faculty and departments in other disciplines resulting in improvements to existing service courses in mathematics or statistics. Papers should describe a challenge faced for a particular service course, a resulting collaboration with faculty or a department in another discipline, subsequent changes in the service course, and the effects of the relationship between faculty and departments. **Linda H. Boyd** (*), Department of Mathematics, Georgia Perimeter College, 555 North Indian Creek Drive, Clarkston, GA 30021-2396, tel: 404-299-4167, fax: 404-298-4815, e-mail: `lboyd@gpc.peachnet.edu`; and **Thomas L. Moore**, Grinnell College.

*The Role of Mathematicians in the Development of Mathematics Teachers and Their Students*, Thursday afternoon. Mathematicians have many opportunities to support and enhance the development of K-12 mathematics teachers and their students. This session invites papers that describe the substantive involvement of mathematicians throughout K-12 education, but especially in (a) planning and delivering professional development for inservice teachers; (b) developing or analyzing curricular/instructional/assessment materials for use in professional development with teachers or for use in classrooms with students, with particular attention to the mathematics presented; and (c) collaborating with mathematics educators and classroom teachers on "action research" (e.g., research based on reflection about teachers' practice), by providing a focus on and close attention to the mathematics involved. **Diane Spresser** (*), National Science Foundation, 4201 Wilson Boulevard, Room 885, Arlington, Virginia 22230, phone: 703-306-1613, fax: 703-306-0412, e-mail: `dspresse@nsf.gov`; John S. Bradley, National Science Foundation; and **Alfred B. Manaster**, University of California, San Diego.

*Looking to Our Future: Recruiting and Preparing the Next Generation of Mathematics Teachers*, Friday and Saturday mornings. Mathematicians and mathematics departments face the critical challenge of preparing the next generation of teachers of mathematics at the K-12 level. These sessions will illustrate ways this challenge is being met. The first session will address the role that mathematics departments at two-year colleges play in the initial recruitment and preparation of future teachers of mathematics. With their emphasis on teaching and ties to common education, departments at two-year colleges provide a unique atmosphere for attracting potential teachers to the subject matter as well as acting as a laboratory for modeling effective teaching techniques. The second session will address the role played by mathematics departments at four-year colleges and universities in the mathematical preparation of future teachers of mathematics. Mathematics departments provide opportunities for a content-rich atmosphere across a wide range of mathematics courses, reflective seminars, peer teaching programs and early field experiences particularly valuable for future teachers.

Papers that discuss effective collaborations across mathematics courses, departments, and institutions will be given special consideration, as will papers that address issues of preparation of middle grades teachers, programs for elementary mathematics specialists, and recruitment and retention of underrepresented minorities to teach mathematics. Specific details about programs and courses, with handouts, are strongly encouraged. **Jay A. Malmstrom** (*), Department of Mathematics, Oklahoma City Community College, 7777 S. May Avenue, Oklahoma City, OK 73159-4444, phone: 405-682-1611, ext. 7365; fax: 405-682-7585, e-mail: `malmstrm@qns.com`, Web: `http://www.unm.edu/~nmmatyc/maaform.htm`; **Gary L. Britton**, University of Wisconsin-Washington County; **Marjorie Enneking**, Portland State University; **James Loats**, Metropolitan State College of Denver; and **Mary Robinson**, University of New Mexico.

*Establishing and Maintaining Undergraduate Research Programs in Mathematics*, Friday and Saturday mornings. In recent years, there has been a growing interest in research in mathematics by undergraduates. We seek papers that address successes and difficulties in establishing, maintaining, funding, and assessing undergraduate research programs of all kinds, especially academic year programs. Descriptions and analyses of any efforts that support and encourage the involvement of students in mathematics research, including informal programs, mentoring individual students, conferences and meetings involving students, REU programs and non-REU formal programs are welcome. **Emelie Kenney** (*), Department of Mathematics, Siena College, Loudonville, NY 12211, phone: 518-783-2913, fax: 518-783-4293, e-mail: kenney@siena.edu; **Joseph A. Gallian**, University of Minnesota, Duluth; and **Daniel J. Schaal**, South Dakota State University.

*Innovations in the Use of Technology in Teaching Ordinary and Partial Differential Equations*, Friday and Saturday afternoons. This session invites papers on recent innovations in the effective use of technology in teaching ordinary and partial differential equations. A great deal of attention has been focused on using Computer Algebra Systems (CAS's) to teach mathematics at the calculus level. However, many upper level mathematics courses can also be significantly enhanced with technology. In particular, instructors can exploit visualization and algebra capabilities to support their instruction. Additionally, students can take advantage of technology in self explorations, active learning or cooperative learning modules which complement the Calculus Reform Movement. We are looking for novel and proven methods for incorporating technology in the teaching of ordinary and partial differential equations. Effective projects requiring the use of CAS's, especially those of an interdisciplinary nature are welcome. **Timothy J. McDevitt** (*), Department of Mathematics, Millersville University, Millersville, PA 17551, phone: 717-872-3957, fax: 717-871-2320, e-mail: tmcdevit@cs.millersv.edu; **Elias Y. Deeba**, University of Houston-Downtown; and **Richard J. Marchand**, U.S. Military Academy at West Point.

*Math and Math Sciences in 2010: What should Graduates Know?*, Friday and Saturday afternoons. The third millennium confronts us with the need to prepare our students for new challenges. Identifying these challenges will guide mathematics departments in setting, addressing, and meeting goals. A broad look at the undergraduate curriculum is particularly timely after over a decade of innovation and debate about content and pedagogy in specific courses. This session presents a panel of commentators on these issues and invites talks of two kinds: "think pieces" on what our majors should know and examples of successful mathematics programs. Research on the preparation of graduates for the workplace and/or post-BA study and examples of collaboration with employers or those in mathematics-using fields are encouraged. This session is organized on behalf of the MAA Committee on the Undergraduate Program in Mathematics (CUPM). **Herbert E. Kasube** (*), Department of Mathematics, Bradley University, Peoria, IL 61625, phone: 309-677-2505, fax: 309-677-2330, e-mail: hkasube@bradley.bradley.edu; and **Harriet S. Pollatsek**, Mount Holyoke College.

*Teaching Statistical Reasoning*, Friday and Saturday afternoons. Statistical reasoning encompasses more than just calculating p-values and confidence intervals—it includes formulating questions, designing experiments, choosing appropriate techniques, and communicating results. Authors will discuss experiences teaching statistical reasoning in a variety of undergraduate settings, including introductory statistics courses, team-taught courses with other departments, a segment of a math-for-liberal-arts courses, or new courses such as "statistics for humanists." There are no restrictions on the techniques used to teach the reasoning, but the emphasis should be on teaching the reasoning. **K.L.D. Gunawardena** (*), Department of Mathematics, University of Wisconsin Oshkosh, Oshkosh, WI 54901, phone: 920-424-1056, fax: 920-424-7317, e-mail: gunaward@uwosh.edu; **Nkechi M. Agwu**, Borough of Manhattan Community College; and **Mary Sullivan**, Rhode Island College.

*Research on the Use of Hand-Held Technology in Teaching Mathematics*, Saturday afternoon. For more than a decade, instructors have been teaching mathematics with graphing calculators. In that time, improvements in design and capabilities have expanded the range of calculator use from computation and function graphing to symbol manipulation and geometric constructions; yet, researchers are only beginning to explore the effects of these advanced technologies on teaching and learning. What have we learned about using calculators in mathematics instruction? This session seeks papers about research on the use of hand-held technology in the teaching of mathematics. Reports of studies using either quantitative or qualitative methodologies are welcome, but anecdotal information is not the focus of this session. Preference will be given to recent investigations, research involving undergraduate mathematics instruction, and studies of newer technologies with advanced capabilities. **Deborah A. Crocker** (*), Department of Mathematical Sciences, Appalachian State University, Boone, NC, phone: 828-262-2381, fax: 828-265-8617, e-mail: crockerda@appstate.edu; and **Penelope H. Dunham**, Muhlenberg College.

## Submission Procedures for MAA Contributed Papers

Send the name(s) and address(es) of the author(s) and a one-page summary of your paper directly to the organizer indicated with an (*). In order to enable the organizer(s) to evaluate the appropriateness of your paper, include as much detailed information as possible within the one-page limitation.

Your summary must reach the designated organizer by **Thursday, September 9, 1999**. Submission of proposals via e-mail is preferred. The organizer will acknowledge receipt of all summaries. If the organizer accepts your paper, you will receive instructions about preparing an abstract. Please submit completed abstracts to the AMS by Tuesday, October 5, 1999. Abstracts received after the deadline will not be published in the booklet of abstracts available in the meetings registration area during the meeting in Washington, D.C.

# Santa Barbara, California

*University of California, Santa Barbara*

### March 11-12, 2000

### Meeting #951

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: June 11, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Lowell, Massachusetts

*University of Massachusetts, Lowell*

### April 1-2, 2000

### Meeting #952

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: July 1, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

### Invited Addresses

**Walter Craig**, Brown University, *Title to be announced.*

**Erwin Lutwak**, Polytechnic University, *Title to be announced.*

**Alexander Nabutovsky**, Courant Institute of Mathematical Sciences, NYU, *Title to be announced.*

**Mary Beth Ruskai**, University of Massachusetts, Lowell, *Title to be announced.*

### Special Sessions

*Invariance in Convex Geometry* (Code: AMS SS A1), **Daniel A. Klain**, Georgia Institute of Technology, and **Elisabeth Werner**, Case Western Reserve University.

*Quantum Information Theory* (Code: AMS SS B1), **M. Beth Ruskai**, University of Massachusetts, Lowell, and **Christopher K. King**, Northeastern University.

# Notre Dame, Indiana

*University of Notre Dame*

### April 7-9, 2000

### Meeting #953

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: July 7, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

### Special Sessions

*Algebraic Geometry* (Code: AMS SS F1), **Karen Chandler** and **Scott Nollet**, University of Notre Dame.

*Commutative Algebra* (Code: AMS SS A1), **Juan Migliore**, University of Notre Dame, and **Chris Peterson**, Washington University.

*Differential Geometry and its Applications* (Code: AMS SS B1), **Jianguo Cao**, **Brian Smyth**, and **Frederico Xavier**, University of Notre Dame.

*Integrable Systems and Nonlinear Waves* (Code: AMS SS E1), **Mark S. Alber** and **Gerard Misiolek**, University of Notre Dame.

*Microlocal Analysis and Partial Differential Equations* (Code: AMS SS D1), **Nicholas Hanges**, CUNY, Lehman College, and **Alex Himonas**, University of Notre Dame.

*Optimization and Numerical Analysis* (Code: AMS SS C1), **Leonid Faybusovich**, University of Notre Dame.

# Lafayette, Louisiana

*University of Southwestern Louisiana*

### April 14-16, 2000

### Meeting #954

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced

Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: July 14, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

### Special Sessions

*Mathematical Models in the Biological and Physical Sciences* (Code: AMS SS B1), **Lan Ke**, **Robert D. Sidman**, and **Azmy Simaan Ackleh**, University of Southwestern Louisiana.

*Rings and Their Generalizations* (Code: AMS SS A1), **Gary F. Birkenmeier** and **Henry E. Heatherly**, University of Southwestern Louisiana.

# Odense, Denmark

*Odense University*

### June 13-16, 2000

### Meeting #955

*First AMS-Scandinaivan 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*: N/A
Program first available on eMATH: N/A
Program issue of electronic *Notices*: N/A
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

**Tobias Colding**, Courant Institute, New York University, *Title to be announced.*

**Nigel J. Hitchin**, University of Oxford, *Title to be announced.*

**Pertti Mattila**, University of Jyväskylä, *Title to be announced.*

**Curtis T. McMullen**, Harvard University, *Title to be announced.*

**Alexei N. Rudakov**, Norwegian University of Science & Technology, *Title to be announced.*

**Dan Voiculescu**, University of California, Berkeley, *Title to be announced.*

### Special Sessions

*Algebraic Groups and Representation Theory*, **Henning Haahr Andersen** and **Niels Lauritzen**, Aarhus University.

*Differential Geometry*, **Claude R. LeBrun**, State University of New York at Stony Brook, and **Peter Petersen**, University of California, Los Angeles.

*Discrete Mathematics*, **Iiro S. Honkala**, University of Turku, and **Carsten Thomassen**, Technical University of Denmark.

*Dynamical Systems*, **Michael Benedicks**, Royal Institute of Science, Stockholm, and **Carsten Lunde Petersen**, Roskilde.

*Geometric Analysis/PDE*, **Gerd Grubb**, University of Copenhagen, and **Bent Orsted**, Odense University.

*K-Theory and Operator Algebras*, **Soren Eilers**, University of Copenhagen, and **Nigel D. Higson**, Pennsylvania State University.

*Mathematical Physics*, **Bergfinnur Durhuus**, University of Copenhagen.

*Stochastic DE and Financial Mathematics*, **Tomas Björk**, University of Stockholm, and **Bernt Oksendal**, University of Oslo.

# Los Angeles, California

*University of California-Los Angeles*

### August 7-12, 2000

*Note: This is a World Math Year 2000 (WMY2000) event.*

### Meeting #956

Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: N/A
For consideration of contributed papers in Special Sessions: N/A
For abstracts: To be announced

### Invited Addresses

**James G. Arthur**, University of Toronto, *will speak on automorphic forms and the Langlands program.*

**Michael V. Berry**, H. H. Wills Physics Laboratory, *will speak on waves, geometry, and arithmetic.*

**David Leigh Donoho**, Stanford University, *Topic to be announced.*

**Helmut H. W. Hofer**, New York University-Courant Institute, *will speak on symplectic geometry/dynamical systems.*

**Richard M. Karp**, University of Washington, *will speak on computational molecular biology.*

**Peter D. Lax**, New York University-Courant Institute, *will speak on mathematics and computing.*

**László Lovász**, Yale University, *will speak on discrete mathematics and algorithms.*

**David Mumford**, Brown University, *will speak on models of perception and inference.*

**Iakov G. Sinai**, Princeton University, *will speak on dynamical systems.*

**Karen Uhlenbeck**, University of Texas, Austin, *Topic to be announced.*

**Edward Witten**, Institute for Advanced Study, *will speak on the mathematical impact of quantum fields and strings.*

**Shing-Tung Yau**, Harvard University, *will speak on geometry and its relation to physics.*

See "AMS Meeting in August 2000", *Notices* March 1999, p. 355.

# 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 first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: December 22, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# San Francisco, California

*San Francisco State University*

### October 21–22, 2000

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: June 2000
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: February 21, 2000
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

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: February 3, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

### Invited Addresses

**Paula Cohen**, Université des Sciences et Technologies de Lille, France, *Title to be announced.*

# Birmingham, Alabama

*University of Alabama-Birmingham*

### November 10–12, 2000

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: April 10, 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 first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: April 11, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

# Columbia, South Carolina

*University of South Carolina*

### March 16–18, 2001

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: June 15, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Lawrence, Kansas

*University of Kansas*

### March 30–31, 2001

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: June 28, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Hoboken, New Jersey

*Stevens Institute of Technology*

### April 28–29, 2001

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: July 28, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

# Lyon, France

### July 17–20, 2001

*First Joint International Meeting between the AMS and the Société Mathématique de France.*
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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The Department also seeks to appoint a Lecturer/Senior Lecturer with interests and expertise in Applied Mathematics. Preference will be given to candidates whose teaching and research interests lie in one or more of Finite Element Methods, Continuum Mechanics, and Computational Mechanics. Applications would also be welcomed from candidates whose main interests lie in areas of Mathematics such as Numerical Analysis, Partial Differential Equations, or Functional Analysis, but whose activities include the application of these disciplines to problems in Mechanics.

Send your CV (including 3 contactable referees) to the Staff Recruitment Office (Ref: 225), UCT, Rondebosch 7701, South Africa by 18 June 1999, although applications will be considered until such time as the posts are filled. Tel: +27 21 650 2196; fax: +27 21 650 2138; email: samuelc@bremner.uct.ac.za. Websites: http://www.uct.ac.za and http://www.mth.uct.ac.za

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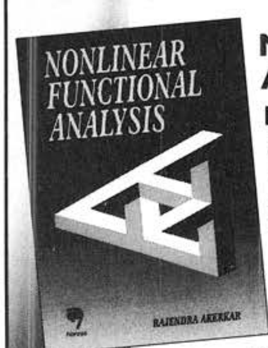
**UNIVERSITY OF CAPE TOWN**



AMERICAN MATHEMATICAL SOCIETY

Supplementary Reading




**Nonlinear Functional Analysis**

**Rajendra Akerkar**, *Chh. Shahu Central Institute of Business Education and Research, Kolhapur, India*

***A publication of Narosa Publishing House.***

This book presents background for the solution of nonlinear equations in Banach spaces. It contains basic techniques in nonlinear analysis and also touches upon today's research. The book deals with recent topics, such as measures on non-compactness, topological degree, and bifurcation theory. It can be used as a text and as a reference source for students and researchers.

Distributed by the AMS exclusively in North America and Europe and non-exclusively elsewhere.

**Narosa Publishing House**; 1999; 157 pages; Softcover; ISBN 81-7319-230-8; List $27; All AMS members $22; Order code NAR/4NA

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# Williamstown, Massachusetts

*Williams College*

### October 13–14, 2001

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: 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

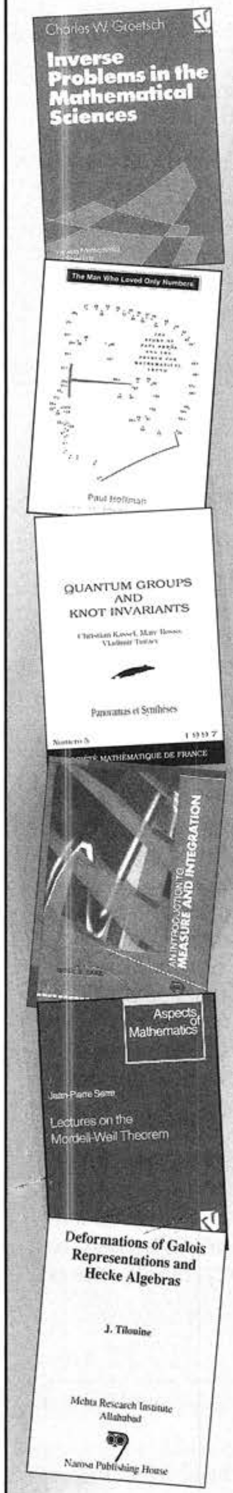
*Joint Mathematics Meetings, including the 108th Annual Meeting of the AMS and 85th Meeting of the Mathematical Association of America (MAA).*
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program first available on eMATH: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

### Deadlines

For organizers: April 4, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

# American Mathematical Society

## Bestselling Publications Distributed by the AMS




These publications are among the bestsellers distributed by the AMS. They are published by various academic publishers—International Press (Boston), Narosa Publishing House (New Delhi, India), Société Mathématique de France (Paris), and Vieweg Verlag (Wiesbaden, Germany). The AMS maintains distribution rights to the works within and outside the USA (unless otherwise noted). Details are listed with the ordering information.

**Recommended Text**

### Basic Partial Differential Equations

**David Bleecker** and **George Csordas**, *University of Hawaii, Honolulu*

***A publication of International Press.***

Distributed worldwide, except in Japan, by the American Mathematical Society.

**International Press**; 1996; ISBN 1-57146-036-5; 735 pages; Hardcover; **All AMS members $47**, List $59, Order Code INPR/23NA

### Inverse Problems in the Mathematical Sciences

**Charles W. Groetsch**, *University of Cincinnati, OH*

***A publication of Vieweg Verlag.***

The AMS is exclusive distributor in North America, and non-exclusive distributor worldwide except in Germany, Switzerland, Austria, and Japan.

**Vieweg Monographs**; 1993; ISBN 3-528-06545-1; 152 pages; Hardcover; **All AMS members $27**, List $30, Order Code VW/2NA

### A First Course in Differential Geometry

**Chuan C. Hsiung**, *Lehigh University, Bethlehem, PA*

***A publication of International Press.***

Distributed worldwide, except in Japan, by the American Mathematical Society.

**International Press**; 1997; ISBN 1-57146-046-2; 343 pages; Hardcover; **All AMS members $36**, List $45, Order Code INPR/24NA

### The Man Who Loved Only Numbers
### The Story of Paul Erdős and the Search for Mathematical Truth

**Paul Hoffman**

***A publication of Hyperion Press.***

*No mathematician is more legendary than Paul Erdős (1913–96) ...* The Man Who Loved Only Numbers *is [Hoffman's] expanded homage to the man and his discipline ... Hoffman does not analyze the man but lets Erdős and his colleagues speak for themselves, and Erdős the person, and his intellectual interests, emerge ... We follow the trains of thought (and some of the personalities) that evolved from the attempts to comprehend the infinite sets lurking behind calculus. We visit Andrew Wiles' recent solution of the second-most famous theorem in mathematics, Fermat's last one. And we pursue the "Monty Hall" problem ... This book opens doors on a world and characters that are often invisible. It is interesting that Hoffman, Erdős and others in the book remember the mathematical tidbit that first intrigued them and bound them to this world. Possibly a future scientist or mathematician, or future scientific writer, will remember something in this book that way.*

***—New York Times Book Review***

Distributed worldwide by the American Mathematical Society.

1998; ISBN 0-7868-6362-5; 302 pages; Hardcover; **All AMS members $16**, List $23, Order Code MLONNA

### Quantum Groups and Knot Invariants

**Christian Kassel**, **Marc Rosso**, and **Vladimir Turaev**, *CNRS, Strasbourg, France*

***A publication of Société Mathématique de France.***

Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

**Panoramas et Synthèses**, Number 5; 1997; ISBN 2-85629-055-8; 115 pages; Softcover; **Individual member $22**, List $24, Order Code PASY/5NA

**Supplementary Reading**

### An Introduction to Measure and Integration

**Inder K. Rana**, *Indian Institute of Technology, Pawai*

***A publication of Narosa Publishing House.***

*A good addition to the standard texts on the subject ... the book is clearly a labour of love. The exuberance of detail, the wealth of examples and exercises and the evident delight in discussing variations and counter examples all attest to that ... highly recommended to serious and demanding students of mathematics.*

***—Resonance***

Distributed by the AMS exclusively in North America and Europe and non-exclusively elsewhere.

1997; ISBN 81-7319-120-4; 380 pages; Hardcover; **All AMS members $39**, List $49, Order Code NAR/3NA

**Supplementary Reading**

### Lectures on the Mordell-Weil Theorem
#### Third Edition

**Jean-Pierre Serre**, *Collège de France, Paris*

***A publication of Vieweg Verlag.***

The AMS is exclusive distributor in North America, and non-exclusive distributor worldwide except in Germany, Switzerland, Austria, and Japan.

**Vieweg Aspects of Mathematics**, Volume 15; 1997; ISBN 3-528-28968-6; 218 pages; Hardcover; **All AMS members $41**, List $45, Order Code VWAM/15NA

### Deformations of Galois Representations and Hecke Algebras

**J. Tilouine**, *Université de Paris Nord, Villetaneuse, France*

***A publication of Narosa Publishing House.***

Distributed by the AMS exclusively in North America and Europe and non-exclusively elsewhere.

1996; ISBN 81-7319-106-9; 108 pages; Softcover; **All AMS members $19**, List $24, Order Code NAR/1NA

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# Meetings and Conferences of the AMS

**Associate Secretaries of the AMS**

**Western Section: Bernard Russo**, Department of Mathematics, University of California, Irvine, CA 92697; e-mail: brusso@math.uci.edu; telephone: 949-824-5505.

**Central Section: Susan J. Friedlander**, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: susan@math.nwu.edu; telephone: 312-996-3041.

**Eastern Section: Lesley M. Sibner**, Department of Mathematics, Polytechnic University, Brooklyn, NY 11201-2990; e-mail: lsibner@magnus.poly.edu; telephone: 718-260-3505.

**Southeastern Section: John L. Bryant**, Department of Mathematics, Florida State University, Tallahassee, FL 32306-4510; e-mail: bryant@math.fsu.edu; telephone: 850-644-5805.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information is available on the World Wide Web at www.ams.org/meetings/.**

## Meetings:



### Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 106 in the January 1999 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

### Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX or AMS-LaTeX may submit abstracts with such coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html or send mail to abs-submit@ams.org, typing help as the subject line, and descriptions and instructions on how to get the template of your choice will be emailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. There is a $20.00 processing fee for each paper abstract. There is no charge for electronic abstracts. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

**Conferences:** (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

**1999:**

July 26–August 13: Summer Research Institute on Smooth Ergodic Theory and Applications, Seattle, WA. See pp. 1442–1443 (November 1998) for details.

August 16–27: 1999 Von Neumann Symposium on Arithmetic Fundamental Groups and Noncommutative Algebra, Berkeley, CA. See pp. 405–406 (March 1999) for details.

**Cosponsored Conference:**

July 18–28, 1999: Foundations of Computational Mathematics (FoCM), University of Oxford, England. See http://www-sccm.stanford.edu/FoCM/ for details.

# New & Noteworthy Titles

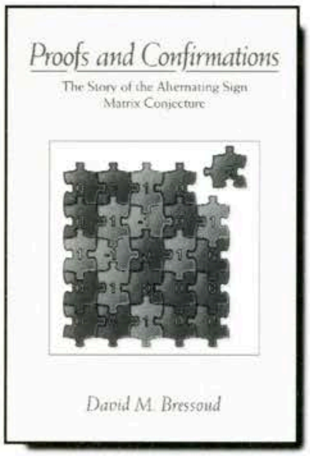
## Complexity and Information

***J. F. Traub*** *and* ***A. G. Werschulz***

*"This short volume packs so much information into so small a space that it stretches the imagination...Clearly written, filled with interesting examples, important theorems and tantalizing conjectures... It's destined to be a classic."*

—**New Scientist**

1999 160 pp.
0-521-48005-1 Hardback $54.95
0-521-48506-1 Paperback $19.95




## Proofs and Confirmations

The Story of the Alternating Sign Matrix Conjecture

***David M. Bressoud***

This introduction to recent developments in algebraic combinatorics provides an illustration of research progress in mathematics.

1999 256 pp.
0-521-66170-6 Hardback $74.95
0-521-66646-5 Paperback $29.95

## A Practical Guide to Pseudospectral Methods

***Bengt Fornberg***

This book explains how, when, and why the pseudospectral approach works, using illustrations, examples, heuristic explanations, and algorithms.

1998 242 pp.
0-521-49582-2 Hardback $59.95
0-521-64564-6 Paperback $29.95

## Young Tableaux

With Applications to Representation Theory and Geometry

***William Fulton***

*"...a book that every student and researcher in algebraic combinatorics, algebraic geometry, and/or representation theory should have on their shelves. The author has organized a wealth of information...It will be particularly useful for graduate students: the author has that magical ability for getting to the good stuff without getting the reader mired in preliminary 'basics'."*

—**Bulletin of the American Mathematical Society**

1996 270 pp.
0-521-56144-2 Hardback $59.95
0-521-56724-6 Paperback $20.95

## Introduction to Hp Spaces

Second Edition

***Paul Koosis***

The first edition of this well-known book was noted for its clear and accessible exposition of the basic theory of Hardy spaces from the concrete point of view. The second edition retains many of the features found in the first edition, such as detailed computation and an emphasis on methods, but greatly expands its coverage. This edition also includes two appendices by V.P. Havin.

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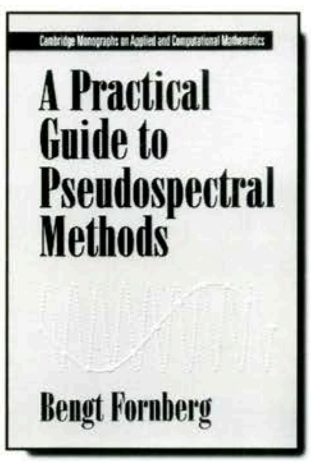
0-521-45521-9 Hardback $69.95




## Level Set Methods and Fast Marching Methods

Evolving Interfaces in Computational Geometry, Fluid Mechanics, Computer Vision, Computer-Aided Design, Optimal Control, and Material Sciences

Second Edition

***J. A. Sethian***

In this new edition of the successful book, *Level Set Methods,* Professor Sethian incorporates the most recent advances in Fast Marching Methods, many of which appear here for the first time. Continuing the expository style of the first edition, he presents cutting edge algorithms using groundbreaking techniques and provides the reader with a wealth of application areas for further study.

1999 384 pp.
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0-521-64557-3 Paperback $29.95

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***Nigel P. Smart***

Here is a coherent modern account of the methods used to find all the solutions to certain diophantine equations, especially those developed for use on a computer. The study is divided into three parts, basic techniques, problems that can be solved using Baker's theory, and problems associated with elliptical curves. Each chapter concludes with a set of exercises.

1999 260 pp.
0-521-64156-X Hardback $69.95
0-521-64633-2 Paperback $26.95

## Birational Geometry of Algebraic Varieties

***János Kollár*** *and* ***Shigefumi Mori***

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1998 262 pp.
0-521-63277-3 Hardback $49.95

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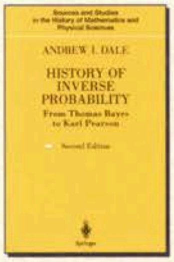
# SPRINGER FOR MATHEMATICS

**ANDREW I. DALE,** University of Natal, South Africa

## HISTORY OF INVERSE PROBABILITY

***From Thomas Bayes to Karl Pearson***
***Second Edition***




This a history of the use of Bayes's theorem over the past 150 years. This second edition focuses on the foundations of statistics, in particular, the examination of the development of one of the fundamental aspects of Bayesian statistics. New sections on contributors to the theory shed light on the use of inverse probability by nineteenth century authors. There is also amplified discussion of relevant work from the first edition. *History of Inverse Probability* will be a valuable reference source in the wider field of the history of statistics and probability.

1999/696 PP., 14 ILLUS./HARDCOVER/$89.95/ISBN 0-387-98807-6
SOURCES AND STUDIES IN THE HISTORY OF MATHEMATICS AND PHYSICAL SCIENCES

**MICHAEL W. FRAZIER,** Michigan State University

## AN INTRODUCTION TO WAVELETS THROUGH LINEAR ALGEBRA

This text was originally written for a capstone course at Michigan State University. Its purpose is to bring together different topics covered in the undergraduate curriculum and introduce students to current developments in mathematics and their applications. Basic wavelet theory seems to be a perfect topic for such a course. As a subject, it dates back only to 1985. Since then there has been an explosion of wavelet research, both pure and applied. Wavelet theory is on the boundary between mathematics and engineering. In particular it is a good topic for demonstrating to students that mathematics research is thriving in the modern day: students can see non-trivial mathematics ideas leading to natural and important applications, such as video compression and the numerical solution of differential equations. The only prerequisites assumed are a basic linear algebra background and a bit of analysis background.

1999/APP. 536 PP., 162 ILLUS./HARDCOVER/$49.95/ISBN 0-387-98639-1
UNDERGRADUATE TEXTS IN MATHEMATICS

**PAULO RIBENBOIM,** Queen's University, Canada

## THE THEORY OF CLASSICAL VALUATIONS

In the second half of the last century, Kummer introduced "local" methods in his study of Fermat's last theorem. Hensel constructed the p-adic numbers and proved the so-called "Hensel lemma." Kurschak formally introduced the concept of a valuation of a field, and the theory was developed by Ostrowski, Hasse, Schmidt, Krull, and others. These classical valuations play a central role in the study of number fields and algebraic functions of one variable. The present book is one of the first texts in English devoted to the beautiful theory of classical valuations. The book is self-contained, up-to-date, and proofs are given in full detail. Thus, *The Theory of Classical Valuations* will be an invaluable resource for graduate students and research mathematicians.

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SPRINGER MONOGRAPHS IN MATHEMATICS

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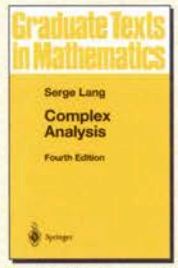
**SERGE LANG,** Yale University, New Haven, CT

## COMPLEX ANALYSIS

***Fourth Edition***




This is the fourth edition of Serge Lang's *Complex Analysis*. The first part of the book covers the basic material of complex analysis, the second part covers many special topics, such as the Riemann mapping theorem, the gamma function, and analytic continuation. Power series methods are used more systematically than in other texts, and the proofs using these methods often shed more light on the results than the standard proofs do. The first part of *Complex Analysis* is suitable for an introductory course on the undergraduate level, and the additional topics covered in the second part give the instructor of a graduate course a great deal of flexibility in structuring a more advanced course. In this revised edition new examples and exercises have been added and many minor improvements have been made throughout the text.

1998/496 PP./HARDCOVER/$64.95/ISBN 0-387-98592-1
GRADUATE TEXTS IN MATHEMATICS, VOLUME 103

**RAMI SHAKARCHI,** Princeton University, NJ

## PROBLEMS AND SOLUTIONS IN COMPLEX ANALYSIS

This volume contains all the exercises, and their solutions, for Serge Lang's fourth edition of *Complex Analysis*. The problems in the first 8 chapters are suitable for an introductory course at the undergraduate level and cover the following topics: power series, Cauchy's theorem, Laurent series, singularities and meromorphic functions, the calculus of residues, conformal mappings, and harmonic functions. The material in chapters 9-16 is more advanced. The reader will find problems on Schwartz reflection, analytic continuation, Jensen's formula, the Phragmen-Lindeloef theorem, entire functions, Weierstrass products and meromorphic functions, the gamma function, and Zeta function. This volume also serves as an independent source of problems with detailed answers beneficial for anyone interested in learning complex analysis.

1999/APP. 256 PP., 35 ILLUS./SOFTCOVER/$34.00/ISBN 0-387-98831-9

**SERGE LANG,** Yale University, New Haven, CT

## MATH TALKS FOR UNDERGRADUATES

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