ISSN 0002-9920

Notices

of the American Mathematical Society

March 1998

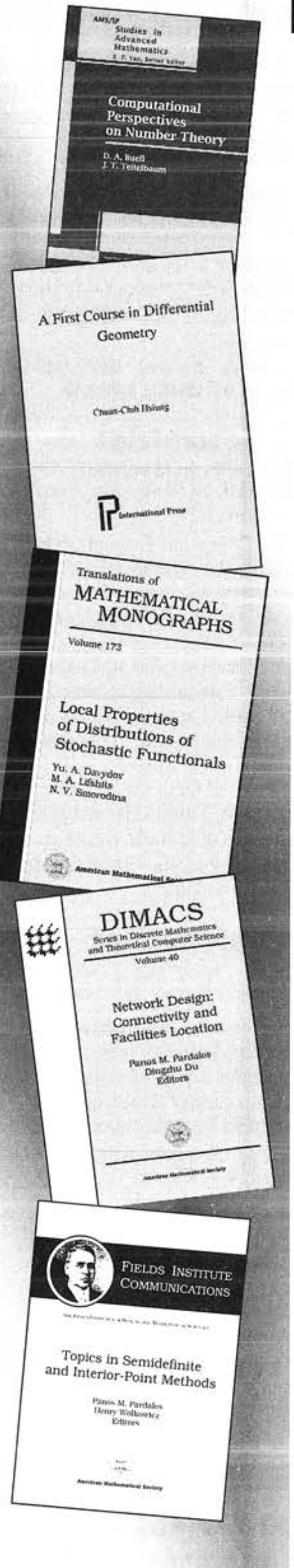
Volume 45, Number 3

Representations of Finite Groups: A Hundred Years, Part I
page 361

Twenty-Five Years with Nicolas Bourbaki, 1949–1973
by Armand Borel
page 373

The Demise of the Young Scholars Program
page 381

A Collection of Mathematical Stamps *(See page 360)*



AMERICAN MATHEMATICAL SOCIETY

New Titles from the AMS

Computational Perspectives on Number Theory

Proceedings of a Conference in Honor of A. O. L. Atkin

D. A. Buell, *Center for Computing Sciences, Bowie, MD*, and **J. T. Teitelbaum**, *University of Illinois at Chicago*, Editors

This volume contains papers presented at the conference "Computational Perspectives on Number Theory" held at the University of Illinois at Chicago in honor of the retirement of A. O. L. Atkin. In keeping with Atkin's interests and work, the papers cover a range of topics, including algebraic number theory, p-adic modular forms and modular curves. Many of the papers reflect Atkin's particular interest in computational and algorithmic questions.

AMS/IP Studies in Advanced Mathematics, Volume 7; 1998; 232 pages; Softcover; ISBN 0-8218-0880-X; List $59; All AMS members $47; Order code AMSIP/7NT83

A First Course in Differential Geometry

Chuan C. Hsiung, *Lehigh University, Bethlehem, PA*

This book is designed to introduce differential geometry to beginning graduate students and advanced undergraduates. The text covers the traditional topics: curves and surfaces in a three-dimensional Euclidean space. Unlike most classical books on the subject, however, the author pays more attention to the relationships between local and global properties rather than to local properties only.

Most global theorems for curves and surfaces in the book can be extended to either higher-dimensional spaces or more general curves and surfaces or both. Geometric interpretations are given along with analytic expressions. This enables students to make use of geometric intuition—a precious tool for studying geometry and related problems.

International Press publications are distributed worldwide, except in Japan, by the American Mathematical Society.

International Press; 1997; 343 pages; Hardcover; ISBN 1-57146-046-2; List $45; All AMS members $36; Order code INPR/24NT83

Local Properties of Distributions of Stochastic Functionals

Yu. A. Davydov, *University of Lille I, Villeneuve d'Ascq, France*, **M. A. Lifshits**, *MANCOMTECH Training Center, St. Petersburg, Russia*, and **N. V. Smorodina**, *Radiation Hygiene Institute, St. Petersburg, Russia*

This book investigates the distributions of functionals defined on the sample paths of stochastic processes. It contains systematic exposition and applications of three general research methods developed by the authors.

(i) The method of stratifications is used to study the problem of absolute continuity of distribution for different classes of functionals under very mild smoothness assumptions. It can be used also for evaluation of the distribution density of the functional.

(ii) The method of differential operators is based on the abstract formalism of differential calculus and proves to be a powerful tool for the investigation of the smoothness properties of the distributions.

(iii) The superstructure method, which is a later modification of the method of stratifications, is used to derive strong limit theorems (in the variation metric) for the distributions of stochastic functionals under weak convergence of the processes.

Various application examples concern the functionals of Gaussian, Poisson and diffusion processes as well as partial sum processes from the Donsker-Prokhorov scheme.

The research methods and basic results in this book are presented here in monograph form for the first time. The text would be suitable for a graduate course in the theory of stochastic processes and related topics.

Translations of Mathematical Monographs, Volume 173; 1998; 184 pages; Hardcover; ISBN 0-8218-0584-3; List $75; Individual member $45; Order code MMONO/173NT83

Network Design: Connectivity and Facilities Location

Panos M. Pardalos, *University of Florida, Gainesville*, and **Dingzhu Du**, *University of Minnesota, Minneapolis*, Editors

Connectivity and facilities location are two important topics in network design, with applications in data communication, transportation, production planning, and VLSI designs. There are two issues concerning these topics: design and optimization. They involve combinatorial design and combinatorial optimization. This volume features talks presented at an interdisciplinary research workshop held at DIMACS in April 1997. The workshop was attended by leading theorists, algorithmists, and practitioners working on network design problems.

Finding the solution of design problems and the optimal or approximate solution of the related optimization problem are challenging tasks because no polynomial time algorithms are known. Such problems include some variations of Steiner tree problems (such as multiple-connected Steiner network, independent flow problem, and subset-interconnection designs), topology network design, nonlinear assignment problems (such as quadratic assignment problems), problems in facilities location and allocation, and network problems appearing in VLSI design.

The focus of this book is on combinatorial, algorithmic, and applicational aspects of these problems. The volume would be suitable as a textbook for advanced courses in computer science, mathematics, engineering and operations research.

DIMACS: Series in Discrete Mathematics and Theoretical Computer Science, Volume 40; 1998; 461 pages; Hardcover; ISBN 0-8218-0834-6; List $79; Individual member $47; Order code DIMACS/40NT83

Topics in Semidefinite and Interior-Point Methods

Panos M. Pardalos, *University of Florida, Gainesville*, and **Henry Wolkowicz**, *University of Waterloo, ON, Canada*, Editors

This volume contains refereed papers presented at the workshop on "Semidefinite Programming and Interior-Point Approaches for Combinatorial Optimization Problems" held at The Fields Institute in May 1996. Semidefinite programming (SDP) is a generalization of linear programming (LP) in that the nonnegativity constraints on the variables is replaced by a positive semidefinite constraint on matrix variables. Many of the elegant theoretical properties and powerful solution techniques follow through from LP to SDP. In particular, the primal-dual interior-point methods, which are currently so successful for LP, can be used to efficiently solve SDP problems.

In addition to the interesting theoretical and algorithmic questions, SDP has found many important applications in combinatorial optimization, control theory and other areas of mathematical programming. SDP is currently a very hot area of research. The papers in this volume cover a wide spectrum of recent developments in SDP. The volume would be suitable as a textbook for advanced courses in optimization.

Fields Institute Communications, Volume 18; 1998; 250 pages; Hardcover; ISBN 0-8218-0825-7; List $69; Individual member $41; Order code FIC/18NT83

AMS
AMERICAN MATHEMATICAL SOCIETY

All prices subject to change. Charges for delivery are $3.00 per order. For optional air delivery outside of the continental U. S., please include $6.50 per item. *Prepayment required.* Order from: **American Mathematical Society**, P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax (401) 455-4046 or call toll free 800-321-4AMS (4267) in the U. S. and Canada, (401) 455-4000 worldwide. Or place your order through the AMS bookstore at http://www.ams.org/bookstore/. Residents of Canada, please include 7% GST.

MATHEMATICS *from Birkhäuser*

Coming February 1998 —

Complex Analysis: Fundamentals of the Classical Theory of Functions

J. Stalker, *Princeton University, NJ*

The classical theory of one complex variable is one of the most beautiful and useful subjects in mathematics. This clear, concise introduction is based on the premise that "anything worth doing is worth doing with interesting examples." Content is driven by techniques and examples rather than by definitions and theorems. Examples, many of which are treated at a level of detail unmatched in similar introductory texts, are chosen from the analytic theory of numbers and classical special functions, but while they are mostly geared towards number theory, mathematical physics, the techniques are generally applicable.

Contents: Chapter I. Special Functions • The Gamma Function • The Distribution of Primes I • Stirling's Series • The Beta Integral • The Whittaker Function • The Hypergeometric Function • Euler-MacLaurin Summation • The Zeta Function • The Distribution of Primes II • Chapter II. Analytic Functions • Contour Integration • Analytic Functions • The Cauchy Integral Formula • Power Series and Rigidity • The Distribution of Primes III • Meromorphic Functions • Bernoulli Polynomials Revisited • Mellin-Barnes Integrals I • Mellin-Barnes Integrals II • Chapter III. Elliptic and Modular Functions • Theta Functions • Eisenstein Series • Lattices • Elliptic Functions • Complex Multiplication • Quadratic Reciprocity • Biquadratic Reciprocity • A Quick Review of Real Analysis • Bibliography • Index

1998 Approx. 224 pp. Hardcover ISBN 0-8176-4038-X **$39.50 (tent.)**

Mathematics of the 19th Century:

Function Theory, Ordinary Differential Equations, Constructive Calculus of Variations

A.N. Kolmogorov, *Moscow State University, Russia* **& A.P. Yushkevich,** *Inst. of History of Science & Technology, Russia (Eds.)*

This third volume concludes the series of historical studies of the mathematics in the 19th century. It includes an essay on the development of Chebyshev's theory of approximation of functions; a systematic analysis of the history of the theory of ordinary differential equations; an essay of the development of the calculus of variations; and a study of the history of finite differences.

April 1998 363 pp., 48 illus. Hardcover ISBN 3-7643-5845-9
$98.00 (tent.)

Einstein: The Formative Years 1879-1909

D. Howard, *University of Notre Dame* **& J. Stachel,** *Boston University, MA (Eds.)*

This volume brings together scholarship on the earliest years of Albert Einstein's life and work.

Topics include: Einstein's early reading and his university education, his views on scientific method and the crucial philosophical influences shaping those views, his early work on statistical mechanics, quantum theory and relativity theory, and his youthful vision of a unified foundation for physics. Eight of the nine papers appear here in print for the first time. The contributors offer a variety of perspectives and draw upon new documentation, including personal letters and unpublished manuscripts.

May 1998 Approx. 352 pp., Hardcover ISBN 0-8176-4030-4
$64.50 (tent.) Einstein Studies Series

Singularity Theory and Gravitational Lensing:

Mathematical Foundations and Physical Applications

A. Petters, *Princeton University, NJ;* **H. Levine,** *Brandeis University, MA* **& J. Wambsganss,** *Astrophysics Institute, Potsdam, Germany*

This monograph is the first of its kind to present a mathematical theory of gravitational-lens optics. It addresses several fundamental mathematical and physical issues in gravitational lensing. Mathematical topics include a study of the stable features of maps arising in lensing, the local and global geometry of caustics due to gravitational lenses, the magnification and multiple imaging of lensed light sources, and multi-plane lensing by singular and nonsingular deflectors. (Astro-)physical topics include Einstein rings and Giant Luminous Arcs, time delay and Hubble's constant, microlensing of stars and quasars, and the detection of dark matter and planets with lensing.

March 1998 Approx. 350 pp., 32 illus. ISBN 0-8176-3668-4
$74.50 (tent.)

Mathematical Essays in Honor of Gian-Carlo Rota

B. Sagan, *Michigan State University* **& R. Stanley,** *MIT, MA*

This volume is dedicated to Gian-Carlo Rota, one of the great enumerators of our time, in honor of his 64th birthday. Contributors include leaders in the fields of combinatorics, invariant theory, combinatorial geometry, special functions, commutative algebra, representation theory and statistics. Contributors include: Andrews, Bailey, Billera, Bonin, Bucchianico, Buchsbaum, Chan, Chen, Crapo, D'Antona, Diaconis, Ehrenborg, Eisenbud, Freeman, Garsia, Ismail, Krattenhaler, Kung, Loeb, Mendez, Oliveira , Ram, Ray, Readdy, Remmel, Rota, Schwartz, Stanley, Stanton, Star, Sturmfels, Taylor, Whitely, Wimp, Yang

March 1998 Approx. 300 pp. Hardcover ISBN 0-8176-3872-5
$69.50 (tent.)

High Dimensional Probability

E. Eberlein, *Universität Freiburg, Germany;* **M. Hahn,** *Tufts University, MA* **& M. Talagrand,** *Université Paris VI, France (Eds.)*

What is high dimensional probability? Under this broad term, one finds a collection of topics associated with the idea of high dimension as expressed either in the problem or in the methods by which it is approached. For example, the study of probability in Banach spaces gave impetus to a number of methods whose importance has gone far beyond the original goal of extending limit laws to the vector valued case.

Familiar applications are in the areas of empirical processes, the use of majorizing measures to study regularity of stochastic processes, and the theory of concentration of measure.

February 1998 Approx. 340 pp. Hardcover ISBN 3-7643-5867-X
$98.50 (tent.) Progress in Probability, Volume 43

Groups and Geometries

L. di Martino; W.M. Kantor, G. Lunardon, A. Pasini, M.C.Tamburini, *all, University of Pisa, Italy (Eds.)*

The Conference on Groups and Geometries held in Siena in 1996 addressed a broad range of topics in group theory and geometry, with emphasis on recent results and open problems. Special attention was drawn to the interplay between group-theoretic methods and geometric and combinatorial ones.

This volume contains a stimulating collection of ideas stemming from work in such areas as 1) the classification of finite simple groups; 2) the structure and properties of groups of Lie type over finite and algebraically closed fields of finite characteristic; 3) buildings and the geometry of projective and polar spaces; and 4) geometries of sporadic simple groups.

March 1998 Approx. 280 pp. Hardcover ISBN 3-7643-5881-5
$118.00 (tent.) Trend in Mathematics

Linear Algebraic Groups

Second Edition

T.A. Springer, *Mathematics Institute, The Netherlands*

This second edition contains important new results in the structure and classification of reductive groups over arbitrary fields. In this expanded edition, standard Borel-Chevalley theory is further streamlined and differs greatly in emphasis from other treatments.

March 1998 Approx. 350 pp. Hardcover ISBN 0-8176-4021-5
$64.50 (tent.) Progress In Mathematics

Table of Contents

March 1998

Feature Articles

Representations of Finite Groups: A Hundred Years, Part I — 361

T. Y. Lam

A hundred years ago the introduction of group representations began to unlock the secrets of finite groups. In this first part of a two-part series, the author explains how Frobenius's study of group determinants led first to characters, then to group representations, and then to a theory that exposed new properties of finite groups.

Twenty-Five Years with Nicolas Bourbaki, 1949–1973 — 373

Armand Borel

Armand Borel gives some personal recollections of his years as a close observer and then a member of Bourbaki.

The Demise of the Young Scholars Program — 381

Allyn Jackson

The termination of the Young Scholars Program by the NSF appears to be a potent mix of politics and legal troubles, together with the governmental fact of life that dollars flow more easily toward new ideas, even when the old ones have proven their worth.

Memorial Articles

Kunihiko Kodaira (1915–1997)
Donald C. Spencer — 388

Louis Auslander (1928–1997)
S. S. Chern, Thomas Kailath, Bertram Kostant, Calvin C. Moore, and Anna Tsao — 390

Communications

The Pleasures of Counting: A Book Review
Brian E. Blank — 396

Life After Academia: How a Mathematician Found a New Career
Dana Mackenzie — 401

Departments

Editorial 356
Commentary 357
Mathematics Opportunities 405
For Your Information 407
Reference 415
Mathematics Calendar 417
New Publications Offered by the AMS 428
Publications of Continuing Interest 434
Classifieds 436
Membership Forms 443
Meetings and Conferences Table of Contents 456

From the AMS

AMS Standard Cover Sheet 410

Notices

of the American Mathematical Society

EDITOR: Anthony W. Knapp
ASSOCIATE EDITORS:
Robert M. Fossum, Susan Friedlander (*Forum Editor*), Martin Golubitsky, Victor Guillemin, David Jerison, Susan Landau, Andy Magid (*Opinion Column Editor*), Judith Roitman, Mary Beth Ruskai, Mark Saul
CONTRIBUTING EDITORS: Hyman Bass, Steven Krantz, Hugo Rossi
SENIOR WRITER and DEPUTY EDITOR:
Allyn Jackson
MANAGING EDITOR: Sandra Frost
PRODUCTION ASSISTANTS:
Muriel Toupin, Anne-Marie Epp
PRODUCTION:
Leda Black, Lori Nero, Donna Salter, Deborah Smith, Peter Sykes, Maxine Wolfson
ADVERTISING SALES: Anne Newcomb

SUBSCRIPTION INFORMATION: Subscription prices for Volume 45 (1998) are \$300 list; \$240 institutional member; \$180 individual member. (The subscription price for members is included in the annual dues.) A late charge of 10% of the subscription price will be imposed upon orders received from nonmembers after January 1 of the subscription year. Add for postage: Surface delivery outside the United States and India—\$15; in India—\$36; expedited delivery to destinations in North America—\$35; elsewhere—\$70. Subscriptions and orders for AMS publications should be addressed to the American Mathematical Society, P.O. Box 5904, Boston, MA 02206-5904. All orders must be prepaid.

ADVERTISING: *Notices* publishes situations wanted and classified advertising, and display advertising for publishers and academic or scientific organizations.

SUBMISSIONS: Letters to the Editor, Forum pieces, articles, and reviews may be sent to the editor by e-mail at `notices@math.sunysb.edu`, by fax at 516-751-5730, or by postal mail at P. O. Box 333, East Setauket, NY 11733. Electronic submissions are preferred. Correspondence with the managing editor may be sent to `notices@ams.org`.

NOTICES ON e-MATH: Most of this publication is available electronically through e-MATH, the Society's resource for delivering electronic products and services. To access the *Notices* on e-MATH, use the URL:

`http://www.ams.org/notices/`

Those with VT100-type terminals or without WWW browsing software can connect to e-MATH via Telnet (`telnet e-math.ams.org`; login and password are "e-math") and use the Lynx option from the main menu.

[*Notices of the American Mathematical Society* is published monthly except bimonthly in June/July by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2213. Periodicals postage paid at Providence, RI, and additional mailing offices. POSTMASTER: Send address change notices to *Notices of the American Mathematical Society*, P.O. Box 6248, Providence, RI 02940-6248.] Publication here of the Society's street address and the other information in brackets above is a technical requirement of the U.S. Postal Service. All correspondence should be mailed to the post office box, not the street address. Tel: 401-455-4000; e-mail: `notices@ams.org`.

Editorial

About Covers

Mathematical images can and do play a role in advancing mathematics for specialists and in advertising mathematics to nonspecialists. Each era has produced its own images—from the Platonic solids of ancient Greece to the regular planar tilings of fourteenth-century Moorish Spain, to the intricacies of plant phyllotaxis (based on thirteenth-century Fibonacci sequences), to the nineteenth-century Bravais lattices (now the province of crystal chemistry), to the two-color tessellations popularized by M. C. Escher and the aperiodic Penrose tilings, and to the striking computer-generated twentieth-century images of the Lorenz attractor and the Mandelbrot set.

This issue of the *Notices* is the 38th in the new series, and with it we have the 38th cover image. The images have ranged from the mundane (pictures of the cities where AMS national meetings are being held) to the mathematically more interesting: geometry, DNA knots, chaos, tilings, and neural nets. The *Notices* is always on the lookout for attractive images that are about or related to mathematics—and better yet—for images that are coupled to a *Notices* article. Suggestions for cover images can be sent to Sandra Frost (`smf@ams.org`) at the AMS or to me (`mg@uh.edu`).

This month's cover is a joint effort with Robin Wilson, who writes the "Stamp Corner" for the *Mathematics Intelligencer*. Robin has collected many stamps related to mathematics and mathematicians during the twelve years he has been writing this column. We have chosen a few of these stamps from a number of countries as a small pictorial celebration of mathematics history.

—Martin Golubitsky for the Editorial Board

Not to Miss

The Demise of the Young Scholars Program

A major emphasis of today's mathematics education reform effort is encapsulated in the phrase "mathematics for all". Raising the general mathematical level of all students is an important goal. Another important goal is giving highly mathematically talented students the inspiration and challenge they need. The demise of the Young Scholars Program at the National Science Foundation, which supported efforts such as the Ross Program at Ohio State University, shows that in the competition for funding for educational programs those aimed at the mathematically talented can easily lose out. The feature article by Allyn Jackson describes how the Young Scholars Program was eliminated for reasons having little to do with the success or effectiveness of the grants it supported.

—Anthony W. Knapp

It's All Greek to Me

The following item is reprinted from The New York Times:

A television review on October 27 about that night's *Nova* program titled "The Proof", referred imprecisely to what was being proved. It was Fermat's Last Theorem, not the Pythagorean theorem. Fermat's last theorem states that the equation $x^n + y^n = z^n$ has no solution when x, y, and z are positive whole numbers and n is a whole number greater than 2. When n equals 2, the equation has many solutions and is known as the Pythagorean theorem: in a right-angle triangle the square of the hypotenuse is equal to the sum of the squares of the other two sides.

Commentary

In My Opinion

Hazardous Mathematical Platitudes

When we mathematicians say something is known, we are on the epistemological high ground. No other aspect of human knowing is as sure and as reproducible as a piece of valid mathematics. When we venture into nonmathematical issues, however, we have to live in the same world of rhetoric, argument, and contingent fact as the rest of the species. In fact, our mathematical training may put us at a disadvantage.

Consider, for example, how the following mathematical principles could be liabilities:

• "Truth is definitive": In mathematics if the proof is valid, the result must be accepted. Is this what leads us to believe that if only we could find the right argument, the proper reasoning chain, the logically compelling way to phrase our points, then the public would finally appreciate the value of our discipline and its practitioners? (And perhaps express its appreciation by better funding our research?) When he addressed the Society at its meeting in San Diego in January 1997, Congressman George Brown urged mathematicians, along with the rest of the scientific community, to make its case in political terms, by which I think he means to be compelling in ways other than just by the logical force of its positions. The success of the "Unified Statement on Research", endorsed by the presidents of over one hundred scientific societies and in which the AMS played a leadership role, is an example.

• "If it's not completely correct, it's all wrong": While there are correctable errors in proposed proofs, there's no such thing as a partly correct mathematical proof. Is that what leads us to try to apply the same principle to expressions of opinion? Errors and mistakes, including willful ones, can creep into written commentary, even when subjected to the careful editorial review of these *Notices*. Does a minor misstatement of fact invalidate the position taken by the author of an opinion piece? I'd say no, but letters to the editor received by the *Notices* suggest this is not a universally held view.

• "An example is not a proof": Of course it isn't, but sometimes it's the best that can be done. In areas where general principles are not universally applicable or where experimentation must be tempered by ethical considerations, like medicine or pedagogy, careful scrutiny of examples ("case studies") or collections of examples ("case series") is a standard research methodology. This is not to be confused with using narrative (including fiction) as a rhetorical device ("anecdotal evidence"). I wonder whether the slow diffusion of the results of education research through the mathematics community may be due in part to a prejudice against the case study method.

• "The mathematics is the only acceptable measure of the mathematician": Even if we occasionally fail to live up to our ideals, belief in a strict meritocracy seems to me central to the organization of mathematics. Most mathematicians seem to have a reasonable sense of how their mathematics rates and in their mathematical relationships defer or presume accordingly. Not unexpectedly, some mathematicians carry this forward into nonmathematical issues as well. It is possible for excellent mathematicians to produce poor commentary, and vice versa, as I learned during the few months I edited the *Notices* last year. And both those who presume that their mathematics entitles them to privileges and those who defer to others on mathematical bases regarding nonmathematical issues are at fault here.

• "Mathematicians are masters of logical thinking": Our tendency as mathematicians, whose view of ourselves as reasoners is central to our self-image, is sometimes to perceive attempts by holders of opinions opposed to our own to justify their positions as attempts to out-reason us, and hence as attacks on our professional identities. The advent of e-mail and the ease (trumping the etiquette) of cc'ing third parties mean that many more of us have looked in on nasty debates over silly points by otherwise sensible colleagues; I'd attribute some of this to that tendency.

So with mathematical truisms exposed as weaknesses in the nonmathematical world, what would I have us do? Have no opinions, or, if we do, keep them to ourselves? Of course not. But I'd like us to keep in mind regarding commentary, especially commentary that finds its way into print, for instance in the *Notices*, or in criticism thereof, that mathematical habits of thought are not always what is needed or wanted. Mathematicians, in my opinion, can be as persuasive, and collegial, as anyone else.

—Andy Magid
Associate Editor

Letters

Origin of the KdV Equation

As Richard Palais intimated in his fine article on "The symmetries of solitons" (*Bulletin*, October 1997), any story about such a wide-ranging subject must select and simplify. Perhaps, though, readers may find these few historical clarifications concerning the early controversy over the solitary wave and the origin of the Korteweg-de Vries equation to be of interest.

The aspects of John Scott Russell's 1844 report concerning his "Wave of Translation" certainly generated mathematical controversy, but for reasons slightly different from those suggested; R. K. Bullough's article in the collection *Solitons* (M. Lakshmanan, ed., Springer, 1988) discusses the situation in depth. On the one hand, it was well known that d'Alembert's solution of the wave equation gave traveling-wave solutions with arbitrary waveform. So it seemed to Airy in 1845 that no particular wave shape should be exceptional in the sense that Russell claimed. On the other hand, Airy also developed a theory that takes nonlinear effects into account (especially the variable depth of water under a wave), which showed that any single-wave solution must steepen. Stokes argued in 1847 that a permanent solitary wave was impossible for a different reason. He computed that nonperiodic traveling waves were impossible if one took account of dispersion. (The effect of dispersion on water waves is pronounced: short waves travel much slower than long waves, as is readily observed.)

It was nearly thirty years before Boussinesq in 1872, and then Rayleigh in 1876, resolved the issue by balancing the effects of dispersion and nonlinearity to produce a solitary wave of permanent form with a particular shape. (It is probably fair to say, though, that it is not well understood even today why this delicate balance should produce a *stable* waveform.)

Boussinesq wrote four works which contain treatments of the problem of the solitary wave. (For bibliographic details, see the historical article by J. W. Miles, *J. Fluid Mech.* 106 (1981), 131–147.) These works can hardly be said to be models of clear exposition or consistency. But while tracing the origins of various "Boussinesq equations", I noticed that the *KdV equation* appears in a footnote on page 360 of Boussinesq's massive 680-page memoir, *Essai sur la théorie des eaux courantes*, which was presented to the French Academy in 1872 and finally appeared in 1877. More careful consideration revealed that Boussinesq based his description of the solitary wave, and his explanation for its stability, on a pair of equations exactly equivalent to the KdV equation, written in his notation as

$$\frac{dh}{dt} + \frac{d.h\omega}{dx} = 0,$$

$$\frac{\omega}{\sqrt{gH}} = 1 + \frac{3h}{4H} + \frac{H^2}{6h}\frac{d^2h}{dx^2}.$$

Here h represents the elevation of the wave, H is constant and represents the depth of the fluid at infinity, and g is the gravitational constant. These are equations (5a) and (7a) of Boussinesq's second 1871 *Comptes Rendus* article, equations (29) and (34) of his 1872 article in *J. Math. Pures Appl.*, and equations (283) and (291) of the memoir. The solitary waves obtained by Boussinesq in these works were exactly traveling-wave solutions of this pair of equations, obtained by requiring that ω be constant.

In addition, Boussinesq's rationale for the stability of solitary waves has had a direct influence on modern developments. T. B. Benjamin credited Boussinesq for the idea that a certain conserved functional, called the "moment of instability" by Boussinesq, is relevant for understanding the stability of solitary waves. This functional is now known as a Hamiltonian energy for the KdV equation. One hundred years after Boussinesq introduced this quantity, Benjamin and Bona used it as a Lyapunov functional to construct a rigorous proof of orbital stability for KdV solitons. Boussinesq's argument that the moment of instability is constant in time rests exactly on the pair of equations above.

It is not clear why Korteweg and de Vries thought the permanence of the solitary wave still controversial in 1895, but perhaps they were not aware of three of Boussinesq's works on the subject, since they refer only to his first 1871 *Comptes Rendus* article, which sketches a different, less satisfactory treatment of the problem.

Miles's article mentioned above appears to be the only modern source (among several historical papers) to properly appreciate Boussinesq's work in this respect, and indeed it contains quite a thorough account, except that it does not mention the 1877 footnote. Maybe for this reason Miles came up shy of pressing Boussinesq's priority in deriving the KdV equation.

Robert Pego
University of Maryland, College Park

(Received December 1, 1997)

Use Convergence to Teach Continuity

In reaction to the January 1998 issue of these *Notices*, page 6, I would like to submit the following.

There is hardly a better way to explain, to define, or to teach the notion of continuity (especially in calculus) other than by saying that "A function f is continuous at c if and only if whenever a sequence $c(1), c(2), c(3), \ldots$ converges to c, then the corresponding sequence $f(c(1)), f(c(2)), f(c(3)), \ldots$ converges to $f(c)$."

Notice also that the notion of "convergence" is much more intuitive than any of the statements such as "the closer x gets to ...", etc.

Most important is that the above sequential definition of continuity is equivalent to the universally accepted "epsilon, delta" definition of continuity. The equivalence uses a very mild version of the Axiom of Choice AC (for which one need not feel apprehensive).

In this connection I would like to note that AC is one of the extremely natural axioms of the standard ZFC set theory. AC, besides being consistent with ZF, is also almost inextricably related to the other axioms of ZF. For more than seventy years before

1963 mathematicians could not construct a model for standard ZF set theory where AC was not stubbornly present and hence valid. No matter how hard they tried, they could not expunge AC from any standard model of ZF, so intimately is AC bound to the other axioms of ZF. The main reason is, of course, that "well ordering things" is almost a way of life in mathematics. Set-theoretical models are usually created as well-ordered sequences of shelves, and on each shelf objects are placed in a well-ordered sequence. Thus, well ordering is mostly built in (in a natural way) in any standard set-theoretical model, and AC was inevitably valid in all of them up until 1963. It was P. J.Cohen's genius which finally in 1963 created a standard model for ZF, extricating AC from it (same thing can be said in connection with the Continuum Hypothesis CH).

Alexander Abian
Iowa State University

(Received December 10, 1997)

Beal Conjecture and Prize

I am writing to update the announcement in the December 1997 issue of the *Notices* of the Beal Conjecture and Prize. Let me report first that it has now come to my attention that the conjecture is stated and discussed in van der Poorten's recent book *Notes on Fermat's Last Theorem*. The problem is also discussed in a March 1997 lecture and paper of Darmon, available from him as a PostScript file. In view of this, I realize now that I should have included more of the story of how and when Beal arrived at his conjecture. Let me also state that although my purpose in writing the original notice was not to give a comprehensive survey of the ideas surrounding the problem (which is beyond me) but simply to report on Beal's conjecture and prize; any essential omissions or oversights in the article are my own responsibility. Thus, I am writing to provide some background about the genesis of Beal's conjecture, to report a simplification of the prize, and to announce a Web site about the prize.

In the summer of 1993 Beal, inspired by hearing about Wiles's stunning achievement, began thinking about Fermat's Last Theorem. From his viewpoint he discovered that there seemed to be a more general relationship at work, which he formulated as his conjecture. Beal mulled over the problem himself. During August 1993 Beal hired an independent contractor, James Wilhelmi, to conduct computer searches for counterexamples. The bank's computers were turned over to this search at night and on weekends. With no counterexamples in sight, Beal became even more convinced that his conjecture was indeed correct. Over the next several months, in his spare time, he tried to prove it. During the summer and fall of 1994 Beal wrote to perhaps fifteen or twenty mathematicians and journals informing them of his conjecture. Some of his choices were very good, whereas others could be expected to be nonresponsive.

Harold Edwards responded in September 1994. He suspected there might be counterexamples and suggested that Beal have someone do a simple computer study which would perhaps reveal them. Beal had also written to Earl Taft as editor of *Communications in Algebra* about his conjecture. Taft had sent it to someone (an anonymous expert) who said they had never heard of the problem, mentioned its relation to the ABC conjecture, and also thought there might be counterexamples.

In the fall of 1995 Beal came to North Texas as a guest of the administration and soon began meeting with some of us here to discuss mathematics. He told us about his conjecture. I thought it seemed interesting, and eventually he proposed to offer a prize for its solution. This culminated with the announcement in the *Notices*.

Since the prize was announced in the *Notices*, Beal has simplified the prize at a fixed \$50,000. Thus, the prize beginning December 1, 1997, is \$50,000 for either a counterexample or a proof. In the case of a proof, the prize will be awarded when the paper has been accepted in a (reputable) standard mathematics journal and also, in the eyes of the committee, when the proof has been accepted as correct by the mathematics community.

Inquiries about the details of the prize may be sent to me via e-mail: `mauldin@dynamics.math.unt.edu` or by regular mail. There is also a Web site: `http://www.math.unt.edu/~mauldin/beal.html`.

R. Daniel Mauldin
University of North Texas

(Received December 11, 1997)

Mathematics Communication in the 21st Century

The last two letters to the editor in the January *Notices* are disturbing. I hate to think of the AMS stepping across the millennium threshold worrying about "typists" and "overlays".

The underlying issue in both letters is the communication of mathematics. The questions we need to address are:

1. What sort of electronic translation services should a mathematics department provide? The Mathematical Markup Language (MathML) standards are nearing completion, as are various automated translation programs. Mathematica, for example, can import and export to a variety of print and electronic formats. To what extent could the AMS help by setting up a Web site that would automatically translate, say, $\mathcal{A}_{\mathcal{M}}\mathcal{S}$-LaTeX to MathML? Should department librarians be expected to purchase scanning software that will translate archival printed documents into MathML, Mathematica, or other systems of choice?

2. What sort of electronic communication systems should the AMS provide at meetings? Wireless communication systems are becoming standard features on notebook computers. AMS meetings could include computer servers with public directories on which conference attendees could post electronic documents. Should we also expect meeting rooms with projection systems connected to the Web?

I'll accept that there is a certain amount of "audiovisual tradecraft" associated with giving a good presentation. The University of Malta has an excellent Web page on details of using the overhead projector. The URL is http://www.ilands.com/education2000/08.htm.

David Fowler
University of Nebraska-Lincoln

(Received December 12, 1997)

Objects to Universities Run as Businesses

It is common nowadays for university administrators to describe their university as a "business", whose "customers" or "clients" are the students. I have at least four objections to make to this outlook.

First, we should make it clear what it is we are selling. If we are selling degrees, we could certainly streamline the operation. No faculty or classes would be needed; students could mail in four years of tuition, and administrators could mail them whatever degree they have paid for.

I hope it is not necessary to explain why selling degrees or grades is reprehensible. Yet we may not be far from this vision of the university; an article on grade inflation in the July 25, 1997, *Chronicle of Higher Education* quoted a recent University of Chicago Ph.D. as saying that professors would raise the grade he had recommended (as a teaching assistant) because "Hey, they're paying $125,000; we ought to give them a good grade."

Second, with the exception of those few truly private—in the sense of receiving no state or federal aid—universities, our customers are not just our students but all of American society. Especially in math, giving the majority of students what they want—an effortless high grade and the illusion of learning—is disastrous in terms of giving society what it needs. What society needs from us more than anything is the identification of people incompetent to hold positions of intellectual responsibility. There is nothing more dangerous to society than ignorant people who believe they are knowledegable and have been falsely identified as being competent; it's like being driven in a bus into a chasm because the driver believes there is a bridge.

What our real customers, the public, want from math departments is teaching, especially the service classes. The extent to which administrators are willing to serve these customers can be measured by the salaries they pay part-time instructors and teaching assistants, whom they increasingly rely on to teach service classes.

Third, if universities really are going to be capitalists first, to avoid the excesses of laissez-faire capitalism, we need the equivalent of the Food and Drug Administration. In particular, we need some explicit truth-in-advertising laws. I know of a master's degree in math that requires no thesis or qualifying exam and may be acquired entirely by taking undergraduate classes, including ones equivalent to sophomore-level classes for engineering majors. Society is paying for a T-bone steak and getting hamburger.

Fourth, I don't believe university adminstrators really want to behave like businesspeople in any constructive way. In business the phrase "top-heavy with administration" is pejorative. The ideal university as apparently envisioned by the average university administrator is top-heavy, bottom-heavy, and middle-heavy with administration. The term "service", which almost invariably means administration, occupies the same moral position in universities that "charity" does in the outside world: ten minutes of "service" per week is morally superior to any amount or quality of teaching and research. If Jaime Escalante were performing his miracles at an average American university, the response of administrators would most likely be "Yes, but what committees have you served on recently?"

We are not a business and we shouldn't be. We are being trusted with a good deal of money and authority, with very little specific accountability: faculty must show up to give some kind of lecture a few hours each week, and administrators must optimize managerial parameters while utilizing careful scrutiny of matters that have come to their attention. It would be a betrayal to twist that trust into profit making. If we really want to be a business and be honest about it, we should renounce all government aid and submit to persistent governmental inspections and evaluations, beginning with proficiency exams for all our degrees. I hope we are not irresponsible enough to make this necessary.

Ralph deLaubenfels
Scientia Research Institute

(Received December 12, 1997)

About the Cover

This month's cover is a joint effort with Robin Wilson, who writes the "Stamp Corner" for the *Mathematics Intelligencer*. The mathematicians portrayed in this collage of stamps are (clockwise from upper right corner) LaGrange, Pascal, Kovalevskaya, al-Khuwarizmi, Dedekind, Newton, Cauchy, Ramanujan, and Bolzano.

Representations of Finite Groups: A Hundred Years, Part I

T. Y. Lam

Introduction

Mathematical ideas in any subject area are often discovered and developed over a period of time, so it is usually not possible to assign a specific date to a discovery. But in a few cases a discovery may have been accompanied by an event of such a unique or peculiar nature that the discovery itself has come to be identified with that event. A well-known instance of this is Hamilton's discovery of the quaternions, which is invariably associated with his famous walk on October 16, 1843, along the Royal Canal in Dublin. His carving of the quaternion equations on a stone of the Brougham Bridge added such an element of romance to the story that the date of 10/16/1843 is indelibly etched in history books of mathematics as the date of birth of the quaternions. Another instance took center stage some fifty years later—this time it was the creation of the theory of representations of finite groups. On April 12, 1896, F. G. Frobenius penned his first letter to R. Dedekind to describe his new ideas on factoring a certain homogeneous polynomial associated with a finite group, called the "group determinant". Two more letters quickly ensued (on April 17 and April 26, 1896), and by the end of April that year, Frobenius was in possession of the rudiments of the character theory of finite groups. It was to take some more time for the idea of group representations to be fully developed, but the famous Frobenius-Dedekind *Briefwechsel* in April 1896 is now hailed by historians as the single most significant event marking the birth of the representation theory of finite groups.

As a student of algebra, I have always been fascinated by the theory of group representations. I dabbled in the subject thirty years ago when I wrote my doctoral dissertation, and have remained a user and admirer of the subject ever since. When I realized that April of 1996 was the one-hundredth anniversary of the discovery of the representation theory of finite groups, the temptation to have some kind of "celebration" of this occasion was great. Purely by chance I got a call in March 1996 from Alan Weinstein, our department's colloquium chairman, who asked me to recommend someone for an unfilled colloquium slot. Before I hung up, I found that I had "volunteered" myself to be colloquium speaker for a talk to commemorate the centennial of group representation theory! I will forever be in shame for suggesting myself as colloquium speaker, but then I got my chance to tell the fascinating stories associated with the birth of representation theory, on April 18, 1996, *almost exactly* one hundred years after Frobenius penned his first famous group-determinant letter to Dedekind. The same talk was repeated with some variations in May at Ohio State University, and then in June of the same year in the "Aspects of Mathematics" Conference at my alma mater, the University of Hong Kong. Due to my administra-

T. Y. Lam is professor of mathematics at the University of California, Berkeley. His e-mail address is `lam@math.berkeley.edu`.

This article, in two parts, is a slightly abridged version of an article appearing concurrently in the Proceedings of the "Aspects of Mathematics" Conference *(N. Mok, ed.), University of Hong Kong, H.K., 1998. Part II, concerning William Burnside, the Burnside problems, and their influence on contemporary mathematics, will appear in the April 1998 issue of the* Notices.

tive duties at MSRI, the writing of the article was put off for more than a year. A fall sabbatical in 1997 finally enabled me to finish the project, so I am now pleased to offer this leisurely written account of my lecture. A somewhat longer version with more technical details will appear concurrently in the proceedings of the "Aspects" conference, published by the University of Hong Kong. In particular, some of the proofs omitted from this article can be found in the Hong Kong proceedings.

Disclaimer and References

Before we try to tell the reader what this article is, we should perhaps first tell him/her what the article is *not*. A proper coverage of the history of the representation theory of finite groups would take no less than a full-length volume, starting with the pioneering work of Molien, Cartan, Dedekind, Frobenius, Burnside, on to the rewriting of the foundations of the subject by Schur, Noether, then to the pivotal work of Brauer on both the ordinary and the modular representation theory of groups, climaxing perhaps with the monumental classification program of finite simple groups (which certainly would not have been possible without the aid of character theory). Such a major undertaking is best left to the experts, and I was glad to learn that Professor Charles Curtis is preparing such a volume [Cu_2] in the History of Mathematics series of the Society. In my one-hour talk, all I had time for was to give the audience a few snapshots of the big story, focusing on the origin of representation theory to suit the centennial occasion. Thus, we started with some background in nineteenth-century mathematics, surveyed the work of Dedekind, Frobenius, and Burnside, and went on to talk a little about Schur and Noether, after which we simply declared ourselves "saved by the bell". This write-up is an expanded version of my talk[1], but still it is sketchy and anecdotal at best, and is no substitute for the more scholarly writings on the subject in the literature. For the latter, we recommend the articles of Hawkins [H_1–H_4], written from the perspective of a historian, and the work of Curtis [Cu_1, Cu_2] and Ledermann [L_1], written from the viewpoint of mathematicians. For surveys of representation theory in the broader framework of harmonic analysis, we recommend Mackey [Ma] and Knapp [Kn]. The recent article of K. Conrad [Con], complete with detailed proofs and interesting computational examples, also makes good reading for those with pencil and paper in hand.

[1] *To save space, the part about Schur and Noether is not included in the present article. Readers interested in the work of Schur and Noether in representation theory may consult [L_2, La, Cu_2].*

Since most material is drawn from existing sources (loc. cit.), we make no pretense of originality in this article. In writing it up, we did try to strike a balance between the mathematics and the human dimensions of mathematics; some of the remarks of a more interpretative nature about mathematicians and mathematical events were my own. It is hoped that, by mixing history with mathematics, and by telling the story in the chatty style of a colloquium lecture, we are able to present a readable and informative account of the origin of the representation theory of finite groups.

I am much indebted to Charles Curtis, who kindly provided me with various chapters of his forthcoming book [Cu_2], and it is my great pleasure to thank him, Keith Conrad, Hendrik Lenstra, Monica Vazirani, and the editorial staff of the *Notices* for comments, suggestions, and corrections on this article.

Backdrop of Late Nineteenth-Century Group Theory

Before we begin our story, a quick look at the group theory scene in Europe in the last decades of the nineteenth century is perhaps in order. If we regard group theory as originating from the time of Gauss, Cauchy, and Galois, the subject was then already more than half a century old. Budding German mathematician Felix Klein inaugurated his Erlangen Program in 1872, proclaiming group theory as the focal point for studying various geometries; in the same year, Norwegian high school teacher Ludwig Sylow published the first proofs of his now famous theorems in the fifth volume of the *Mathematische Annalen*. Arthur Cayley and Camille Jordan were the reigning group theorists of the day. Among the first treatises in group theory were Jordan's *Traité des Substitutions et des Équations Algébriques* (1870) and Netto's *Substitutionentheorie und Ihre Anwendungen auf die Algebra* (1882). Both books were on the theory of permutation groups, then synonymous with group theory itself. (The only notable exception was the work of von Dyck on groups defined by generators and relations in 1882–83.) One of the most popular algebra texts of the day was Serret's *Cours d'Algèbre Supérieure*, the second volume of which (3rd ed., 1866) contained a good dose of groups of substitutions. Abstract groups were treated only later, perhaps first in text form, in Weber's *Lehrbuch der Algebra*. Authors of group theory papers were not always careful, and in fact were sometimes prone to making mistakes. Otto Hölder apparently started the tradition of writing long papers in group theory, analyzing groups case by case, but was not above forgetting a few. Even the great Arthur Cayley, known to be "thoroughly conversant with everything that had been done in every branch of mathematics" [C: pp. 265–266], bewildered his readers by blithely listing, as late as 1878, *three* groups of order 6 in his paper [Ca] in the first issue of the *American Journal of Mathematics.*

As far as representation of groups is concerned, there was not much in evidence. In his work in the 1870s and 1880s, Klein certainly used matrices to realize groups, but he did this only for a few specific groups, and there was no hint at a possible theory. In number theory, the Legendre symbol $(\frac{a}{p})$ (p an odd prime) perhaps provided the first instance of a "character". This symbol takes values in $\{\pm 1\}$, and is multiplicative in the variable a. Gauss used similar symbols in dealing with Gauss sums and with binary quadratic forms, but allowed these symbols to take roots-of-unity values. In Dirichlet's work on primes in an arithmetic progression, the Dirichlet L-series

$$L(s,\chi) = \sum_{n=1}^{\infty} \frac{\chi(n)}{n^s}$$

figured prominently a "mod k character" χ, which is multiplicative in n, and zero when n is not relatively prime to k. The abstract definition of an (abelian) character we owe to Richard Dedekind. In one of his supplements to Dirichlet's lectures in number theory [D], c. 1879, Dedekind formally defined a *character* on a finite abelian group G to be a homomorphism from G to the multiplicative group of nonzero complex numbers. Under the pointwise multiplication of functions, the characters of G form a group $\hat{G}$ (called the *character group*), with cardinality equal to $|G|$, the cardinality of the group G itself. Orthogonality relations among characters were proved, and were included in book form in Band II of Weber's *Lehrbuch.* The stage was now set for the discovery of the general character theory of arbitrary finite groups.

Dedekind and the Group Determinant

To a modern student of mathematics, it would have been perfectly natural to extend the definition of a character by taking homomorphisms D of a group G into $GL_n(\mathbb{C})$ (the group of invertible $n \times n$ complex matrices) and defining $\chi_D(g) = \mathrm{trace}(D(g))$ $(g \in G)$ to get a character. This, however, was *not* an obvious step for the mathematicians in the nineteenth century. Thus the discovery of the notion of characters for general groups was to take a rather circuitous route, through something which Dedekind called the *group determinant.*

A last descendant of Gauss's famous school in Göttingen, Richard Dedekind (1831–1916) was undisputedly the dean of abstract algebra in Germany toward the end of the nineteenth century. Though he preferred a teaching position at a local institute in his hometown of Braunschweig[2] to a chair in a more prestigious university, the mathematical influence he exerted was perhaps a close second to that of Karl Weierstrass. Dedekind's greatest contributions were in the area of number theory. In contemplating the form of the discriminant of a normal number field with a normal basis, Dedekind arrived at a similar determinant in group theory. Given a finite group G, let $\{x_g : g \in G\}$ be a set of commuting indeterminates, and form a $|G| \times |G|$ matrix whose rows and columns are indexed by elements of G, with the (g,h) entry given by $x_{gh^{-1}}$. (One could have taken the (g,h) entry to be x_{gh} (as Dedekind first did), but the two matrices would have differed only by a permutation of columns.) The determinant of $(x_{gh^{-1}})$ was christened the "group determinant" of G; following Dedekind, we denote it by $\Theta(G)$.

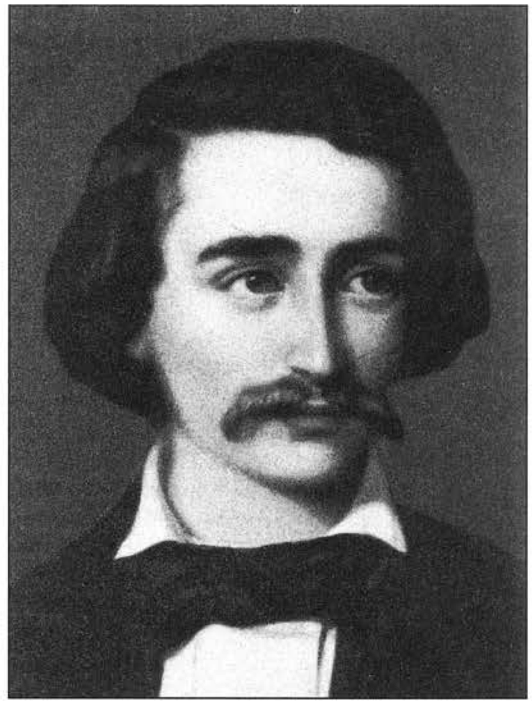


Image (reproduced from oil painting) courtesy of Heiko Harboth.

Richard Dedekind.

In the case of an *abelian* group G, $\Theta(G)$ factors completely into linear forms over $\mathbb{C}$ through the characters of G, as follows:

$$\Theta(G) = \prod_{\chi \in \hat{G}} \left(\sum_{g \in G} \chi(g) x_g \right), \tag{4.1}$$

where $\hat{G}$ is the character group of G. The proof is pretty easy. Indeed, for a fixed $\chi \in \hat{G}$, multiply the gth row of the determinant by $\chi(g)$ and add up all the rows. On the hth column, we get

$$\sum_{g \in G} \chi(g) x_{gh^{-1}} = \left(\sum_{g' \in G} \chi(g') x_{g'} \right) \chi(h).$$

Thus, $\Theta(G)$ is divisible by $\sum_{g \in G} \chi(g) x_g$ for each character χ. Since there are $|G|$ different characters and these give rise to different linear forms, we obtain (4.1). The factorization of $\Theta(G)$ was certainly not without precedent. In the case of a cyclic group, the "group matrix" $(x_{gh^{-1}})$ is just a circulant matrix, and the factorization of its determi-

[2] *Now the Technical University of Braunschweig.*

Photograph courtesy of the Institut Mittag-Leffler.

Ferdinand Georg Frobenius.

nant in terms of $|G|$-th roots of unity was well known to nineteenth-century mathematicians.

In the case of a general group G, we can form an "abelianization" $G/[G,G]$, where $[G,G]$ is the (normal) subgroup generated by the commutators in G. The above proof would still give (at least) $|G/[G,G]|$ linear factors of $\Theta(G)$, corresponding to the characters of $G/[G,G]$. However, these will no longer exhaust the group determinant. For instance, if $G = [G,G]$, this would give only the trivial factor $\sum_{g \in G} x_g$. Like most nineteenth-century mathematicians, Dedekind was well grounded in computations. He computed explicitly $\Theta(G)$ for the first nonabelian group S_3 and found that, besides the linear factors $\sum_{g\in G} x_g$ and $\sum_{g \in G} \operatorname{sgn}(g) x_g$ corresponding to the trivial character and the sign character of $G/[G,G]$, $\Theta(G)$ has a remaining squared factor of an irreducible quadratic. He also made similar computations with the quaternion group of order 8, and made the curious observation that, if the scalar field is extended from $\mathbb{C}$ to suitable "hypercomplex systems" (or "algebras" in current terminology), both of his examples of $\Theta(G)$ would factor into linear forms as in the abelian case. Dedekind worked sporadically on this problem in 1880 and 1886, but did not arrive at any definitive conclusions. In a letter to Frobenius dated March 25, 1896, largely concerning Hamiltonian groups, Dedekind mentioned on the side his earlier excursions into the group determinant, including his factorization (4.1) in the abelian case and his thoughts on the possible role of hypercomplex systems in the general case. A follow-up letter dated April 6, 1896, contained the two nonabelian examples he had worked out, along with some conjectural remarks to the effect that the number of linear factors of $\Theta(G)$ should be equal to $|G/[G,G]|$. Feeling, however, that he himself could not achieve anything with the problem, Dedekind invited Frobenius to look into this matter. As it turned out, it was these two letters written by Dedekind that would become the catalyst for the creation of the character theory for abstract nonabelian groups.

Ferdinand Georg Frobenius (1849–1917)

Eighteen years Dedekind's junior, Frobenius himself had achieved great fame by 1896. He got his mathematical education at the famous Berlin University, under the tutelage of illustrious teachers such as E. Kummer, L. Kronecker, and K. Weierstrass. He wrote a thesis under Weierstrass in 1870 on the series solution of differential equations, and thereafter taught briefly in the Gymnasium and at the University. The University of Berlin was traditionally a feeder school for faculty positions at the Polytechnicum in Zürich (now the Eidgenössische Technische Hochschule), so it was not surprising that Frobenius moved to Zürich in 1875 to accept a professorial appointment there.

During his seventeen-year tenure at E.T.H., Frobenius made a name for himself by contributing to a wide variety of mathematical topics, especially in linear differential equations, elliptic and theta functions in one and several variables, determinant and matrix theory, and bilinear forms. His preference for dealing with algebraic objects was increasingly apparent by the late 1880s, when he began to make his influence felt also in finite group theory. In 1887 he published[3] the first proof of the Sylow theorems for abstract groups (rather than for permutation groups): his inductive proof for the existence of a Sylow group using the class equation is the one still in use today. The same year saw another great group theory paper of his [F: (36)]; this one offered his penetrating analysis of double-cosets in a finite group, and contained the famous Cauchy-Frobenius Counting Formula, now ubiquitous in combinatorics. Unbeknownst to Frobenius, all of this group-theoretic work was preparing him for the greatest gift he would bestow on mathematics: the theory of group characters, which he was soon to invent.

Careerwise the early 1890s was a time of change for Frobenius. With the death of Leopold Kronecker in December 1891, a chair became vacant at the University of Berlin. It was hardly a surprise to anyone that the call went to the university's former favorite son, F. G. Frobenius. Then forty-three and at the height of his creative powers, Frobenius was clearly a worthy successor to Kronecker. It was just not as clear if Kronecker himself would have

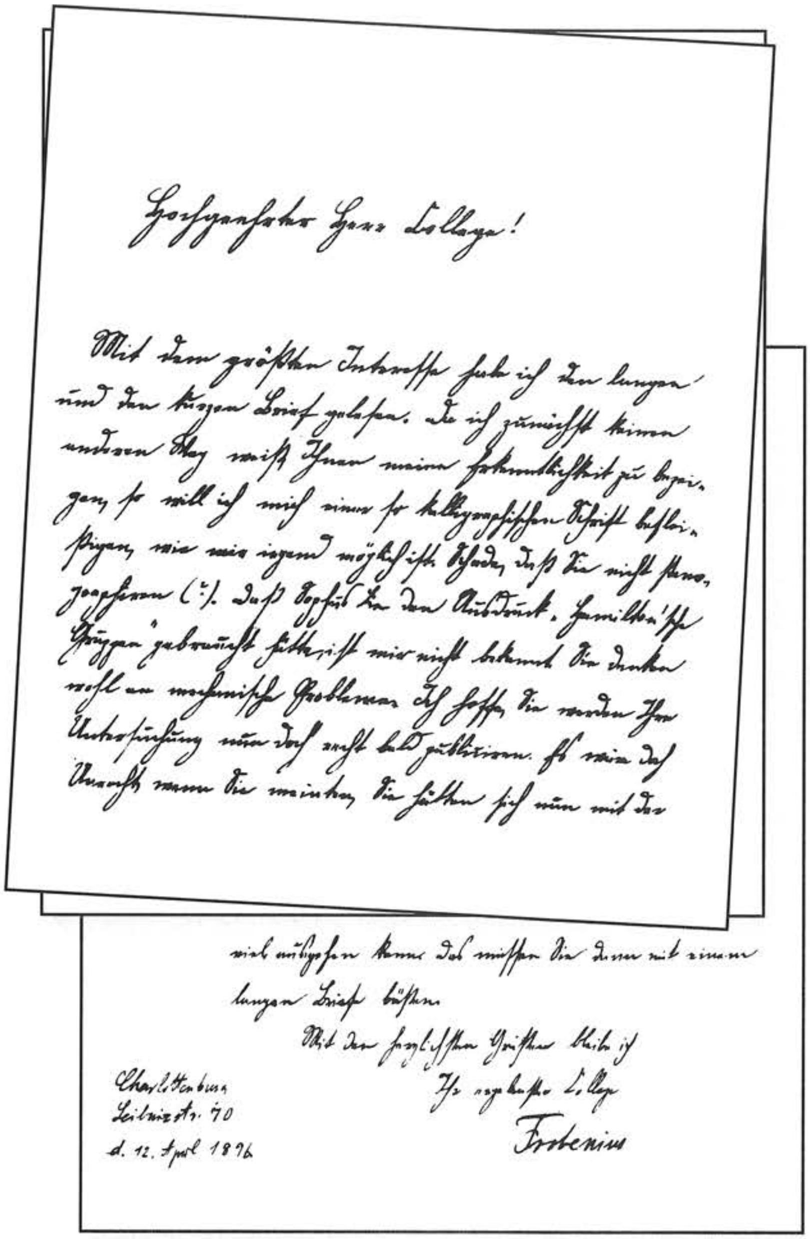
[3] *There seemed to have been an inordinate delay in the publication of [F: (35)]. (This citation means Frobenius's paper (35) in his* Collected Works *[F].) Frobenius communicated this paper to the* Crelle Journal *in March of 1884, but the paper came out only in 1887. By this time some of Frobenius's subsequent papers providing various generalizations of Sylow's Theorems had already come out in* S'Ber. Akad. Wiss. Berlin.

approved of the choice. An ardent believer in his motto "God created the integers, all the rest is the work of men", Kronecker had severely criticized almost everyone engaged in mathematical pursuits involving real or transcendental numbers. His attacks on function theorists were so unsparing and vociferous that at one point even the old Professor Karl Weierstrass was reduced to tears. Kronecker would probably have balked at the idea that his successor be a student of Weierstrass, but then obviously the choice wasn't his.

Frobenius was born in Charlottenburg, a suburb of Berlin. Seventeen years was a long time to be away from home, and in those days people had distinct leanings toward spending their lifetime in their birthtown. Thus, with the call from Berlin, Frobenius was happy to take his family back to Germany in 1893, and settled down in his new home at 70 Leibnizstrasse, Charlottenburg. In the same year, he was elected to membership in the prestigious Prussian Academy of Sciences. With Kronecker and Kummer both dead and his former teacher Weierstrass reaching eighty, Frobenius was to become one of the main torchbearers for the Berlin school of mathematics from that time on.

Though already well versed in group theory, before 1896 Frobenius had never heard of the definition of the group determinant.[4] However, he was a great expert in determinant theory, and he had actually dealt with somewhat similar determinants in his earlier work in theta functions and in linear algebra. As a result, Dedekind's problem of factoring the group determinant caught his immediate attention. He was struck by Dedekind's factorization of $\Theta(G)$ in the abelian case, but was not convinced that hypercomplex numbers would provide the right tool for its generalization. Thus, he set out to investigate the factorization of $\Theta(G)$ just over the complex field. He was amazingly quick in coming to grips with this problem. Working with almost feverish intensity, he invented in less than a month the general character theory of finite groups, and applied this new-found theory to solve the factorization problem for the group determinant. He reported his findings in three long letters to Dedekind on April 12, 17, and 26 of 1896. These letters, together with others in the Frobenius-Dedekind correspondence currently held in the archives of the Technical University of Braunschweig, are now the first written record of the invention of the character theory of finite groups.

[4] *Dedekind had not published any of his findings on this topic.*



The top portion is part of the first page of Frobenius's April 12, 1896, letter to Dedekind. The letter began with "Hochgeehrter Herr College!", a common salutation between colleagues in Frobenius's time. The lower portion is part of the last page, on which Frobenius signed off as "Ihr ergebenster College, Frobenius", and wrote in the left margin his home address, "Charlottenburg, Leibnizstr. 70", dating the letter "d. 12. April 1896". The letter was written on six large sheets of paper, with four pages per sheet.

I want to thank Clark Kimberling for kindly supplying me with a copy of this letter. The mathematical community owes much to Kimberling, who rediscovered the letters written by Frobenius to Dedekind (and various other Dedekind correspondences) among the papers left in the estate of Emmy Noether. The interesting circumstances surrounding the recovery of these letters are reported in Kimberling's Web page at the URL `http://www.evansville.edu/~ck6/bstud/dedek.html`.

—T. Y. L.

Since the Frobenius letters have already been analyzed in detail in the writings of Hawkins and Curtis (loc. cit.), we will try to approach them from a different angle. Assuming we are talking to a modern audience, we will first discuss how the group determinant can be factored by using the current tools of representation theory. With this hindsight we will then return to Frobenius's work, and explain how he solved the factorization problem for $\Theta(G)$ in 1896 and invented the theory of group characters in the meantime.

There is actually also a strategic reason for our approach. Although it was the group determinant which first led Frobenius to the invention of group characters, the modern theory of group representations is no longer developed through group determinants. In fact, few current texts on representation theory even touch upon this subject, so it is rather likely that modern students of representation theory have never heard of the group determinant. The following section explaining a part of Frobenius's work in terms of the modern methods of representation theory will therefore serve as a useful link between the old approach and the new.

Factorization of $\Theta(G)$ for Modern Readers

Actually, what we are going to do in this section is not all that "modern". Everything we shall say here was known to Emmy Noether, as the reader can easily verify by reading her account of the group determinant in her fundamental paper on representation theory [N: §23, pp. 685–686]. In fact, true to form, Noether considered more generally "system-matrices" and "system-determinants" over possibly nonsemisimple algebras. It suffices for our purposes to work with the group algebra $\mathbb{C}G$: this is the algebra consisting of finite formal linear combinations $\sum_{g\in G} a_g g$ ($a_g \in \mathbb{C}$), which are added and multiplied in the natural way.

As we have noted in an earlier section, a *representation* of a group G means a group homomorphism $D : G \longrightarrow \mathrm{GL}_n(\mathbb{C})$; the number n is called the *dimension* (or the *degree*) of the representation. The representation D is said to be *irreducible* if no (nontrivial) subspace of $\mathbb{C}^n$ is invariant under the action of $D(G)$. Each representation D (irreducible or not) gives rise to a *character* $\chi_D : G \longrightarrow \mathbb{C}$, defined by

$$\chi_D(g) = \mathrm{trace}(D(g)) \quad \text{(for any } g \in G).$$

Two n-dimensional representations D, D' are said to be *equivalent* if there exists a matrix $U \in \mathrm{GL}_n(\mathbb{C})$ such that $D'(g) = U^{-1}D(g)U$ for all $g \in G$. In this case, clearly $\chi_D = \chi_{D'}$. Conversely, if $\chi_D = \chi_{D'}$ and G is a finite group, a basic result in representation theory guarantees that D and D' are equivalent.

Let us now broaden our view of the group determinant by introducing a determinant for any representation of a finite group G, as follows. Given a representation $D : G \longrightarrow \mathrm{GL}_n(\mathbb{C})$, we take a set of indeterminates $\{x_g : g \in G\}$ as before, and let

$$\Theta_D(G) = \det\left(\sum_{g\in G} x_g D(g)\right). \tag{6.1}$$

We note the following three facts:

1. If we think of $\sum_{g\in G} x_g g$ as a "generic" element $\mathbf{x}$ of the group algebra $\mathbb{C}G$, the matrix $\sum_{g\in G} x_g D(g)$ above is just $D(\mathbf{x})$ upon extending D to a $\mathbb{C}$-algebra homomorphism $\mathbb{C}G \longrightarrow \mathbb{M}_n(\mathbb{C})$. Indeed, it is often convenient to think of the representation D as being "given" by this algebra homomorphism.

2. $\Theta_D(G)$ depends only on the equivalence class of the representation D, since a conjugation of the representing matrices will not change the determinants.

3. In the case where D is the *regular representation* (so that $D(g)$ is the permutation matrix associated with the left multiplication of g on G), $\Theta_D(G)$ is precisely the group determinant $\Theta(G)$. In fact, on the hth column, the matrix $x_{g'}D(g')$ has an entry $x_{g'}$ on the $g'h$th row and zeros elsewhere. Therefore, on the hth column, $\sum_{g'\in G} x_{g'}D(g')$ has exactly the entry $x_{gh^{-1}}$ on the gth row.

Clearly $\Theta_{D_1\oplus D_2}(G) = \Theta_{D_1}(G)\Theta_{D_2}(G)$. Therefore, to compute $\Theta(G)$, we can first "break up" the regular representation into its irreducible components. This is a standard procedure in the representation theory of finite groups, which utilizes the fundamental structure theorem on $\mathbb{C}G$ due to Maschke and Wedderburn. According to this result,

$$\mathbb{C}G \cong \mathbb{M}_{n_1}(\mathbb{C}) \times \cdots \times \mathbb{M}_{n_s}(\mathbb{C}) \tag{6.2}$$

for suitable n_i's (such that $\sum_i n_i^2 = |G|$). The projection from $\mathbb{C}G$ onto $\mathbb{M}_{n_i}(\mathbb{C})$ provides the ith irreducible complex representation D_i, and, using a little bit of ring theory, one sees from (6.2) that the regular representation is equivalent to $\bigoplus_i n_i D_i$. Next we make the following observation.

Lemma 6.3. Each $\Theta_{D_i}(G)$ is an irreducible polynomial over $\mathbb{C}$, and it is not proportional to $\Theta_{D_j}(G)$ for each $j \neq i$.

Proof. The crucial point here is that, if we write $D_i(\mathbf{x}) = (\lambda_{jk}(\mathbf{x}))$, then the linear forms $\lambda_{jk}(\mathbf{x})$'s are linearly independent over $\mathbb{C}$. In fact, suppose $\sum_{j,k} c_{jk}\lambda_{jk}(\mathbf{x}) = 0$ where $c_{jk} \in \mathbb{C}$. Since $D_i : \mathbb{C}G \longrightarrow \mathbb{M}_{n_i}(\mathbb{C})$ is *onto*, we can find suitable values of the x_g's in $\mathbb{C}$ such that $D_i(\mathbf{x})$ becomes a matrix unit $E_{j_0k_0}$. Plugging in these values of x_g's into $\sum_{j,k} c_{jk}\lambda_{jk}(\mathbf{x}) = 0$, we see that each $c_{j_0k_0} = 0$. Having proved the linear independence of the $\lambda_{jk}(\mathbf{x})$'s, we can then extend them to a basis of the space of all linear forms in $\{x_g : g \in G\}$. This basis will now serve as new variables for the polynomial ring $\mathbb{C}[x_g : g \in G]$, and in terms of these new variables, it is well known that $\det(\lambda_{jk}(\mathbf{x}))$ is irreducible.

To prove the last statement in (6.3), it suffices to see that $\Theta_{D_i}(G)$ actually determines the representation D_i. To this end, think of $\Theta_{D_i}(G)$ as a polynomial in x_1. Since $D_i(1) = I_{n_i}$, x_1 appears only in the diagonal of $D_i(\mathbf{x})$. Writing $D_i(g) = (a_{jk}(g))$, we have $\lambda_{jj}(\mathbf{x}) = \sum_{g\in G} a_{jj}(g)x_g$, and so

$$\begin{aligned} \Theta_{D_i}(G) &= \prod_{j=1}^{n_i} \lambda_{jj}(\mathbf{x}) + \cdots \\ &= x_1^{n_i} + \sum_{g\in G\setminus\{1\}} \chi_{D_i}(g)x_1^{n_i-1}x_g + \cdots . \end{aligned} \tag{6.4}$$

Thus, this irreducible factor determines the character χ_{D_i}, and, as we have observed before, χ_{D_i} determines D_i, as desired. □

In view of the above, it follows that

$$\Theta(G) = \prod_{i=1}^{s} \Theta_{D_i}(G)^{n_i} \tag{6.5}$$

is the *complete* factorization of the group determinant into irreducibles over $\mathbb{C}$. Here, since the representation D_i has dimension n_i, the degree of the irreducible factor $\Theta_{D_i}(G)$ is n_i—the same as the multiplicity with which $\Theta_{D_i}(G)$ appears in $\Theta(G)$. Also, from (6.2) s is seen to be the $\mathbb{C}$-dimension of $Z(\mathbb{C}G)$ (the center of $\mathbb{C}G$), which is given by the number of conjugacy classes of G. We shall return to this point a little later in the next section.

From (6.4) and (6.5), we see clearly that the factorization of $\Theta(G)$ is intimately linked to the irreducible characters of G.

Frobenius's First Definition of (Irreducible) Characters

Of course, the efficient treatment of the factorization of $\Theta(G)$ given in the last section was based on a lot of hindsight. The pioneers of mathematics did not have hindsight, and must bank on only serendipity and sheer determination. As we all know, the first step in any new direction of mathematics is very often the most difficult one to take. Frobenius knew that he needed to invent a new character theory to factor the group determinant, but unlike us he started essentially without a clue. It will thus be very instructive for us to see how he actually managed to find the first light in a pitch-dark tunnel.

As we have pointed out before, "group representation" was not in the vocabulary of the nineteenth-century mathematician, so the modern definition of "character" was inaccessible to Frobenius in 1896. Instead, Frobenius first arrived at the definition of characters by working with a certain commutative $\mathbb{C}$-algebra which he later recognized to be $Z(\mathbb{C}G)$, the center of the group algebra. In order to explain his ideas quickly, it is again easier to take advantage of what modern readers already know, although we will try to make relevant comments on the points where Frobenius had difficulty due to the lack of modern machinery at his disposal. The theoretical underpinning of the exposition below is the notion of a commutative semisimple algebra over $\mathbb{C}$.

Let g_j $(1 \le j \le s)$ be a complete set of representatives for the conjugacy classes of a finite group G (with $g_1 = 1$), and let $C_j \in \mathbb{C}G$ be the "class sums" (sums of group elements conjugate to g_j). It is well known (and easy to prove) that these C_j's give a $\mathbb{C}$-basis for $Z(\mathbb{C}G)$, with structure constants $\{a_{ijk}\}$ defined by the equation:

$$C_j C_k = \sum_i a_{ijk} C_i. \tag{7.1}$$

Here, up to a multiple (given by the size of the ith conjugacy class), a_{ijk} is the number of ordered triples $(x, y, z) \in G^3$ such that $x \sim g_j, y \sim g_k$, $z \sim g_i$, and $z = xy$. (Here, "$\sim$" means conjugacy in G.) Frobenius set up these numbers a bit differently by working with an equation $xyw = 1$ instead of $xy = z$; the difference is only notational. The point is that he was extremely familiar with these constants, which count the number of solutions of such equations in groups. Now we bring in something a bit more modern, namely, the Wedderburn decomposition (6.2). Taking the centers in this decomposition, we get

$$Z(\mathbb{C}G) = \mathbb{C}\epsilon_1 \times \cdots \times \mathbb{C}\epsilon_s \tag{7.2}$$

for suitable central idempotents $\epsilon_i \in \mathbb{C}G$ with $\epsilon_i\epsilon_j = 0$ for $i \ne j$. From (7.2), we know that $Z(\mathbb{C}G)$ is (commutative and) semisimple. Frobenius was not equipped with all this modern jargon, so instead he had to do a lot of ad hoc calculations with the counting numbers $\{a_{ijk}\}$ to check what we now know as the trace condition for semisimplicity. Anyway, Frobenius did this, so he could use this semisimplicity information, if only implicitly.

Starting with (6.2), let $D_i : \mathbb{C}G \longrightarrow \mathbb{M}_{n_i}(\mathbb{C})$ be the projection map giving the ith irreducible representation, and let χ_i be the corresponding character $(\chi_i(g) = \text{trace}(D_i(g)))$. Since D_i maps center to center, we have

$$D_i(C_j) = c_{ij} I_{n_i} \quad \text{for suitable } c_{ij} \in \mathbb{C}. \tag{7.3}$$

Computing traces, we get $h_j\chi_i(g_j) = n_i c_{ij}$, where h_j is the cardinality of the jth conjugacy class. Therefore,

$$c_{ij} = \frac{h_j\chi_i(g_j)}{n_i} = \frac{h_j\chi_i(g_j)}{\chi_i(1)}. \tag{7.4}$$

From (7.3) we have $C_j = \sum_i c_{ij}\epsilon_i$; in particular,

$$C_j\epsilon_i = c_{ij}\epsilon_i. \tag{7.5}$$

Thus $\{\epsilon_1, \ldots, \epsilon_s\}$ is a basis of $Z(\mathbb{C}G)$ consisting of common eigenvectors for the (commuting) left multiplication operators by $\{C_1, \ldots, C_s\}$. The eigenvalues of the left multiplication operator by C_j are the c_{ij}'s as given in (7.4).

We have gotten the above conclusions much more quickly than Frobenius did, since he had to summon up the main results from his earlier paper [F: (51)] on commuting operators to show the existence and independence of the eigenvectors, and the independence proof depended critically on the aforementioned semisimplicity property of $Z(\mathbb{C}G)$. His paper [F: (51)], the first in the famous trilogy of 1896 papers [F: (51), (53), (54)] in *S'Ber. Akad. Wiss. Berlin*, was in turn inspired by the earlier work of Weierstrass, Dedekind, and Study on commutative hypercomplex systems. With modern techniques, however, all of Frobenius's work can be done as above in a few lines.

This work having been done, the eigenvalues c_{ij} can now be used to *define* the character values $\chi_i(g_j)$ via the equation (7.4). (Of course, one has to know $n_i = \chi_i(1)$ first, but this is a relatively minor problem.[5]) Circuitous as it looks, this was exactly how Frobenius in [F: (53)] first defined the characters χ_i as class functions on G! After defining the χ_i's, Frobenius promptly obtained the First and Second Orthogonality Relations between the (irreducible) characters in [F: (53)] (see box).

$$\sum_{g \in G} \chi_i(g)\overline{\chi_j(g)} = \delta_{ij}|G|$$

$$\sum_i \chi_i(g)\overline{\chi_i(h)} = \delta_{g,h}|C_G(g)|$$

These First and Second Orthogonality Relations among the irreducible characters χ_i's, proved by Frobenius in his inaugural paper [F: (53)], have remained a benchmark of the character theory of finite groups. Here the δ_{ij}'s are the usual Kronecker deltas, and $\delta_{g,h}$ is 1 if g, h are conjugate in G, and 0 otherwise; $C_G(g)$ denotes the centralizer of g in G.

Although today we have a much easier approach to characters (via representations), the original approach taken by Frobenius is by no means forgotten. Nowadays Frobenius's results above simply survive in the following form:

Theorem 7.6. The structure constants $\{a_{ijk}\}$ and the character table $(\chi_i(g_j))$ determine each other.

Indeed, suppose the a_{ijk}'s are given. Then the a_{1jk}'s determine the h_j's, and the above work determined the χ_i's. Conversely, if the χ_i's are given, a calculation using the Second Orthogonality Relation leads to an explicit formula expressing a_{ijk} in terms of the various character values.

Frobenius's Theorem (7.6) above has remained a deeply significant result in character theory. Inherent in its proof is the result that the $\mathbb{Q}$-span of the values of an irreducible character χ is always an algebraic number field, nowadays called the *character field* of χ. And the explicit expression of the a_{ijk}'s in terms of character values has various interesting applications to the construction and study of finite simple groups; a pertinent reference for this is Higman's article [Hi].

Frobenius realized from the start that the characters of a group are objects of a highly arithmetic nature. He observed in [F: (53), §2, Eq. (15)] that the constants c_{ij} are all algebraic integers[6], and showed later in [F: (54), §12] that the character values are also algebraic integers. Using all this in conjunction with the First Orthogonality Relation, he deduced the important arithmetical result that each character degree n_i divides $|G|$.

Frobenius's Group Determinant Paper

Having published the group character paper [F: (53)], Frobenius was finally ready to demonstrate to the world the applications he had in mind for Dedekind's factorization problem for the group determinant $\Theta(G)$. This he did in the final paper [F: (54)] of the 1896 series. Since he did not have any of our modern techniques at his disposal, the factorization of $\Theta(G)$ took another giant step.

First Frobenius wrote down the factorization of $\Theta(G)$ as follows:

$$\Theta(G) = \prod_{i=1}^{t} \Phi_i^{e_i}, \tag{8.1}$$

where the Φ_i's are distinct (homogeneous) irreducibles, say, of degree f_i. After a scaling, we may assume that each Φ_i has a term $x_1^{f_i}$; this determines the Φ_i's uniquely (up to their order of appearance). The job is to describe the Φ_i's and to determine the exponents e_i in (8.1). If we take the modern approach to $\Theta(G)$ and assume the work

[5] *Frobenius was somewhat vague about this problem, which caused Hawkins [H_3: p. 239] to remark that in [F: (53)] "the characters are never completely defined." But so much information is available in [F: (53)] that this problem can be resolved one way or another. For instance, once we know the ratios $\chi_i(g_j)/\chi_i(1)$ for all j, $\chi_i(1)$ can be determined from the First Orthogonality Relation.*

[6] *An efficient modern proof is as follows. Since the ring $\sum_i \mathbb{Z}C_i$ is a finitely generated abelian group, each C_i is integral over $\mathbb{Z}$. Applying this to (7.5), we see that the same is true for each c_{ij}.*

we did in the earlier section on its factorization, the following information is at hand:

(1) The number t of distinct irreducible factors in (8.1) equals the number s of conjugacy classes in G.

(2) For all i, f_i (the degree of Φ_i) equals the multiplicity e_i in (8.1).

For Frobenius, however, each of these statements was to require a proof. (1) was not too hard; he took care of it using the orthogonality relations he developed in [F: (53)] (see box). But (2) turned out to be a real challenge! Of course (2) was confirmed by all the examples known to Frobenius and Dedekind. But Frobenius was a cautious man, and any cautious man (or woman) knows that a few overly simplified examples in mathematics could be totally misleading! So at first Frobenius was not ready to believe that $e_i = f_i$. This proved to be a fortuitous circumstance for students of the history of mathematics, for they have here a unique opportunity to observe directly, through letters written by Frobenius to Dedekind, how Frobenius went about attacking (and sometimes *not* attacking) this difficult problem.[7] He first proved (2) in the case of linear factors ($f_i = 1$), which was not hard; then he managed to settle the case of quadratic factors ($f_i = 2$), which was very hard. He wrote to Dedekind to ask for help or for possible counterexamples; in the meantime, he computed some examples of cubic factors to confirm (2). He confided to Dedekind how he would sometimes try to "attain the goal of proving $e_i = f_i$" by occupying himself with totally unrelated activities, such as going with his wife to the trade exhibition, and then to the art exhibition, by reading a novel at home, or else by ridding his fruit trees of caterpillars. Showing a nice sense of humor, he went on to write in his June 4, 1896, letter to Dedekind:

> I hope you will not give away the trade secret to anyone. My great work *On the Methods of Mathematical Research* (with an appendix on caterpillar catching), which makes use of it, will appear after my death.

Frobenius's promised book never appeared, but apparently his "methods of mathematical research" are still widely practiced among math professors and their graduate students today. Frobenius's skirmishes with the $e_i = f_i$ problem lasted five months, but ended on a happy note: he finally managed to prove it in full generality toward the end of 1896. This enabled him to write up his paper [F: (54)] on the group determinant. In Section 9 of this paper, he wrote:

> The power exponent, wherein a prime factor is contained in the group determinant, is equal to the degree of that factor,

declaring it the "Fundamental Theorem of the theory of group determinants." This was certainly the crown jewel of his monumental work in character theory in 1896. Frobenius's proof was an amazing display of technical wizardry, occupying four and a half pages of the *Sitzungsberichte*. Today, of course, it is much easier to prove this Fundamental Theorem as we did in the earlier section on the factorization of $\Theta(G)$. The approach used in that section also showed clearly how the irreducible factors of $\Theta(G)$ correspond to the irreducible characters χ_i: up to a permutation, the Φ_i in (8.1) is simply the $\Theta_{D_i}(G)$ in (6.4), therefore corresponding to the character $\chi_i := \chi_{D_i}$ (and of course $e_i = f_i = n_i$). The equation (6.4) showed that the coefficient of $x_1^{n_i-1}x_g$ in Φ_i is $\chi_i(g)$ for $g \neq 1$. More generally, the other coefficients can be determined explicitly too. Frobenius proceeded by first extending each χ_i by induction, from a unary function to an n-ary function (for any $n \geq 1$); each $\chi_i(g_1, \ldots, g_n)$ is a polynomial function of the values of χ_i. (For instance, to start the induction, $\chi_i(g,h) = \chi_i(g)\chi_i(h) - \chi_i(gh)$.) With these "$n$-characters" defined, Frobenius then determined Φ_i by the following remarkable formula [F: (54), §3, Eq. (15)]:

$$(8.2)\quad n_i! \cdot \Phi_i = \sum \chi_i(g_1, g_2, \ldots, g_{n_i}) x_{g_1} x_{g_2} \ldots x_{g_{n_i}},$$

where the summation is over all n_i-tuples of elements of G. This computes all coefficients of Φ_i as polynomial functions of the ordinary character values $\{\chi_i(g) : g \in G\}$. So far, group theorists have not made use of these "higher" characters in any substantial way; possibly, a lot more can be done here.

Before we leave group determinants, we should mention a couple of rather surprising recent developments in the subject. It is well known that the characters of a group are not sufficient to determine the group; for instance, the dihedral group and the quaternion group of order 8 happen to have the same character tables. Nevertheless, Formanek and Sibley [FS] have shown that the group determinant $\Theta(G)$ does determine G, and Hoehnke and Johnson [HJ] have shown that the 1-, 2-, and 3-characters of G (mentioned above) also suffice to determine G. These newly discovered facts might have surprised the forefathers of the theory of group determinants.

So far we have only discussed group determinants in characteristic zero (namely, over the complex numbers). In several papers in 1902 and 1907, L. E. Dickson had studied the group determinant over fields of characteristic $p > 0$. We refer the

[7] *Our account of Frobenius's exploits here follows the excellent documentary of Hawkins in [H_3, H_4].*

reader to Conrad's paper [Con] for a good survey on Dickson's work.

The Harvest: 1897–1917

As early as in the introduction to his first group character paper [F: (53)], Frobenius had expressed his belief that this new character theory would lead to essential enrichment and significant advancement of finite group theory. In the twenty remaining years of his life, he was to write, with seemingly unstoppable energy, some fifteen more papers in group theory (not to mention numerous papers in other areas), further developing the theory of group characters and group representations, and applying these to the theory of finite groups. We shall give only a summary of this part of the story here.

1. The first significant development after the trilogy of the 1896 papers was that Frobenius was able to introduce formally the notion of group representations and relate it to the group determinant; he did this again following the suggestion of Dedekind. It is of historical interest to see how Frobenius formulated this definition, so we quote directly from the source [F: (56), §2]:

> Let $\mathfrak{H}$ be an abstract group, $A, B, C\dots$ be its elements. One associates to the element A the matrix (A), to the element B the matrix (B), etc., in such a way that the group $\mathfrak{H}'$ is isomorphic[8] to the group $\mathfrak{H}$, that is, $(A)(B) = (AB)$. Then I say that the substitutions or the matrices $(A), (B), (C), \dots$ *represent* the group $\mathfrak{H}$.

Though a bit clumsy to the modern reader, this is essentially the definition of group representation as we know it today. Frobenius also pointed out for the first time, in [F: (56), §4, Eq. (5)], that the characters he defined in [F: (53)] are given by traces of the representing matrices of irreducible (or, in his own term, "primitive") representations. For Frobenius, the irreducibility of a representation D was *defined* by the irreducibility of its determinant $\Theta_D(G)$. The notion of irreducibility was to undergo several reworkings and reformulations in the years to come.

Highly significant is the fact that, in [F: (56)], Frobenius explicitly acknowledged the contributions of Molien's papers [M_1, M_2], which had come to his attention through Eduard Study. Molien's powerful method of analyzing the group algebra as a hypercomplex system was inspired by the Lie algebra methods of W. Killing and É. Cartan. To a considerable extent, it anticipated the later work of Maschke, Wedderburn, and Noether; it is also much closer to one of the ways of studying representation theory today. Molien's understanding of the notion of semisimplicity (and his ability to use it efficiently) was the benchmark of his work, though this work was not widely recognized by his contemporaries. Frobenius, however, did not hesitate to praise it, and referred to [M_1] as an "excellent work" ([F: (56), p. 92]). Upon learning that Molien was only a Privatdozent in Dorpat, Frobenius even wrote to the influential Dedekind to see if he could help advance Molien's career. Nevertheless, Molien's work remained in relative obscurity; today he is remembered mainly through his generating function formula in the theory of polynomial invariants. Fortunately for modern readers, an excellent analysis of Molien's contributions to representation theory is available from Hawkins's paper [H_2].

2. In two subsequent papers [F: (57), (58)], Frobenius introduced the "composition" (now called tensor product) of characters, and developed the relationship between the characters of a group and those of its subgroups. From the latter work came the all-important notion of *induced representations.* It is truly a stroke of genius that, within only a couple of years of his invention of character theory, he came up with the brilliant reciprocity law for induced representations, which now bears his name. The two papers [F: (57), (58)] were to provide some of the most powerful tools for the many applications of representation theory to the structure theory of groups to be found in the twentieth century.

Nowadays we have the techniques of group algebras, tensor products, Hom-functors, etc., which make everything easy and "natural". But in mathematics, "naturalness" is only a function of time. What is natural to us today was simply nonexistent at the end of the nineteenth century. To prove the main facts about induced representations and compositions of characters, Frobenius could resort to only one tool, the group determinant. For modern readers, it is actually quite amazing to see how Frobenius turned the group determinant into a veritable workhorse of representation theory, and used it in paper after paper to get new miles in the subject! While most (if not all) of Frobenius's group determinant proofs have now been superseded by easier modern ones, in my opinion they remain a most fitting testament to the formidable power and consummate skill of a nineteenth-century mathematician.

3. Frobenius's computations of the characters of some specific groups have had a profound impact in representation theory, starting with the characters of the projective unimodular groups $PSL_2(p)$, which he already computed in his inaugural paper [F: (53)] in character theory. Years later, this work blossomed into the amazingly rich subject of representation theory of finite groups

[8] *In Frobenius's time, this term did not preclude the mapping $A \mapsto (A)$ from being many-to-one.*

of Lie type.[9] Frobenius already observed as early as in [F: (53), end of §8] that the character values of the symmetric groups are all rational integers. Shortly thereafter, in [F: (60), (61)], he single-handedly opened up the investigation into the representation theory of the symmetric groups S_n and the alternating groups A_n. His classification and analysis of the characters (and therefore the representations) of S_n anticipated the work of Rev. Alfred Young, and laid firm foundations for much of the future work on symmetric functions in the new century. In [F: (60)], Frobenius built certain generating functions from the character values of S_n, and determined these generating functions. Thus, at least in principle, he managed to compute the characters of S_n on any given conjugacy class. The most memorable case of this computation is Frobenius's determinantal formula for the character degrees of S_n: for an irreducible character χ_λ corresponding to a partition $\lambda = (\lambda_1, \ldots, \lambda_r)$ of n (where $\lambda_1 \geq \cdots \geq \lambda_r \geq 0$), Frobenius showed (cf. [F: (60), §3, Eq. (6)]) that

$$\begin{aligned} \chi_\lambda(1) &= n! \det\left(\frac{1}{(\lambda_i - i + j)!}\right)_{1\leq i,j\leq r} \\ &= \frac{n!\,\Delta(\mu_1, \mu_2, \ldots, \mu_r)}{\mu_1!\mu_2!\cdots\mu_r!}, \end{aligned} \tag{9.1}$$

where $\mu_i = \lambda_i + r - i$ and $\Delta(\mu_1, \mu_2, \ldots, \mu_r)$ is the Vandermonde determinant with the parameters μ_i. The same formula was obtained independently by Young, but Frobenius seemed to have the priority here. Much later, the Frobenius-Young determinantal formula for character degrees (for S_n) was to be given another equivalent combinatorial form in terms of the "hook-lengths" $h_{ij}(\lambda)$ in the Ferrers diagram of the partition λ: the Frame-Robinson-Thrall hook-length formula recasts the character degrees in the form

$$\chi_\lambda(1) = \frac{n!}{\prod_{i,j} h_{ij}(\lambda)}. \tag{9.2}$$

Today the representation theory of S_n lies at the heart of algebra and combinatorics, and impacts many branches of pure and applied mathematics.

4. Even before his work in character theory, Frobenius had taken a keen interest in finite solvable groups, and had published two papers on them in 1893 and 1895, focusing on the existence and structure of their subgroups. At the turn of the century, his interest in the subject was heightened by his newly invented theory of group characters. He was to write three more papers in the solvable group series, and a handful of other papers on multiply transitive groups, some of them using character theory. One of his most spectacular results (in [F: (63), p. 199]) is now a staple in any graduate course in the representation theory of finite groups:

Theorem 9.3. If G is a finite group acting transitively on a set such that no element in $G \setminus \{1\}$ fixes more than one point, then the set of fixed-point-free elements of G together with the identity forms a (normal) subgroup K of G. (If $K \subsetneq G$, G is called a *Frobenius group*, and K is called its *Frobenius kernel*. Any one-point stabilizer of the action is called a *Frobenius complement*.)

A century later, Frobenius's proof of this theorem using induced characters and the idea of the kernel of an irreducible representation has not lost its magic and charm. Even more remarkably, no purely group-theoretic proof of this beguilingly simple statement has been found to date, so Frobenius's original argument in [F: (63)] has remained the *only* known proof of (9.3)! Years later, Frobenius's Theorem inspired the Brauer-Suzuki theory of exceptional characters, and Zassenhaus classified the doubly transitive Frobenius groups, linking them to the classification of finite near-fields. The theory of Frobenius groups also helped launch the distinguished career of Fields Medalist J. G. Thompson, who proved in his Chicago thesis (1959) the long-standing conjecture that Frobenius kernels are *nilpotent* groups.

5. With his student Issai Schur, Frobenius introduced the notion of the *index* (or *indicator*):

$$s(\chi) := \frac{1}{|G|}\sum_{g\in G} \chi(g^2) \tag{9.4}$$

of an irreducible character χ, and showed that $s(\chi)$ takes values in $\{1, -1, 0\}$. In this Frobenius-Schur theory, the χ's fall into three distinct types: $s(\chi) = 1$ if χ comes from a real representation, $s(\chi) = -1$ if χ does not come from a real representation but is real-valued, and $s(\chi) = 0$ if χ is not real-valued. The Frobenius-Schur indices contain important information about a group G which goes beyond the character table of G: for instance, the number of square roots of an element $g \in G$ can be computed via the indices in (9.4) by the expression $\sum_\chi s(\chi)\chi(g)$, a fact quite important in group theory. In connection with their work on characters of the first type, Frobenius and Schur also proved the interesting result that any complex orthogonal representation of a finite group is equivalent to a real orthogonal representation.

Frobenius and Number Theory

A close kinship between number theory and group theory is provided by the fact that any normal extension of number fields K/F gives rise to a finite Galois group $G = \mathrm{Gal}(K/F)$. Thus, the applicability of Frobenius's character theory to number theory should come as no surprise. The true interaction

[9] *There is a bit of irony here, since Frobenius was known to have a great disdain for the work of Sophus Lie.*

between the two theories, however, did not take place during Frobenius's lifetime, and had to wait until the 1920s, when algebraic and analytic number theory became more fully developed.

The idea of using representations of Galois groups in number theory first emerged in Artin's work in 1923. For any character χ on a Galois group $G = \mathrm{Gal}(K/F)$ as in the last paragraph, Artin introduced what is now called the *Artin L-function* $L(s, \chi, K/F)$ associated with χ. This is a function in a complex variable s ($|s| > 1$), which encodes both information about χ and about the primes in F and K. For instance, when χ is the trivial character (respectively the regular character) of G, $L(s, \chi, K/F)$ is the Dedekind zeta function of F (respectively of K). (The Dedekind zeta function of a number field is, in turn, a direct generalization of the Riemann zeta function for the rationals.) Artin's theory of L-functions made use of Frobenius's work in two ways. First, Artin showed that, in the case when G is abelian and $\chi(1) = 1$, his L-functions coincide with the L-functions studied earlier by Hecke. This required the full force of Artin's Reciprocity Law, which Artin established by using ideas of Tchebotarëv's proof of a conjecture of Frobenius (now called Tchebotarëv's Density Theorem). Second, Artin showed that, in the non-abelian case, Frobenius's induced characters provided the perfect means to relate the Artin L-functions to the (abelian) Hecke L-functions. Later, Brauer completed Artin's work by proving that any character of G is an integral combination of characters induced from 1-dimensional characters of suitable subgroups of G. With this powerful induction theorem, Brauer proved that $L(s, \chi, K/F)$ extends to a meromorphic function in $\mathbb{C}$, and that the quotient of the Dedekind zeta functions $\zeta_K(s)/\zeta_F(s)$ is an entire function. In this work (for which Brauer received the Society's Frank Nelson Cole Prize in 1949), the interplay between character theory and number theory came to its fruition. Later, the representations of Galois groups became an important topic in the theory of modular forms, but that is another story.

Coda

About a hundred years ago Dedekind posed to Frobenius the problem of factoring a certain determinant associated with a finite group. The solution of this abstract problem led Frobenius to the invention of character theory, and subsequently the representation theory of finite groups. Today, these theories provide basic tools for various branches of algebra, and their generalizations to the case of topological and Lie groups play an important role in harmonic analysis. In the meantime, group characters and representations have come to be used extensively in many applied fields, such as spectroscopy, crystallography, quantum mechanics, molecular orbital theory, and ligand field theory. These amazingly diverse applications, made possible by the purely theoretical work of Dedekind and Frobenius which predated them by decades, seem to provide another striking instance of the great "unreasonable effectiveness" of mathematics.

References

[C] F. Cajori, *Teaching and history of mathematics in the U.S.* (W. P. Durfee quotation, 265–266), Washington, 1890.

[Ca] A. Cayley, *Desiderata and suggestions*, Amer. J. Math. **1** (1878), 50–52.

[Con] K. Conrad, *The origin of representation theory*, to appear.

[Cu1] C. W. Curtis, *Representation theory of finite groups: from Frobenius to Brauer*, Math. Intelligencer **14** (1992), 48–57.

[Cu2] ____, *Frobenius, Burnside, Schur and Brauer: Pioneers of representation theory*, Amer. Math. Soc., Providence, RI, to appear.

[D] P. G. Lejeune Dirichlet, *Vorlesungen über Zahlentheorie*, 3rd ed., published and supplemented by R. Dedekind, Vieweg, Braunschweig, 1879.

[FS] E. Formanek and D. Sibley, *The group determinant determines the group*, Proc. Amer. Math. Soc. **112** (1991), 649–656.

[F] F. G. Frobenius, *Gesammelte Abhandlungen* I, II, III (J.-P. Serre, ed.), Springer-Verlag, Berlin, 1968.

[H1] T. Hawkins, *The origins of the theory of group characters*, Archive Hist. Exact Sci. **7** (1971), 142–170.

[H2] ____, *Hypercomplex numbers, Lie groups, and the creation of group representation theory*, Archive Hist. Exact Sci. **8** (1971), 243–287.

[H3] ____, *New light on Frobenius' creation of the theory of group characters*, Archive Hist. Exact Sci. **12** (1974), 217–243.

[H4] ____, *The creation of the theory of group characters*, Rice Univ. Stud. **64** (1978), 57–71.

[Hi] G. Higman, *Construction of simple groups from character tables*, Finite Simple Groups (M. B. Powell and G. Higman, eds.), Academic Press, London-New York, 1971.

[HJ] H.-J. Hoehnke and K. W. Johnson, *The 1-, 2-, and 3-characters determine a group*, Bull. Amer. Math. Soc. (N.S.) **27** (1992), 243–245.

[Kn] A. Knapp, *Group representations and harmonic analysis from Euler to Langlands*, I, II, Notices Amer. Math. Soc. **43** (1996), 410–415, 537–549.

[La] T. Y. Lam, *Representation theory*, Emmy Noether: A Tribute to Her Life and Work (J. Brewer and M. K. Smith, eds.), Marcel-Dekker, New York-Basel, 1981, pp. 145–156.

[L1] W. Ledermann, *The origin of group characters*, J. Bangladesh Math. Soc. **1** (1981), 35–43.

[L2] ____, *Issai Schur and his school in Berlin*, Bull. London Math. Soc. **15** (1983), 97–106.

[Ma] G. Mackey, *Harmonic analysis as exploitation of symmetry*, Bull. Amer. Math. Soc. (N.S.) **3** (1980), 543–698.

[M1] T. Molien, *Über Systeme höherer complexer Zahlen*, Math. Ann. **41** (1893), 83–156.

[M2] ____, *Eine Bemerkung zur Theorie der homogenen Substitutionsgruppen*, S'Ber. Naturforscher-Ges. Univ. Jurjeff (Dorpat) **11** (1897), 259–274.

[N] E. Noether, *Hyperkomplexe Grössen und Darstellungstheorie*, Math. Zeit. **30** (1929), 641–692.

Twenty-Five Years with Nicolas Bourbaki, 1949–1973

Armand Borel

The choice of dates is dictated by personal circumstances: they roughly bound the period in which I had inside knowledge of the work of Bourbaki, first through informal contacts with several members, then as a member for twenty years, until the mandatory retirement at fifty.

Being based largely on personal recollections, my account is frankly subjective. Of course, I checked my memories against the available documentation, but the latter is limited in some ways: not much of the discussions about orientation and general goals has been recorded.[1] Another member might present a different picture.

To set the stage, I shall briefly touch upon the first fifteen years of Bourbaki. They are fairly well documented[2], and I can be brief.

In the early thirties the situation of mathematics in France at the university and research levels, the only ones of concern here, was highly unsatisfactory. World War I had essentially wiped out one generation. The upcoming young mathematicians had to rely for guidance on the previous one, including the main and illustrious protagonists of the so-called 1900 school, with strong emphasis on analysis. Little information was available about current developments abroad, in particular about the flourishing German school (Göttingen, Hamburg, Berlin), as some young French mathematicians (J. Herbrand, C. Chevalley, A. Weil, J. Leray) were discovering during visits to those centers.[3]

In 1934 A. Weil and H. Cartan were Maîtres de Conférences (the equivalent of assistant professors) at the University of Strasbourg. One main duty was, of course, the teaching of differential and integral calculus. The standard text was the *Traité d'Analyse* of E. Goursat, which they found wanting in many ways. Cartan was frequently bugging Weil with questions on how to present this material, so that at some point, to get it over with once and for all, Weil suggested they write themselves

Armand Borel is professor emeritus at the School of Mathematics, Institute for Advanced Study, Princeton, NJ.

This article is an outgrowth of a lecture given at the University of Bochum, Germany, October 1995, in a Colloquium in honor of R. Remmert, and at the International Center for Theoretical Physics, Trieste, Italy, September 1996. With permission of the author, it is being published concurrently in the Notices *and in the* Mitteilungen der Deutsche Mathematiker-Vereinigung.

[1] *The Archives of Bourbaki at the École Normale Supérieure, Paris, contain reports, surveys, successive drafts or counterdrafts of the chapters, remarks on those resulting from discussions, and proceedings of the Congresses, called "Tribus". Those provide mainly a record of plans, decisions, commitments for future drafts, as well as jokes, sometimes poems.*

[2] *See [2, 3, 6, 7, 8, 14].*

[3] *For this, see pp. 134–136 of [8].*

a new *Traité d'Analyse*. This suggestion was spread around, and soon a group of about ten mathematicians began to meet regularly to plan this treatise. It was soon decided that the work would be collective, without any acknowledgment of individual contributions. In summer 1935 the pen name Nicolas Bourbaki was chosen.[4]

The membership varied over the years; some people in the first group dropped out quickly, others were added, and later there was a regular process of additions and retirements. I do not intend to give a detailed account. At this point let me simply mention that the true "founding fathers", those who shaped Bourbaki and gave it much of their time and thoughts until they retired, are:

Henri Cartan
Claude Chevalley
Jean Delsarte
Jean Dieudonné
André Weil

born respectively in 1904, 1909, 1903, 1906, 1906—all former students at the École Normale Supérieure in Paris.[5]

A first question to settle was how to handle references to background material. Most existing books were found unsatisfactory. Even B. v.d. Waerden's *Moderne Algebra*, which had made a deep impression, did not seem well suited to their needs (besides being in German). Moreover, they wanted to adopt a more precise, rigorous style of exposition than had been traditionally used in France, so they decided to start from scratch and, after many discussions, divided this basic material into six "books", each consisting possibly of several volumes, namely:

I *Set Theory*
II *Algebra*
III *Topology*
IV *Functions of One Real Variable*
V *Topological Vector Spaces*
VI *Integration*

These books were to be linearly ordered: references at a given spot could only be to the previous text in the same book or to an earlier book (in the given ordering). The title "Éléments de Mathématique" was chosen in 1938. It is worth noting that they chose "Mathématique" rather than the much more usual "Mathématiques". The absence of the "s" was of course quite intentional, one way for Bourbaki to signal its belief in the unity of mathematics.

The first volumes to appear were the *Fascicle of Results on Set Theory* (1939) and then, in the forties, *Topology* and three volumes of *Algebra*.

At that time, as a student and later assistant at the E.T.H. (Swiss Federal Institute of Technology) in Zurich, I read them and learned from them, especially from *Multilinear Algebra*, for which there was no equivalent anywhere, but with some reservations. I was rather put off by the very dry style, without any concession to the reader, the apparent striving for the utmost generality, the inflexible system of internal references and the total absence of outside ones (except in Historical Notes). For many, this style of exposition represented an alarming tendency in mathematics, towards generality for its own sake, away from specific problems. Among those critics was H. Weyl, whose opinion I knew indirectly through his old friend and former colleague M. Plancherel, who concurred, at a time I was the latter's assistant.

In fall 1949 I went to Paris, having received a fellowship at the C.N.R.S. (Centre National de la Recherche Scientifique), benefiting from an exchange convention just concluded between the C.N.R.S. and the E.T.H. I quickly got acquainted with some of the senior members (H. Cartan, J. Dieudonné, L. Schwartz) and, more usefully for informal contacts, with some of the younger ones, notably Roger Godement, Pierre Samuel, Jacques Dixmier, and, most importantly, Jean-Pierre Serre, the beginning of intense mathematical discussions and a close friendship. Of course, I also attended the Bourbaki Seminar, which met three times a year, offering each time six lectures on recent developments.

Those first encounters quickly changed my vision of Bourbaki. All these people—the elder ones, of course, but also the younger ones—were very broad in their outlook. They knew so much and knew it so well. They shared an efficient way to digest mathematics, to go to the essential points, and reformulate the math in a more comprehensive and conceptual way. Even when discussing a topic more familiar to me than to them, their sharp questions often gave me the impression I had not really thought it through. That methodology was also apparent in some of the lectures at the Bourbaki seminar, such as Weil's on theta functions (Exp. 16, 1949) or Schwartz's on Kodaira's big *Annals* paper on harmonic integrals (Exp. 26, 1950). Of course, special problems were not forgotten—in fact, were the bread and but-

---

[4] *See [3] for the origin of the name.*

[5] *They all contributed in an essential way. For Cartan, Chevalley, Dieudonné, and Weil I could witness it at firsthand, but not for Delsarte, who was not really active anymore when I came on board. But his importance has been repeatedly stressed to me by Weil in conversations. See also [14] and comments by Cartan, Dieudonné, Schwartz in [3, pp. 81–83]. In particular, he played an essential role in transforming into a coherent group, and maintaining it so, a collection of strong, some quite temperamental, individuals. Besides, obviously, Book IV,* Functions of one real variable, *owes much to him. Some other early members, notably Szolem Mandelbrojt and René de Possel, also contributed substantially to the work of the group in its initial stages.*

ter of most discussions. The writing of the books was obviously a different matter.

Later I was invited to attend (part of) a Bourbaki Congress and was totally bewildered. Those meetings (as a rule three per year: two of one week, one of about two) were private affairs, devoted to the books. A usual session would discuss a draft of some chapter or maybe a preliminary report on a topic under consideration for inclusion, then or later. It was read aloud line by line by a member, and anyone could at any time interrupt, comment, ask questions, or criticize. More often than not, this "discussion" turned into a chaotic shouting match. I had often noticed that Dieudonné, with his stentorian voice, his propensity for definitive statements, and extreme opinions, would automatically raise the decibel level of any conversation he would take part in. Still, I was not prepared for what I saw and heard: "Two or three monologues shouted at top voice, seemingly independently of one another" is how I briefly summarized for myself my impressions that first evening, a description not unrelated to Dieudonné's comments in [8]:

> Certain foreigners, invited as spectators to Bourbaki meetings, always come out with the impression that it is a gathering of madmen. They could not imagine how these people, shouting—some times three or four at the same time—could ever come up with something intelligent....

It was only about ten years ago, reading the text of a 1961 lecture by Weil on organization and disorganization in mathematics [13], that I realized this anarchic character, if not the shouting, was really by design. Speaking of Bourbaki, Weil said, in part (freely translated):

> ...keeping in our discussions a carefully disorganized character. In a meeting of the group, there has never been a president. Anyone speaks who wants to and everyone has the right to interrupt him....
>
> The anarchic character of these discussions has been maintained throughout the existence of the group....
>
> A good organization would have no doubt required that everyone be assigned a topic or a chapter, but the idea to do this never occurred to us....
>
> What is to be learned concretely from that experience is that any effort at organization would have ended up with a treatise like any other....

The underlying thought was apparently that really new, groundbreaking ideas were more likely to arise from confrontation than from an orderly discussion. When they did emerge, Bourbaki members would say, "the spirit has blown" ("l'esprit a soufflé"), and it is indeed a fact that it blew much more often after a "spirited" (or should I say stormy) discussion than after a quiet one.

Other rules of operation also seemed to minimize the possibility of a publication in a finite time:

Only one draft was read at a given time, and everyone was expected to take part in everything. A chapter might go through six or even more drafts. The first one was written by a specialist, but anyone might be asked to write a later one. Often this was hardly rewarding. Bourbaki could always change his mind. A draft might be torn to pieces and a new plan proposed. The next version, following those instructions, might not fare much better, and Bourbaki might opt for another approach or even decide that the former one was preferable after all, and so on, resulting sometimes in something like a periodicity of two in the successive drafts.

To slow down matters further, or so it seemed, there were no majority votes on publications: all decisions had to be unanimous, and everyone had a veto right.

However, in spite of all those hurdles, the volumes kept coming out. Why such a cumbersome process did converge was somewhat of a mystery even to the founding members (see [6, 8]), so I do not pretend to be able to fully explain it. Still, I will venture to give two reasons.

The first one was the unflinching commitment of the members, a strong belief in the worthiness of the enterprise, however distant the goals might seem to be, and the willingness to devote much time and energy to it. A typical Congress day would include three meetings, totaling about seven hours of often hard, at times tense, discussions—a rather grueling schedule. Added to this was the writing of drafts, sometimes quite long, which might take a substantial part of several weeks or even months, with the prospect of seeing the outcome heavily criticized, if not dismissed, or even summarily rejected after reading of at most a few pages, or left in abeyance ("put into the refrigerator"). Many, even if read with interest, did not lead to any publication. As an example, the pièce de résistance of the second Congress I attended was a manuscript by Weil of over 260 pages on manifolds and Lie groups, titled "Brouillon de calcul infinitésimal", based on the idea of "nearby points" ("points proches"), a generalization of Ehresmann's jets. This was followed later by about 150 pages of elaboration by Godement, but Bourbaki never published anything on nearby points.

On the other hand, whatever was accepted would be incorporated without any credit to the author. Altogether, a truly unselfish, anonymous, demanding work by people striving to give the best possible exposition of basic mathematics, moved by their belief in its unity and ultimate simplicity.

My second reason is the superhuman efficiency of Dieudonné. Although I did not try to count pages, I would expect that he wrote more than any two or three other members combined. For about twenty-five years he would routinely start his day (maybe after an hour of piano playing) by writing a few pages for Bourbaki. In particular, but by far not exclusively, he took care of the final drafts, exercises, and preparation for the printer of all the volumes (about thirty) which appeared while he was a member and even slightly beyond.

This no doubt accounts to a large extent for the uniformity of style of the volumes, frustrating any effort to try to individualize one contribution or the other. But this was not really Dieudonné's style, rather the one he had adopted for Bourbaki. Nor was it the personal one of other Bourbaki members, except for Chevalley. Even to Bourbaki he seemed sometimes too austere, and a draft of his might be rejected as being "too abstract". The description "severely dehumanized book...", given by Weil in his review of a book by Chevalley [12, p. 397] is one many people would have applied to Bourbaki itself. Another factor contributing to this impersonal, not user-friendly presentation[6] was the very process by which the final texts were arrived at. Sometimes a heuristic remark, to help the reader, would find its way into a draft. While reading it, in this or some later version, its wording would be scrutinized, found to be too vague, ambiguous, impossible to make precise in a few words, and then, almost invariably, thrown out.

As a by-product, so to say, the activity within Bourbaki was a tremendous education, a unique training ground, obviously a main source of the breadth and sharpness of understanding I had been struck by in my first discussions with Bourbaki members.

The requirement to be interested in all topics clearly led to a broadening of horizon, maybe not so much for Weil, who, it was generally agreed, had the whole plan in his mind almost from the start, or for Chevalley, but for most other members, as was acknowledged in particular by Cartan [7, p. xix]:

> This work in common with men of very different characters, with a strong personality, moved by a common requirement of perfection, has taught me a lot, and I owe to these friends a great part of my mathematical culture.[7]

and by Dieudonné [8, pp.143-44]:

> In my personal experience, I believe that if I had not been submitted to this obligation to draft questions I did not know a thing about, and to manage to pull through, I should never have done a quarter or even a tenth of the mathematics I have done.

But the education of members was not a goal per se. Rather, it was forced by one of the mottoes of Bourbaki: "The control of the specialists by the nonspecialists". Contrary to my early impressions in Zurich, related earlier, the aim of the treatise was not the utmost generality in itself, but rather the most efficient one, the one most likely to fill the needs of potential users in various areas. Refinements of theorems which seemed mainly to titillate specialists, without appearing to increase substantially the range of applications, were often discarded. Of course, later developments might show that Bourbaki had not made the optimal choice.[8] Nevertheless, this was a guiding principle.

Besides, many discussions took place outside the sessions about individual research or current developments. Altogether, Bourbaki represented an awesome amount of knowledge at the cutting edge which was freely exchanged.

This made it obvious that for Bourbaki current research and the writing of the "Éléments" were very different, almost disjoint, activities. Of course, the latter was meant to supply foundations for the former, and the dogmatic style, going from the general to the special, was best suited for that purpose (see [5]). However, the "Éléments" were not meant to stimulate, suggest, or be a blueprint for, research (as stressed in [8, p. 144]). Sometimes I have wondered whether a warning should not have been included in the "Mode d'emploi".

All this bore fruit, and the fifties was a period of spreading influence of Bourbaki, both by the treatise and the research of members. Remember in particular the so-called French explosion in algebraic topology, the coherent sheaves in analytic geometry, then in algebraic geometry over $\mathbb{C}$, later in the abstract case, and homological algebra. Although very much algebraic, these developments

[6] *Called "abstract, mercilessly abstract" by E. Artin in his review of* Algebra *[1], adding however "...the reader who can overcome the initial difficulties will be richly rewarded for his efforts by deeper insights and fuller understanding" (p. 479).*

[7] *"Ce travail en commun avec des hommes de caractères très divers, à la forte personnalité, mus par une commune exigence de perfection, m'a beaucoup appris, et je dois à ces amis une grande partie de ma culture mathématique."*

[8] *For instance, the emphasis on locally compact spaces in* Integration, *on which P. Halmos had expressed strong reservations in his review [11], indeed did not address the needs of probability theory, and this led to the addition of a chapter (IX) to* Integration.

also reached analysis, via Schwartz's theory of distributions and the work of his students B. Malgrange and J.-L. Lions on PDE. Early in 1955 A. Weinstein, a "hard analyst", had told me he felt safe from Bourbaki in his area. But less than two years later he was inviting Malgrange and Lions to his institute at the University of Maryland.

I am not claiming at all that all these developments were solely due to Bourbaki. After all, the tremendous advances in topology had their origin in Leray's work, and R. Thom was a main contributor. Also, K. Kodaira, D. Spencer, and F. Hirzebruch had had a decisive role in the applications of sheaf theory to complex algebraic geometry, but undeniably the Bourbaki outlook and methodology were playing a major role. This was recognized early on by H. Weyl in spite of the critical comments mentioned earlier. Once R. Bott told me he had heard negative remarks on Bourbaki by H. Weyl in 1949 (similar to those I knew about), but by 1952 the latter said to him, "I take it all back." Others, however (like W. Hurewicz, in a conversation in 1952), would assert that all that had nothing to do with Bourbaki, only that they were strong mathematicians. Of course, the latter was true, but the influence of Bourbaki on one's work and vision of mathematics was obvious to many in my generation. For us H. Cartan was the most striking illustration, almost an incarnation, of Bourbaki. He was amazingly productive, in spite of having many administrative and teaching duties at the École Normale Supérieure. All his work (in topology, several complex variables, Eilenberg-MacLane spaces, earlier in potential theory (with J. Deny), or harmonic analysis on locally compact abelian groups (with R. Godement)) did not seem to involve brand new, groundbreaking ideas. Rather, in a true Bourbaki approach, it consisted of a succession of natural lemmas, and all of a sudden the big theorems followed. Once, with Serre, I was commenting on Cartan's output, to which he replied, "Oh, well, twenty years of messing around with Bourbaki, that's all." Of course, he knew there was much more to it, but this remark expressed well how we felt Cartan exemplified Bourbaki's approach and how fruitful the latter was. At the time Cartan's influence through his seminar, papers, and teaching was broadly felt. Speaking of his generation, R. Bott said of him, "He has been truly our teacher," at the colloquium in honor of Cartan's seventieth year [4].

The fifties also saw the emergence of someone who was even more of an incarnation of Bourbaki in his quest for the most powerful, most general, and most basic—namely, Alexander Grothendieck. His first research interests, from 1949 on, were in functional analysis. He quickly made mincemeat of many problems on topological vector spaces put to him by Dieudonné and Schwartz and proceeded to establish a far-reaching theory. Then he turned his attention to algebraic topology, analytic and algebraic geometry and soon came up with a version of the Riemann-Roch theorem that took everyone by surprise, already by its formulation, steeped in functorial thinking, way ahead of anyone else. As major as it was, it turned out to be just the beginning of his fundamental work in algebraic geometry.

The fifties was thus outwardly a time of great success for Bourbaki. However, in contrast, it was inwardly one of considerable difficulties, verging on a crisis.

Of course there were some grumblings against Bourbaki's influence. We had witnessed progress in, and a unification of, a big chunk of mathematics, chiefly through rather sophisticated (at the time), essentially algebraic methods. The most successful lecturers in Paris were Cartan and Serre, who had a considerable following. The mathematical climate was not favorable to mathematicians with a different temperament, a different approach. This was indeed unfortunate, but could hardly be held against Bourbaki members, who did not force anybody to carry on research in their way.[9]

The difficulties I want to discuss were of a different, internal nature, partly engineered by the very success of Bourbaki, tied up with the "second part", i.e., the treatise beyond the first six books. In the fifties these were essentially finished, and it was understood the main energies of Bourbaki would henceforth concentrate on the sequel; it had been in the mind of Bourbaki very early on (after all, there was still no *Traité d'Analyse*). Already in September 1940 (Tribu No. 3), Dieudonné had outlined a grandiose plan in twenty-seven books, encompassing most of mathematics. More modest ones, still reaching beyond the "Éléments", also usually by Dieudonné, would regularly conclude the Congresses. Also, many reports on and drafts of future chapters had already been written. However, mathematics had grown enormously,

[9]*In this connection, I would like to point out that the subtitle* Le choix bourbachique *in [9] is extremely misleading. Bourbaki members gave many talks at the seminar and had much input in the choice of the lectures, so it is fair to say that most topics discussed were of interest to at least some members, but many equally interesting ones turned out to be left out, if only because no suitable speaker appeared to be available. So the seminar is by no means to be viewed as a concerted effort by Bourbaki to present a comprehensive survey of all recent research in mathematics of interest to him and a ranking of contributions. Such conclusions by Dieudonné are solely his own. He says that much in his introduction, p. xi, but it seems worth repeating. Of course, like most mathematicians, Bourbaki members had strong likes and dislikes, but it never occurred to them to erect them as absolute judgments by Bourbaki, as a body. Even when it came to his strong belief in the underlying unity of mathematics, Bourbaki preferred to display it by action rather than by proclamation.*

the mathematical landscape had changed considerably, in part through the work of Bourbaki, and it became clear we could not go on simply following the traditional pattern. Although this had not been intended, the founding members had often carried a greater weight on basic decisions, but they were now retiring[10] and the primary responsibility was shifting to younger members. Some basic principles had to be reexamined.

One, for instance, was the linear ordering and the system of references. We were aiming at more special topics. To keep a strict linear ordering might postpone unduly the writing of some volumes. Also, when that course had been adopted at the beginning, there was indeed a dearth of suitable references. But Bourbaki had caught on, some new books were rather close to Bourbaki in style, and some members were publishing others. To ignore them might lead to a considerable duplication and waste of effort. If we did not, how could we take them into account without destroying the autonomous character of the work? Another traditional basic tenet was that everyone should be interested in everything. As meritorious as it was to adhere to, it had been comparatively easy while writing the "Éléments", which consist of basic mathematics, part of the baggage of most professional mathematicians. It might, however, be harder to implement it when dealing with more specialized topics closer to the frontier. The prospect of dividing up, of entrusting the primary responsibility of a book to a subset of Bourbaki, was lurking but was not one we would adopt lightly. These questions and others were debated, though not conclusively for a while. There were more questions than answers. In short, two tendencies, two approaches, emerged: one (let me call it the idealistic one) to go on building up broad foundations in an autonomous way, in the tradition of Bourbaki; the other, more pragmatic, to get to the topics we felt we could handle, even if the foundations had not been thoroughly laid out in the optimal generality.

Rather than remain at the level of vague generalities, I would like to illustrate this dilemma by an example.

At some point a draft on elementary sheaf theory was produced. It was meant to supply basic background material in algebraic topology, fibre bundles, differential manifolds, analytic and algebraic geometry. However, Grothendieck objected[11]: we had to be more systematic and provide first foundations for this topic itself. His counterproposal was to have as the next two books:

Book VII: *Homological Algebra*
Book VIII: *Elementary Topology*

the latter to be tentatively subdivided into:

Chap. I: Topological categories, local categories, gluing of local categories, sheaves
Chap. II: H^1 with coefficients in a sheaf
Chap. III: H^n and spectral sequences
Chap. IV: Coverings

to be followed by

Book IX: *Manifolds*

which had already been planned.

He also added a rather detailed plan for the chapter on sheaves that I shall not go into.

This was surely in the spirit of Bourbaki. To oppose it would have been a bit like arguing against motherhood, so it had to be given a hearing. Grothendieck lost no time and presented to the next Congress, about three months later, two drafts:

Chap. 0: Preliminaries to the book on manifolds. Categories of manifolds, 98 pages

Chap. I: Differentiable manifolds, The differential formalism, 164 pages

and warned that much more algebra would be needed, e.g., hyperalgebras. As was often the case with Grothendieck's papers, they were at points discouragingly general, but at others rich in ideas and insights. However, it was rather clear that if we followed that route, we would be bogged down with foundations for many years, with a very uncertain outcome. Conceived so broadly, his plan aimed at supplying foundations not just for existing mathematics, as had been the case for the "Éléments", but also for future developments to the extent they could be foreseen. If the label "Chapter 0" was any indication, one could fear that the numbering might go both ways, Chapters -1, -2,...being needed to give foundations to foundations, etc.

On the other hand, many members thought we might achieve more tangible goals in a finite time, not so fundamental maybe, but still worthwhile. There were quite a number of areas (algebraic topology, manifolds, Lie groups, differential geometry, distributions, commutative algebra, algebraic number theory, to name a few) in which they felt the Bourbaki approach might produce useful expositions, without needing such an extensive foundational basis as a prerequisite.

The ideal solution would have been to go both ways, but this exceeded by far our possibilities. Choices had to be made, but which ones? The

[10]*It had been apparently agreed early on that the retirement age would be fifty (at the latest). However, when the time came to implement that rule, from 1953 on, there was little mention of it until 1956, when Weil wrote a letter to Bourbaki announcing his retirement. From then on it has been strictly followed.*

[11]*At the March 1957 Congress, later called "Congress of the inflexible functor".*

question was not answered for some time, resulting in a sort of paralysis. A way out was finally arrived at a year later: namely, to write a fascicle of results on differential and analytic manifolds, thus bypassing, at least provisorily, the problem of foundations, at any rate for the main topics we had in mind. After all, as far as manifolds were concerned, we knew what kind of basic material was needed. To state what was required and prove it for ourselves was quite feasible (and was indeed carried out rather quickly).

This decision lifted a stumbling block, and we could now set plans for a series of books which we hoped would essentially include commutative algebra, algebraic geometry, Lie groups, global and functional analysis, algebraic number theory, and automorphic forms.

Again, this was too ambitious. Still, in the next fifteen years or so a sizable number of volumes appeared:

Commutative Algebra (9 chapters)
Lie Groups and Lie Algebras (9 chapters)
Spectral Theory (2 chapters)

besides preliminary drafts for several others.

In 1958 a decision had also been made to solve in principle a problem which had been plaguing us for quite a while: additions to the "Éléments". On occasions, while writing a new chapter, we would realize that some complement to one of the first six books was in order. How to handle this? Sometimes, if a volume was out of print, it was possible to include these complements in a revised edition. If not, one could conceivably add an appendix to the new chapter. But this threatened to create a lot of confusion in the references. In 1958 it was resolved to revise the "Éléments" and publish a "final" edition, not to be tampered with for at least fifteen years. Unfortunately, it took more time and effort than anticipated. It is in fact not quite finished as of now, and (I feel) it slowed down progress in the more innovative parts of the treatise. But it was certainly in the logic of Bourbaki and hardly avoidable.

Of the three books listed above, *Commutative Algebra* was obviously well within Bourbaki's purview; it could, and did in fact, proceed independently of the resolution of the dilemma we had faced. But the fascicle of results on manifolds was an essential prerequisite for the book on Lie groups and Lie algebras. The latter also shows that the more pragmatic way could lead to useful work. A good example is provided by Chapters 4, 5, and 6 on reflection groups and root systems.

It started with a draft of about 70 pages on root systems. The author was almost apologetic in presenting to Bourbaki such a technical and special topic, but asserted this would be justified later by many applications. When the next draft, of some 130 pages, was submitted, one member remarked that it was all right, but really Bourbaki was spending too much time on such a minor topic, and others acquiesced. Well, the final outcome is well known: 288 pages, one of the most successful books by Bourbaki. It is a truly collective work, involving very actively about seven of us, none of whom could have written it by himself. Bourbaki had developed a strong technique to elicit a collaboration on a given topic by specialists and people with related interests looking at it from different angles. My feeling (not unanimously shared) is that we might have produced more books of that type but that the inconclusive discussions and controversies, and the difficulties in mapping out a clear plan of activity had created a loss of momentum from which Bourbaki never fully recovered. There is indeed a tremendous amount of unused material in Bourbaki's archives.

This approach was less ambitious than the Grothendieck plan. Whether the latter would have been successful, had we gone fully in that direction, seems unlikely to me, but is not ruled out. The development of mathematics does not seem to have gone that way, but implementation of that plan might have influenced its course. Who knows?

Of course, Bourbaki has not realized all its dreams or reached all of its goals by far. Enough was carried out, it seems to me, to have a lasting impact on mathematics by fostering a global vision of mathematics and of its basic unity and also by the style of exposition and choice of notation, but as an interested party I am not the one to express a judgment.

What remains most vividly in my mind is the unselfish collaboration over many years of mathematicians with diverse personalities toward a common goal, a truly unique experience, maybe a unique occurrence in the history of mathematics. The underlying commitment and obligations were assumed as a matter of course, not even talked about, a fact which seems to me more and more astonishing, almost unreal, as these events recede into the past.

References

[1] E. Artin, *Review of* Algebra (I–VII) *by N. Bourbaki*, Bull. Amer. Math. Soc. **59** (1953), 474–479.

[2] L. Baulieu, *A Parisian café and ten proto-Bourbaki meetings (1934–35)*, Math. Intelligencer **15** (1993), 27–35.

[3] ——, *Bourbaki: Une histoire du groupe de mathématiciens français et de ses travaux*, Thèse. Université de Montréal, 1989.

[4] R. Bott, *On characteristic classes in the framework of Gelfand-Fuks cohomology*, Colloque Analyse et Topologie en L'honneur de H. Cartan, Astérisque **32–33** (1976), 113–139; *Collected papers* vol. 3, Birkhäuser, 1995, pp. 492–558.

[5] N. Bourbaki, *L'architecture des mathématiques*, Les Grands Courants de la Pensée Mathématique (F. Le

Lionnais, ed.), Cahiers du Sud (1948); English trans., Amer. Math. Monthly **57** (1950), 221–232.
[6] H. Cartan, *Nicolas Bourbaki and contemporary mathematics*, Math. Intelligencer **2** (1979–80), 175–180.
[7] ____, Oeuvres Vol. 1, Springer, 1979.
[8] J. Dieudonné, *The work of Nicholas Bourbaki*, Amer. Math. Monthly **77** (1970), 134–145.
[9] ____, *Panorama des mathématiques pures, Le choix bourbachique*, Bordas, Paris, 1977.
[10] D. Guedj, *Nicholas Bourbaki, collective mathematician: An interview with Claude Chevalley*, Math. Intelligencer **7** (1985), 18–22.
[11] P. Halmos, *Review of* Integration (I–IV) *by Bourbaki*, Bull. Amer. Math. Soc. **59** (1963), 249–255.
[12] A. Weil, *Review of "Introduction to the theory of algebraic functions of one variable by C. Chevalley"* Bull. Amer. Math. Soc. **57** (1951), 384–398; Oeuvres Scientifiques II, Springer, 1979, pp. 2–16.
[13] ____, *Organisation et désorganisation en mathématique*, Bull. Soc. Franco-Japonaise des Sci. **3** (1961), 23–35; Oeuvres Scientifiques II, Springer, 1979, pp. 465–469.
[14] ____, *Notice biographique de J. Delsarte*, Oeuvres de Delsarte I, C.N.R.S., Paris 1971, pp. 17–28; Oeuvres Scientifiques III, Springer, 1980, pp. 217–228.

The Demise of the Young Scholars Program

Allyn Jackson

Starting in 1988, the Young Scholars Program at the National Science Foundation funded summer programs for high school students showing special talent in mathematics and science. The legendary program run by Arnold Ross at Ohio State University, which draws some of the top mathematical talent in the nation, received funding through Young Scholars for many years. Among the other well-regarded and long-running mathematics programs funded by Young Scholars are PROMYS (Program in Mathematics for Young Scientists) at Boston University, run by Glenn Stevens, and one at Hampshire College, run by David Kelly. In 1996 the NSF ended funding for Young Scholars, leaving these and other programs scrambling for funding and, in some cases, closing down altogether. The NSF itself acknowledges that Young Scholars has been very successful. So why did it cut off funding? The reason appears to be a potent mix of politics and legal troubles, together with the governmental fact of life that dollars flow more easily toward new ideas, even when the old ones have proven their worth.

Examples of Young Scholars Successes

The NSF funded summer programs for many years through SSTP (Summer Science Training Program), which was part of the post-Sputnik push to improve science and mathematics education. Funding faltered during the Reagan administration's attempt to wipe out the NSF's education directorate, but by 1988 worries about the "pipeline" for scientists and engineers led to the resurrection of SSTP in the form of Young Scholars. At the time of its demise Young Scholars was funding 114 summer programs that reached around 5,000 students annually. Funding totaled about $10 million a year, or 5% of the budget of the NSF's Division of Elementary, Secondary, and Informal Education. Generally the programs ran several weeks, brought in 20–60 students, and were directed by scientists and mathematicians. The size of a typical grant was $25,000--$50,000 per year. Some of the cost of the programs was covered by student tuition, and there was usually substantial cost sharing on the part of the sponsoring institutions. About 15% of the Young Scholars programs were in mathematics. A look at the three Young Scholars programs mentioned above gives a sense of what these programs aimed for and accomplished.

Among the Young Scholars programs in mathematics, the Ross program at Ohio State was probably the best known, partly because of its age—it started in 1957 and has run every year since then—and also because it has drawn students of such tremendous talent and has inspired many to pursue careers in mathematics. The distinctions of the alumni of the program include positions in some of the top mathematics departments, Sloan Fellowships, various prizes (including a Steele Prize and a Cole Prize), and at least one MacArthur Fellowship. The heart of the Ross program is a collection of problem sets that students are given to work on each day. The problems, many of them in number theory, encourage students to do extensive explorations and to draw conclusions from what they find. The problems are very different from what the students usually encounter in high school. For example, the sets include a list of statements headed with the instruction "Prove or Disprove and Salvage If Possible", with no hints provided as to whether the statements are true or false. Each day the students put intense effort into solving as much of the problem sets as they can, and each day their solutions are read by undergraduate counselors, many of whom are program alumni. There are also lectures by mathematics faculty, including Ross himself, who last summer at the age of ninety was still giving daily number theory lectures for first-year participants. These lectures lag behind the problem sets, revisiting and reinforcing ideas that the students have already explored for themselves in the problems. There are also courses on combinatorics and other subjects. [1]

Allyn Jackson is senior writer and deputy editor of the Notices. *Her e-mail address is* axj@ams.org.

As an alumnus of the Ross program, Glenn Stevens used it as his model when he and his Boston University colleague David Fried started PROMYS in 1989. The students who come to the program are already good problem solvers, Stevens notes. PROMYS gets them to move from seeing the "answer out there" as the ultimate goal to seeing answers to particular problems as forming patterns. "Ross's problem list is ideal for this," Stevens says. In fact, he tells the students that the most important problems are the numerical ones: observing the data gleaned from these problems allows the students to formulate and test hypotheses to explain their observations. With the undergraduate counselors and faculty members around, there are plenty of people for the students to talk to. Indeed, Daniel Shapiro, one of the co-directors of the Ross program, says that the "real reason" for the success of the program is the counselors, who live together with the students in the dorms. This provides an atmosphere in which the students are steeped in mathematics all day long and for many days on end: the Ross program runs eight weeks, and PROMYS runs six weeks.

David Kelly's program, Hampshire College Summer Studies in Mathematics, has a goal similar to that of PROMYS and the Ross program, which is, as Kelly puts it, to get the students to see themselves as "active creators of mathematics rather than passive learners." Kelly's program is different in that it is centered not on problem sets but on workshops designed to encourage the students to come up with their own definitions, conjectures, and theorems. The entire staff live in the dormitories and join students for meals and recreational activities, as well as the seven hours of class each day. The second half of the program includes courses on topics that students are unlikely to see in high school, such as real and complex dynamics, four-dimensional geometry, game theory, and probability. At the end of the six weeks the students "hate to leave," Kelly notes. With that much enthusiasm coming from the students, Kelly's love of the program has not dimmed after twenty-five years of running it. "This is one of the most gratifying teaching experiences you can imagine," he says.

In a conversation with about ten PROMYS students, it is clear that the program's goal of getting them to look at mathematics in a new light is amply realized (see sidebar on page 386). "When you do math in high school, you kind of get an idea of it as already done for you," said Peter Frazier, a student from Rhinebeck, New York. "But when you come to PROMYS, you get the idea that it's not really all cut and dried and there's new stuff always going on that you have to figure out." Another student, Radu Iòvita, pointed out that in high school the justification for learning mathematics is often that it is useful in another subject, such as chemistry or physics, but what they learn in PROMYS is mathematics that is interesting in its own right. "Here you find out that pure math is incredible, you can do all these incredibly weird things, and use your imagination to the full twist," he declared. It is "basically full liberty of imagination." Their only complaint? The program could be longer.

The Young Scholars programs have sometimes been criticized for catering to "elite" students. The argument is that these students are already highly talented and motivated and such programs simply add to their advantages. Some of the programs, especially the more rigorous and challenging ones like the PROMYS, Ross, and Kelly programs, have also been criticized for what is seen as inadequate representation of women and minorities. The Ross program has probably come in for the heaviest criticism of this type, in part because it does not advertise widely and relies mostly on a group of high school teachers to recommend the program to their students. PROMYS and the Hampshire program advertise more widely, but applications from women and minorities are not plentiful. The main criterion for admission to these programs is performance on a set of problems sent out with application materials. Any student doing well enough on the problems is admitted. According to Shapiro many students get discouraged by the difficulty of the problems and do not send any solutions back.

In all these programs, when an application from a female or minority student is received, the directors do all they can to bring the student into the program. Kelly has gone as far as to work with minority students during the school year to try to bring them up to speed for the demands of the program, because the program "won't be a service if they are not qualified." While the actual number of women students in Kelly's program has been small, about a dozen have gone on to advanced degrees in mathematics. Three are nearby in New England: Susan Landau of the University of Massachusetts, Marcia Groszek of Dartmouth College, and Ann Trenk of Wellesley College. The Ross, PROMYS, and Hampshire programs have met with success with the individual female and minority students who participate, but they get few applications from such students.

There are some Young Scholars programs in mathematics that target women, a prominent example being the one run by Harvey Keynes at the University of Minnesota. Some have a high minority enrollment, such as the program run by Max Warshauer at Southwest Texas State University. About 25% of the students in Donald Goldberg's

---

[1] *The article "A Conference Honoring Arnold Ross on His Ninetieth Birthday", by Daniel Shapiro, presents background and history about Ross and his program. The article appeared in the* Notices, *October 1996, pages 1151–1154.*

program at Occidental College were members of underrepresented minorities. Warshauer's program is continuing despite the loss of NSF funding, but Goldberg's has closed down. These programs provide two more examples of how the established, long-running programs have provided models that can be used successfully in other settings: Warshauer is a three-time participant in the Ross program, and Goldberg was in Kelly's program as a student and later as a counselor. The SUMMA (Strengthening Underrepresented Minority Mathematics Achievement) program at the Mathematical Association of America also helped to create more minority-focused Young Scholars programs by providing advice, technical assistance, and small grants to those who wished to get such programs off the ground. In fact, all but one of the new grants in Young Scholars in mathematics since 1992 were obtained with the assistance of SUMMA.

Legal Headaches at NSF

The NSF encouraged the directors of the Young Scholars programs to include women and minorities among their participants, but the numbers remained small. In 1992 Congress directed the NSF to create the Summer Science Camps (SSC), which were similar to the Young Scholars programs but were aimed exclusively at minority students. The guidelines were explicit: "Participants in the SSC must be underrepresented students." The NSF defined underrepresented minorities as including Native Americans (American Indians and Alaska Natives), Blacks, Native Pacific Islanders (Micronesians and Polynesians), and Hispanics. The SSC started out with a budget of $2 million, which grew to about $5 million by 1994, when it supported around eighty projects.

The SSC was short lived. In 1994 a white ninth-grader from Corpus Christi, Texas, sued the U.S. Government, with the NSF and Texas A&M University named as defendants in the suit, because she had applied to and been denied admission to a Summer Science Camp. The student had applied to Camp Planet Earth: Summer Environmental Science Camp, held at Texas A&M. According to a piece in the *Washington Times* that appeared on January 9, 1995, the student was told during an admission interview for the program that she was ineligible to attend because she is white.

The Center for Individual Rights (CIR) took on the girl's case, which was settled out of court on February 5, 1996. The CIR has become well known for its work on two high profile legal battles: Hopwood v. Texas, which successfully challenged affirmative action policies at the law school of the University of Texas, and California's Proposition 209, which amended the state's constitution to prohibit affirmative action. In the Summer Science Camp case, the settlement stipulated that the government had to ensure that "no person, on the grounds of race, color, age, sex, national origin, or disability shall be excluded from participation in, denied the benefits of, or be subjected to discrimination under any Summer Science Camps Program receiving financial assistance from the National Science Foundation." In addition, the NSF was to supply material about its programs so that the CIR could check that the NSF had complied with the settlement. (In an unusual twist, the same student has filed a second lawsuit after having been denied admission to another minority-oriented program at Texas A&M, this one funded by the National Institutes of Health and the Department of Agriculture. CIR has taken on this suit as well.)

At the time of its demise, Young Scholars was funding 114 summer programs that reached around 5,000 students annually.

NSF officials cannot speak publicly about the lawsuit, but it is clear that the Foundation was badly shaken. The settlement dictated that the NSF adjust the admission criteria of the SSC projects to include nonminority participants; instead, NSF wiped out the program entirely. Some have speculated that the NSF—watching support for affirmative action erode in many quarters, particularly in the Republican-controlled Congress—was moving to head off future legal troubles. Around this same time the NSF also changed the names of some of its programs for minorities. For example, the Comprehensive Partnership for Minority Student Achievement Program was changed to Comprehensive Partnerships for Mathematics and Science Achievement. In addition, some of the wording in certain NSF program descriptions was amended to shift away from an exclusive focus on minorities. The official word from the NSF is that the SSC lawsuit had no impact on any other NSF programs. According to NSF general counsel Lawrence Rudolph, "The resolution of the SSC lawsuit was limited to that program, and any subsequent changes in other Foundation activities were solely for programmatic reasons."

In 1996 the NSF awarded a grant to Laila Denoya of State University of New York College at Fredonia to carry out an "accountability project" of the SSCs. Denoya, who was herself a director of an SSC, wanted to disseminate the models and ideas developed by the SSCs to provide a resource for people interested in starting up such programs. The result was an attractive epitaph for the SSCs: "Leaving a Legacy of Successes", a 207-page, four-color report printed on glossy paper and crammed with

A Sampling of Problems

The following problems were taken from problem sets designed by Arnold Ross and are in use in the Ross program and in PROMYS.

Numerical Problems: Some Food for Thought

1. How many square roots of -1 are there in $\mathbf{Z}_m$ for $m = 3, 5, 7, 9, 11, 13, 15, 17, 19, 65$? Any conjectures?
2. Construct a table of "logarithms" (indices) for $\mathbf{Z}_{29}$. Use this table to find all the solutions in $\mathbf{Z}_{29}$ of (a) $7x = 6$, (b) $x^2 = 3$, (c) $x^3 = 6$.
3. Write the polynomial $f(x) = x^5 + 3x^4 + x^3 - 2x^2 + 6x - 3$ in $\mathbf{Z}_7[x]$ in base $x - 3$.
4. What are the units in $\mathbf{Z}_5[x]$? in $\mathbf{Z}_9[x]$? in $\mathbf{Z}_{45}[x]$?

Prove or Disprove and Salvage If Possible

1. If $a|bc$ and $(a,b) = 1$, then $a|c$. True in $\mathbf{Z}$? in $\mathbf{Z}[i]$? in $\mathbf{Z}[\sqrt{-5}]$?
2. A polynomial of degree n with coefficients in $\mathbf{Z}_m$ has at most n distinct roots in $\mathbf{Z}_m$.
3. For a rational prime $p > 2$, u is a primitive root in $\mathbf{Z}_p$ $\Leftrightarrow$ $u^{\frac{p-1}{2}} = -1$.

Miscellaneous

1. Find all positive integers that are both square and triangular.
2. The sum $1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$ for $n > 1$ is never an integer.
3. Is it possible to draw a regular pentagon in the plane all of whose vertices are lattice points?
4. Find all integer solutions of the Diophantine equation $y^2 = x^3 - 2$.

photographs and handsome graphics. Denoya sounds rueful about the closure of SSCs, saying that there was "no question" that they were very successful. She believes that the NSF is still dedicated to increasing minority participation in science and mathematics. "The commitment is 100 percent," she declares.

While the SSC lawsuit was progressing in 1995, the directors of some of the Young Scholars programs began getting signals from the NSF that the ground was shifting under Young Scholars as well. The NSF announced that there would be no competition that year, but that proposals would be accepted the following year. Don Goldberg at Occidental became concerned about this change, because it meant that in case there was no new competition in 1996 his program would end that year. He says he discussed this with NSF staff and was told that he would have to live with some uncertainty for a few months but that a new competition would take place. Still, Goldberg was worried not only about his own program but about the Young Scholars effort as a whole. In March 1996 he sent an e-mail message to many people, including other directors of Young Scholars programs. "I believe the Young Scholars Program is a valuable program that is in grave danger," he wrote. "If you agree, please express your views to people who can save it." Goldberg said in the e-mail that he planned to write to his senators and congressional representatives, as well as to top NSF officials, and urged others to do the same. Afterward he got the impression that the NSF did not appreciate the move to go above their heads to get the program restored: Goldberg said that a colleague told him, "I heard you're making trouble. A friend of mine at NSF said to back off." Later that year Goldberg's fears were confirmed when NSF announced it was closing down Young Scholars. Many directors of the programs were mystified, saying that the NSF never made clear to them its reasons for ending Young Scholars.

The AMS Committee on Education (COE) discussed the demise of Young Scholars at a meeting in 1996. In August of that year, COE chair Hyman Bass and National Council of Teachers of Mathematics (NCTM) President Gail Burrill sent a letter to Luther Williams, Assistant Director for Education and Human Resources at the NSF. The letter urged the NSF to restore funding for Young Scholars. COE staff and Bass report that no reply was received. The NSF received similar letters from others as well. Gail Richmond has run SSTP and Young Scholars programs since 1959 at Michigan State University and served at the NSF as a Young Scholars program director during 1989–1990. She says that when the termination of Young Scholars was announced she sent letters protesting the move to NSF officials—including Luther Williams and NSF Director Neal Lane—as well as to the National Science Board, the governing body of the NSF. Richmond says she never received any reply. In December 1997, the NCTM Student Services Committee, acting on behalf of the Executive Board, wrote to the NSF expressing concern about the erosion of programs aimed at high ability students and questioning the considerations that appeared to lead to the elimination of Young Scholars.

The fact that the demise of Young Scholars came around the same time as the legal troubles over SSC has led some to believe that the two events are related. After the NSF canceled its summer programs for minorities, it might have been politically impossible to retain Young Scholars, which had to some extent gained the reputation of being for the white and the privileged. It is difficult to confirm whether such considerations actually came into play at the NSF. Harvey Keynes of Minnesota says that, during the legal skirmish over SSC, his Young Scholars program for female students got unofficial word from Washington sources that it should change its rules to allow males to participate. Keynes said they made the adjustment by admitting males but providing financial support only to females. "There are solutions, other than being Chicken Little and saying, 'The sky is falling,'" he remarks. Keynes also believes that certain myths about talented students—such as that embodied in the statement, "These kids are talented, so it doesn't matter what you do with them"—weakened support for Young Scholars. Other directors of Young Scholars programs express similar views, but it is again difficult to ascertain what role such attitudes may have played in the NSF's decision to end Young Scholars. There are two other factors whose influence is perhaps clearer: a less-than-enthusiastic evaluation report, and a general trend at the NSF toward large, comprehensive programs.

A Lukewarm Evaluation, a Quest for New Programs

The NSF commissioned an evaluation of Young Scholars by COSMOS Corporation, which had been amassing data about the programs since 1988. The 1994 COSMOS report was based on information from questionnaires given to participants at the start and end of the programs, as well as to a group of students who applied to the programs but were not admitted. The questionnaires mostly asked participants about their plans for college majors, graduate study, and careers. A typical table in the COSMOS report presents a breakdown by race and gender of the numbers of Young Scholars participants intending to pursue various college majors.

The report was generally approving of the Young Scholars programs, but questioned whether they were truly effective in encouraging students to pursue careers in science, engineering, and mathematics: it appeared that the students might have chosen such careers without having participated in the programs. Because the participants already had an interest in these fields, the report noted, Young Scholars programs did not change the minds of students not disposed to pursue such careers. The conclusions of the COSMOS report were equivocal and probably not sufficiently negative to be the sole basis for closing down Young Scholars, but the report may have bolstered arguments for its closure.

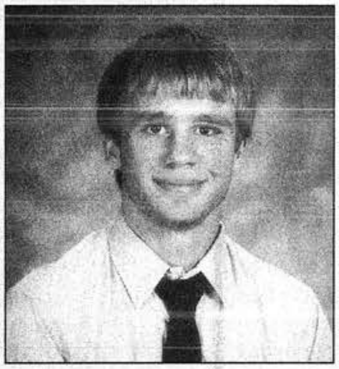
Many of the directors of Young Scholars programs vigorously deny the validity and conclusions of the COSMOS report. William Fleischman of Villanova University, who has run programs under both Young Scholars and SSTP, argues that the questions COSMOS asked the students did not provide a basis for understanding what the students were gaining from the program. David Kelly makes a similar point: One of his students who filled out the COSMOS questionnaire before and after participating in the program said that she gave the same answers but that the words meant something different to her at the end of the program than at the beginning. Kelly also notes that some students might in fact decide not to go into mathematics because of his program. "We give a clearer perception of what the field is, and maybe we lose some because of this," he explains. Such an outcome might look bad, given the tack that COSMOS took in its evaluation.

Trying to come up with quantitative measures to evaluate such programs may be more difficult and subtle than COSMOS realized. Of the success of Young Scholars, Fleischman says: "The data are all anecdotal, but they are massive." "If you go anywhere in the community of biologists, chemists, physicists, or mathematicians," he notes, "you will find people who have a passion for what they do in research and education and as mentors and who trace it to these experiences." Fleischman recently attended a ceremony for recipients of a presidential award for mentors in science, mathematics, and engineering, especially those working with women and minorities. He says he was struck by the fact that those who spoke pointed to programs like SSTP and Young Scholars as having inspired them in the activities for which they were being honored.

The other factor that contributed to the demise of Young Scholars is a general trend at the NSF toward large, comprehensive programs. As Harvey Keynes puts it, the NSF thought it could get "more bang for its buck" by moving toward larger programs and away from the "10 kids here, 20 kids there" mode of Young Scholars. In fact, the NSF maintains that it has not actually terminated Young Scholars but has transformed it into Teacher and Student Development Through Research Experiences Projects (TSD/REP), which will support summer programs that give students and their teachers a taste of scientific research. "There is no doubt that students who participated in Young Scholars benefited immensely, so from that perspective Young Scholars was highly successful," notes Judd Freeman, a program director for TSD/REP. They "did wonderful things for the kids who participated in them. But that's where the impact stopped." The NSF is hoping to broaden the impact by including teachers in the summer programs. The general model is to have one teacher and up to three of his or her students, so that during the regular school year these students can act as "peer mentors". As with Young Scholars, the programs would generally be directed by college and university faculty, who would involve the teachers and students in research projects.

The shift from Young Scholars to TSD/REP dovetails neatly with NSF's moves in recent years toward "systemic" programs in education, most visibly manifested by the State Systemic Initiative grants it has given in recent years. The emphasis at the NSF is clearly on raising the general level of scientific and mathematical literacy rather than on creating an elite group with a very high level of skills and education. In addition, the NSF sees its role as a catalyst for new ideas, not as a perpetual funder of proven ones. Of the Young Scholars model, Freeman says, "The value of that is proven. Now

In His Own Words: Bryden Cais, High School Student and PROMYS Participant



Bryden Cais is a high school student in Virginia Beach. By the ninth grade he had finished all of the courses available at his high school, and there was no college nearby where he could take more advanced courses. PROMYS allowed him not only to learn more mathematics but also to meet professors and undergraduate mathematics majors who could give him suggestions on books to read during the school year. A budding mathematician, he presented a paper, "Using Ramanujan-like Techniques to Derive Series and Infinite Products" in the student paper session at the 1996 Mathfest in Seattle. Below are some of his observations about PROMYS.

"I think a really big and important difference is the teachers [in PROMYS]. They are really, really enthusiastic about math, and they instill that in their students. It's just a great feeling when everybody's thinking math, and you're all working on it.

"Another really great thing is we do a lot of numerical exercises in our problem sets. We don't do that a whole lot, at least not in the high school I go to. I find that actually immersing yourself in the numerical work when you're solving the problems really helps you understand in depth exactly how it works so you can formulate things in precise terms and prove theorems. For example, one problem was to find all numbers less than 100 that are the sum of two squares. And from that you make a few conjectures, maybe prove them if they're good.

"The problem sets are very well designed. Certain problems come up, and they will give you a hint of what's coming next, and you'll say, 'That's nice.' Then you find other problems, and you'll find they're connected. The more problems you do and the more types that you do, you find that they're all connected in this really deep way, and you can then prove much deeper things. It gets so interesting, it's great.

"I went through fourth, fifth, and sixth-grade math, and it's the same stuff over and over again. I thought it was pretty boring at first. I read a couple of books, really simple stuff, and I started playing around with some algebraic stuff. I accidentally stumbled upon this really nice theorem of Fermat. And I thought, 'Wow, this is really cool,' because I thought I'd discovered it. Then I got this book, Hardy and Wright, and I found it in there. I was really crushed that somebody else had it before me. But at the same time it felt so great just to have discovered something that Fermat had discovered 300 years before. Discovering is just so much fun. Ever since then I loved the discovery part. At PROMYS we do exactly that."

we need to push for another model that works as well." The thinking at NSF is that programs with a track record of success should be able to raise funds from other sources or get institutional funding. Indeed, according to Freeman, the TSD/REP program emphasizes the need for substantial cost sharing by institutions or fundraising to keep the projects alive after NSF support ends. These considerations are taken into account in reviewing proposals.

Some of the directors of Young Scholars programs have applied for funding from TSD/REP, but there is skepticism about how well it suits mathematics. Glenn Stevens of PROMYS notes that the TSD/REP guidelines say that the participants are supposed to work as "research" apprentices to scientists, which is a "wonderful idea for the laboratory sciences, but unrealistic for most of mathematics." On the other hand, Stevens says that he has for some time been wanting to include teachers in some of the PROMYS activities, and TSD/REP may provide this opportunity. Others are not sure that putting students and their teachers together in the same program is a good model. Goldberg says that he is very interested in teacher development but believes that the needs of teachers and students are so different that putting them into the same program would not be successful in all circumstances. Some point out that providing what teachers need would fundamentally alter the programs. According to Keynes, teacher enhancement programs are "much more elaborate and extensive" than Young Scholars programs and would require a great deal of additional effort.

NSF officials do not believe that these concerns represent serious impediments to mathematicians' participating in TSD/REP. Margaret Cozzens is the director of the Elementary, Secondary, and Informal Education Division, which was the home of Young Scholars and now oversees TSD/REP. Cozzens, who is a mathematician, says she has taught in programs involving teachers and students at DIMACS at Rutgers University. Even though the programs for teachers and students were separate, they provided ways for the groups to interact. Rather than having everyone doing the same things together all the time in a "one-size-fits-all" mode, she points out that one can have some activities for teachers only, some for students only, and some for the two groups together. She acknowledges that it might be easier to set up such a program in a laboratory science, but also contends that "the opportunities in mathematics are every bit as present." Projects in applied mathematics might be the easiest to construct, but she also believes that areas such as group theory, geometry, discrete mathematics, and combinatorics are amenable to such projects. "This is an opportunity to think differently about high-potential and gifted students and our ability to work with them and to affect more students than before," she declares. Given the emphasis on mathematics in high school, she says it would be natural for 50% of the TSD/REP grants to be in mathematics. However, only about 10% of the proposals were in mathematics.

A few years back, Fleischman says, the NSF suggested that teachers be included in the Young Scholars activities, and his program did so. "In fact, it was a wonderful part of our experience," he says. But "the truth is, there is a difference in the level of intensity with which we can connect with teachers." This is partly because the teachers bring with them a heavy set of responsibilities—relating both to their families and their demanding profession—while the students have few responsibilities and great energy to learn. The NSF has argued that the Young Scholars programs reached only the students in them, while TSD/REP programs would in time touch far more students because of the inclusion of teachers. Fleischman sees another perspective in having college and university faculty work directly with the students: it helps open up dialogue between faculty and teachers. Says Fleischman, "The most productive means for understanding what I can do in working with high school teachers is to have the sort of 'laboratory' that Young Scholars provided for working with their students."

Programs Fight to Stay Afloat

Stevens and Fleischman have submitted proposals for TSD/REP, but they are uncertain about their chances (at the time of this writing decisions about the proposals had not yet been made but are likely to have been announced by the time this issue of the *Notices* reaches readers). Max Warshauer is also applying for a TSD/REP grant, despite a negative reaction to a preliminary proposal he sent to the NSF. Dan Shapiro says the Ross program got a similarly negative reaction to its preliminary proposal to TSD/REP and as a result decided not to apply.

The NSF was betting that many Young Scholars programs would survive without its help, and it turned out to be right: a lot of them have scraped by. In 1996 David Kelly's program missed a year—for the first time in twenty-four years—but managed a comeback in 1997 by cutting corners ("like my salary," he says wryly). PROMYS was in much the same situation, and in 1997 it relied on unspent funds from previous years' NSF grants as well as some support from Boston University. Stevens says PROMYS will definitely run in the summer of 1998, but that the costs to students will go up "dramatically" if the TSD/REP proposal falls through. He is also pursuing other fundraising avenues. The Ross program is in a similar situation, though it benefited from a special one-time grant from the National Security Agency in 1996; it has also started a small endowment fund. Some programs are pursuing corporate funding but have not met with much success so far. Many are raising student tuition to cover costs. Max Warshauer of Southwestern Texas University reports that while he had NSF funding about half of the students in his program would have been unable to attend without support; now that he has had to raise the tuition, such students probably will not participate. After the loss of NSF funding, Southwestern Texas provided institutional support for the next two years. Permanent institutional funding for such programs can be hard to secure, because the programs do not act as recruiting vehicles for the sponsoring institutions; the students who participate are usually very well prepared academically and choose to attend college at higher-tier institutions.

What the future holds for such programs is not clear. Kelly suggests that the AMS, the Mathematical Association of America, and the National Council of Teachers of Mathematics might be able to collaborate on an allocation of NSF funds for these programs. "They could do it better, it would be real peer review, and it would save a lot of NSF money on administration," he notes. A new, up-and-coming organization called MathCamps has launched an aggressive fundraising drive and even rented booths at mathematics meetings to promote itself. Its efforts might provide a model for fundraising that other programs can use, but the result may be that they all chase the same dollars.

Without the Young Scholars programs, mathematically talented students would lose opportunities to grow beyond their usual coursework. On the other hand, they would likely remain among the top students, attend top colleges, and have productive careers. It is not clear that any more or fewer of them would go into mathematics without these programs; many who have never attended such programs have nevertheless become mathematicians. What then would be lost were these programs to disappear? Perhaps the greatest loss would be to the mathematical community, which would lose exactly the thing that is hardest to explain to funding agencies and writers of evaluation reports: a connection to the wellspring of mathematical enthusiasm. As Fleischman puts it, "The kids come here with this tremendous thirst and this tremendous tide of energy.... They just come tumbling at us." Were the mathematical community to lose that connection, it would be a profound loss indeed.

Kunihiko Kodaira (1915–1997)

Donald C. Spencer

Kunihiko Kodaira

Kunihiko Kodaira was born March 16, 1915, and died on July 26, 1997. His father was an agricultural scientist who, at one time, was Vice-Minister of Agriculture in the Japanese government and who also played an active role in agricultural developments in South America. His mother, a remarkable woman, will be remembered by all of us who visited the Kodairas in Tokyo as a warm and generous hostess. She spoke English well, having said to her son immediately after World War II: "Now all of us must learn English." His wife, Seiko, also came from a distinguished family, the Iyanagas. Her brother, S. Iyanaga, a well-known mathematician, influenced Kodaira's early years at Tokyo Imperial University where he first studied mathematics and later theoretical physics. Another brother, K. Iyanaga, was at one time president of the well-known Nikon camera firm, and a third brother, T. Iyanaga (now deceased), was a professor of Japanese history at the University of Tokyo.

At Tokyo Imperial University, Kodaira graduated first from the department of mathematics in 1938, then from the department of physics in 1941. From 1944 to 1951, he was an associate professor of physics there. He obtained his Ph.D. in mathematics in 1949 by submitting a thesis which appeared in the *Annals of Mathematics*, Vol. 50 (1949), pp. 587–665, under the title "Harmonic fields in Riemannian manifolds (generalized potential theory)". This paper caught the attention of H. Weyl, who brought Kodaira, in the fall of 1949, to the Institute for Advanced Study (IAS) in Princeton, New Jersey. This was the start of Kodaira's 18-year residence in the United States.

This paper also impressed others, including me, and I invited Kodaira to lecture on his paper at Princeton University during the academic year 1949–1950. This was the beginning of a collaboration which resulted in twelve papers and our close friendship extending to his recent death.

Donald C. Spencer is a retired professor of mathematics. He resides in Durango, CO.

Editor's Note: *A feature article on aspects of the mathematics of Kunihiko Kodaira will appear in a future issue of the* Notices.

Kodaira's time in Princeton was divided between the IAS and Princeton University until 1961 when he became a visiting professor at Harvard University for the year 1961–1962. In 1962, he resigned his university professorship to accept a professorship at Johns Hopkins University, where he remained until 1965 when he accepted a professorship at Stanford University. His tenure at Stanford ended when he returned to Japan, and to the University of Tokyo in 1967. Since I had accepted a professorship at Stanford University from 1963 to 1968, I had two more years with Kodaira.

Kodaira's wife and two young daughters did not join him in Princeton until 1951, so he rented a room on Bank Street for his first two years in Princeton. When his family arrived, he bought a house where they lived until 1961.

I arrived in Princeton from Stanford University in 1949, at about the same time as Kodaira. At Stanford, I had worked mainly on the deformation of 1-dimensional complex structures, first on variational methods, with A. C. Schaeffer, which were used to characterize the coefficient regions of univalent (schlicht) functions, and resulted in a Colloquium Volume of the American Mathematical Society (Volume 35, 1950). Later, with M. Schiffer, I worked on deformation of the complex structures of Riemann surfaces.

Deformation of complex structures was therefore much on my mind when I arrived in Princeton. Since quadratic differentials are connected to the moduli of Riemann surfaces, I wondered what mathematical objects were connected to moduli in higher complex dimensions. Finally, Frölicher and Nijenhuis showed, in an important paper, that the vanishing of the first cohomology group with values in the sheaf of germs of holomorphic vector fields implies the rigidity, or the nondeformability, of the complex structure on a compact manifold. At about the same time, J.-P. Serre proved a duality theorem which, applied to a Riemann surface, implies that the quadratic differentials are dual to this cohomology. This was the starting point of Kodaira's and my joint work on the deformation of the structures on higher dimensional complex manifolds. Most of the work is described by Kodaira in his monograph *Complex Manifolds and Deformation of Complex Structures*, Springer Verlag, 1986.

Our departure from Princeton in the early 1960s ended the collaboration between Kodaira and myself, although we kept in close contact with each other's work until 1967, and even later, especially on our visits. Kodaira's research after 1961 was centered around the problem of classifying compact analytic surfaces and their structures.

After returning to the University of Tokyo in 1967, Kodaira had an impressive number of excellent students. At Princeton, he had fewer, but one is outstanding, namely W. L. Baily Jr. Since his student days, Baily has been a close friend of the Kodairas, and he wrote the preface to Kodaira's *Collected Works*, Iwanami Shoten Publishers and Princeton University Press, 1975. This preface provides an overview of Kodaira's work up to 1975.

During his three years at Johns Hopkins, Kodaira had two students, A. Kas, and J. Wavrik, and they followed Kodaira to Stanford, receiving their Ph.D.s there. J. Morrow is also one of his Stanford students, and wrote a book *Complex Manifolds* with Kodaira, which apeared in 1971.

In conclusion, I shall list some of Kodaira's awards. In 1954 he received, with J.-P. Serre, the Fields Medal. The President of the Fields Medal Committee was H. Weyl, and its other members were E. Bompiani, F. Bureau, H. Cartan, A. Ostrowski, A. Pleijel, G. Szegö, and E. C. Titchmarsh. Weyl's address, at the International Congress of Mathematicians in Amsterdam, summarizes Kodaira's work up to that time (see *Proc. Int. Congress*, Vol. 1, 1954, pp. 161–174). In 1957, Kodaira received the Japan Academy Prize, and in the same year, the Cultural Medal, the highest level of recognition in Japan for cultural achievement. Since 1965, he has been a member of the Japan Academy, and since 1975, a foreign associate of the National Academy of Sciences, USA. Also, he was an honorary member of the London Mathematical Society. In 1985 he received the Wolf Prize from Israel.

I am very fortunate to have known Kodaira, and to have been able to collaborate with him.

Louis Auslander (1928–1997)

S. S. Chern; Thomas Kailath; Bertram Kostant; Calvin C. Moore, Coordinator; and Anna Tsao

Louis Auslander died on February 25, 1997, from complications following a cerebral hemorrhage. He was sixty-eight. Born July 12, 1928, in Brooklyn, New York, he received his Ph.D. under S. S. Chern at the University of Chicago in 1954. He held faculty positions at Yale University, Indiana University, Purdue University, University of California at Berkeley, and Yeshiva University before joining the faculty at the City University Graduate Center in 1965. Since 1971 he had been Distinguished Professor of Mathematics and Computer Science at CUNY Graduate Center, receiving the President's Medal there in 1989. He was a Guggenheim Fellow in 1971–72 and was a member of the Institute for Advanced Study in Princeton for the years 1955–56, 1956–57, and 1971–72. He was also a frequent consultant at the U.S. Naval Research Laboratory and for IBM, AT&T, and Hughes Laboratories during his career, and for two years, 1989–91, he served as program manager for the Applied and Computational Mathematics Program at DARPA (Defense Advanced Research Projects Agency).

Equally at home in pure and applied mathematics, Lou was an insightful mathematician with wide-ranging interests who made contributions to many different areas. Over the years he worked in Finsler geometry, in the geometry of locally affine and locally Euclidean spaces, in the theory of solvmanifolds and nilmanifolds, on the representation theory of solvable Lie groups, on many aspects of harmonic analysis (both in continuous and discrete situations), on development of new fast algorithms for discrete Fourier transforms, and on the design of signal sets for communications and radar, among other areas. He was the author of over one hundred papers and ten books, and he supervised the dissertations of eighteen doctoral students (see the accompanying box.)

He was an unusually effective advocate for the development of applications of mathematics, and in his two years of government service as a DARPA program manager he was very effective in shaping and enhancing funding for applied mathematics programs. Indeed, he aggressively sought out opportunities for mathematics and mathematicians and in an active manner defined, shaped, and encouraged research areas and connections. His successes at DARPA were driven by his scientific insights, his vision, and his political astuteness (all of which he had in abundance).

Following are reflections by five people who worked closely with Lou at different times in his career.

—Calvin C. Moore, Coordinator

S. S. Chern

I joined the University of Chicago in the summer of 1949, and Louis was one of my first students. An interesting thing happened: Chicago was a large department and offered many mathematical topics of choice, and he chose Finsler geometry. I had just written a paper on the subject and had suggested he write what might be called the first paper on global Finsler geometry [1]. He was a courageous man. His thesis is now of historical significance in Finsler geometry. I recently came into contact with the subject again. I have great difficulty in talking to people about a great landscape; Louis was unique.

Louis was a talented and devoted mathematician. His later works are in the areas of functional

Calvin C. Moore is professor of mathematics at the University of California, Berkeley. His e-mail address is ccmoore@math.berkeley.edu.

S. S. Chern is director emeritus at MSRI, Berkeley, CA.

analysis, and I leave it to others to comment on this. We maintained a continuous social and mathematical contact, and I always enjoyed talking to him. He never lost interest in mathematics, and we were generally in agreement.

Calvin C. Moore

I first met Lou in the fall of 1963 when he came to Berkeley as a visiting professor for the 1963–64 academic year. Lou was by then an established mathematician, and I was a newly appointed and rather junior assistant professor. Lou was full of ideas, and we started to talk. The results of Kirillov describing the dual space of a connected and simply connected nilpotent Lie group had recently burst upon the mathematical scene and were being absorbed. Lou suggested that we work on the case of solvable groups. Lou brought with him a profound knowledge and intuitive feeling for solvable Lie groups from his previous work in differential geometry, especially work on locally affine and locally Euclidean spaces. Lou was just learning unitary representation theory, in which I had some background, so we were well matched, and the collaboration was extremely fruitful and exciting. Lou taught me a lot about doing mathematics and about the process of collaborating with others, which was especially important to me. This was the first joint work that I had undertaken. I am forever in his debt for all the things mathematical and otherwise that I learned from him during this year. We ended up publishing a lengthy jointly authored AMS Memoir [3] on our work. We made good progress on the problem but did not solve it, and it was a few years later that Lou and Bert Kostant made the real breakthrough and obtained a result for solvable Lie groups fully as elegant, complete, and penetrating as the Kirillov result. During his stay in Berkeley Lou also attracted a Berkeley graduate student, Jon Brezin, to work with him. Jon followed Lou to New York the next year, completing his dissertation and making significant contributions to the representation theory of solvable Lie groups. Jon was Lou's first Ph.D. student at City University.

During the 1963–64 year when Lou was in Berkeley, he also introduced me to nilmanifolds and solvmanifolds (these are manifolds of the form G/H where G is a nilpotent or solvable Lie group H a closed subgroup). The most interesting case is when G/H is compact. Lou had written a number of important and path-breaking papers on solvmanifolds and nilmanifolds, including an extension of the Bieberbach theorem on space groups where n-dimensional Euclidean space is replaced by a connected and simply connected nilpotent Lie group. Lou, with Leon Green and Frank Hahn, had done some beautiful work [2] on analyzing when a one parameter subgroup of a solvable group G acts ergodically on the manifold G/H. Insightful conversations with Lou during this year inspired my own subsequent work in this direction over the next several years.

Louis Auslander, 1995.

Although Lou and I did not work together on any research projects after this year in Berkeley, we talked about mathematics and other topics frequently and remained good friends. Lou continued his work on harmonic analysis on solvmanifolds and nilmanifolds with many interesting papers. The focus of his work then shifted to analysis of discrete Fourier transforms, where he developed new fast algorithms of interest in computer science. He applied harmonic analysis to problems in radar (analysis of the radar ambiguity function) and then to general mathematical problems in various aspects of signal processing. Our scientific paths crossed briefly once more just recently in our common interest in the phase reconstruction problem in crystallography, a problem in finite Fourier analysis.

I have many fond memories of working with Lou—his insight and intuition were marvelous, and it was a joy to work with him. I learned a lot about mathematics and how to do mathematics and about many other things. Lou was certainly what I would call "streetwise" (interestingly, a description that I see Tom Kailath uses as well to describe Lou), and I recall his recounting stories from his youth about outsmarting other kids and cleverly avoiding getting into fights, especially with kids bigger than he was. I am forever very much in his debt and will miss him.

Bertram Kostant

I met Lou Auslander for the first time when we were graduate students at Chicago in the early 1950s. It was an exciting time and place for mathematics. If I remember correctly, Lou's primary interest at that time was differential geometry. He, like so many others (including me), was highly influenced by Chern. After Chicago I remember a productive conversation with Lou in the 1950s on holonomy groups. The conversation certainly influenced a paper I was writing on that subject. However, the main interaction I had with Lou Auslander began after a lecture he gave, I believe, at MIT in the mid-1960s. After a long, heated discussion we both came away with a common exciting agenda: find the unitary dual of a type 1 simply connected solvable Lie group. The background for such an enterprise is as follows. Lou had written an important paper with Cal Moore on unitary representations of solvable Lie groups. As a consequence he was heavily armed with Mackey theory [8]. From Mackey to Moore to Auslander. On the other hand, I had seen a couple of years earlier that what the work of Kirillov, Borel-Weil, Harish-Chandra, and Gelfand had in common was a quantization of a symplectic structure on coadjoint orbits. Among other things I introduced the concept of polarization of a symplectic manifold. This term with this meaning, now well known, appeared for the first time in my subsequent joint paper with Lou. A very strong motivation for me in my collaboration with Lou was to show that what is now called geometric quantization could break new ground in representation theory. Besides Lou's earlier paper with Moore, there were preceding us other steps beyond Kirillov's nilpotent result. Bernat found the unitary dual of any exponential solvable Lie group. In the general case we faced coadjoint orbits which were no longer necessarily simply connected (more than one quantum line bundle per orbit). Worse, there could be no invariant real polarizations. Still worse was the problem of how to characterize type 1-ness. R. F. Streater visited MIT in the mid-1960s and complained to me that the 4-dimensional solvable Lie group he was studying (the oscillator group) had no invariant real polarizations, so how was he to find its unitary dual? I suggested using an invariant positive complex polarization. It worked. This was an encouragement for us.

Ph.D. Students of Louis Auslander

Clifford Perry (1965)
John Scheuneman (1966)
Jonathan Brezin (1967)
Robert Johnson (1969)
Richard Tolimieri (1969)
Carol Heinz-Jacobowitz (1972)
Harvey Braverman (1973)
Evelyn Mayer Roman (1973)
Sharon Goodman (1978)
Ephraim Feig (1980)
Bharti Temkin (1983)
Michael Vulis (1983)
Myoung Shenefelt (1986)
James Seguel (1987)
Michael Cook (1989)
Frank Bernard Geshwind (1993)
Jeffrey Litwin (1995)
Irina Gladkova (1998)

My collaboration with Lou was fun. Each week alternately either I would go to CUNY or he would come to MIT. It was also mutually educational. He taught me Mackey theory, and I taught him the ins and outs of geometric quantization. Together we were able to translate successfully the relevant aspects of the Mackey machine to the language of symplectic geometry. The final result was nicer than we had hoped for. Not only was the unitary dual neatly determined, but the condition for type 1-ness turned out to be expressible geometrically in an elegant way. The paper [4] was published in *Inventiones* in 1971. It is not the best-written paper. A much nicer version, which gets to the heart of the matter in a clearer way than we had seen it, appears in a Bourbaki seminar (1973–74) by Michèle Vergne [9].

I have fond memories of Lou. He brought to the table excitement, brilliance, and marvelous insights. After our paper was written Lou liked to tease me by telling a story in gatherings about our lunch times together. When I visited New York, he would take me out for an elaborate meal. When he came to Boston, I would take him to the sandwich machines in the basement of MIT. (I had no idea at the time how painful this was to him.)

My collaboration with Lou Auslander was one of the best collaborative experiences I have ever had. I am very grateful to him.

Bertram Kostant is professor emeritus at the Massachusetts Institute of Technology. His e-mail address is kostant@math.mit.edu.

Anna Tsao

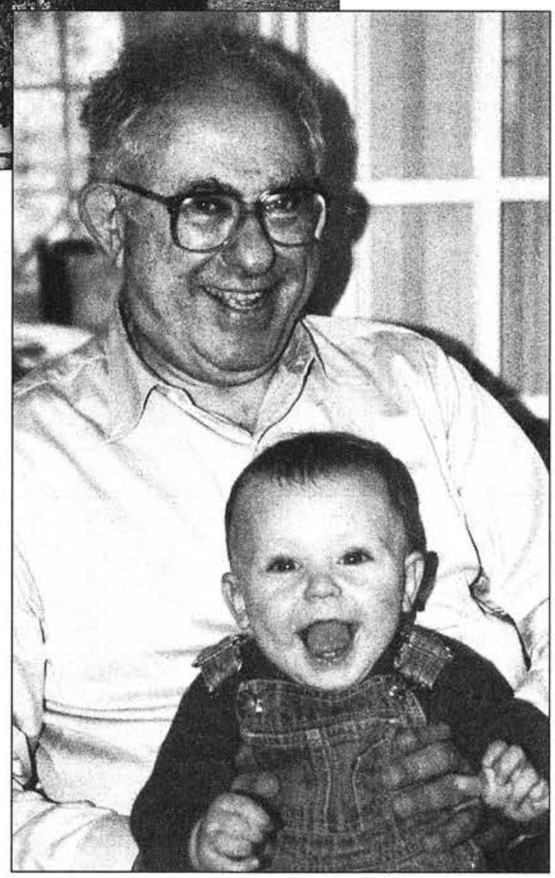
I met Lou Auslander while a member of the technical staff at AT&T Bell Laboratories in 1987. It was a pivotal moment in my life, as Lou became a mentor, colleague, and above all a close friend who had a major impact on both my professional and personal development. At Bell Labs I was assigned the task of designing a parallel algorithm for adaptive beamforming. A critical part of the processing was solving a symmetric eigenvalue problem. Lou had some intriguing ideas about computing eigenvalues of large dense matrices by thinking of the so-

Anna Tsao is program manager, Applied and Computational Mathematics Program DARPA/Defense Sciences Office. Her e-mail address is atsao@darpa.mil.

lution as a direct sum decomposition of certain commutative algebras. Since I was trained as a pure complex analyst, I was apprehensive about plunging headlong into areas in which I had a less-than-comprehensive background. Lou would exhort me not to be concerned because (paraphrased) "Mathematics is like a river. You just jump in some place, and the current will help take you where you need to go." Our subsequent collaboration [6] on eigenproblems after I joined the Supercomputing Research Center led to considerable activity in numerical linear algebra.

Shortly thereafter Lou decided to join DARPA as the program manager for the Applied and Computational Mathematics Program. To Lou the significant personal sacrifice of putting his research aside for two years was more than offset by the opportunity to make a difference to both the Department of Defense mission and to mathematics in general. And make a difference he did, in profound ways. Several programs that Lou started led to spectacular mathematical and scientific achievements that are receiving wide attention in the scientific and Department of Defense communities. Two examples are wavelets and the Fast Multipole Method for solving the Helmholtz equation. The impact on important DoD problems resulting from the significant funding in these areas by Lou and his DARPA successors has been highlighted in briefings to members of Congress and the Pentagon numerous times, including detailed briefings to officials such as the then Secretary of Defense William Perry.

Lou's success at DARPA was a direct result of his ability to inspire others with his vision of mathematics as a cohesive, integrated, and powerful discipline that can open exciting new vistas to be conquered when combined with science and engineering. He was considered to be a singularly effective mathematician and program manager at DARPA who actively sought out and created new mathematical opportunities. His quick intellect and congenial manner enabled him to engage a wide range of program managers from competing offices and disciplines in meaningful discussions of their technical programs which led to joint formulation of the underlying mathematical challenges. His success in this is legend at DARPA and required great energy, objectivity, creativity, and knowledge of the breadth of mathematics. Often after first learning an entirely new field, he would then identify the appropriate mathematical expertise needed to meet these challenges and seek out experts in those areas to team with the application scientists. On other occasions he would draw on his considerable scientific insights and abilities to identify application areas to which current areas of mathematical activity could make an impact. Lou's tireless, personal dedication to demonstrating the power of mathematics in science



Auslander with granddaughters Michelle and Danielle, top photo, and grandson Taran, bottom.

and engineering not only resulted in substantial funding of mathematical research at DARPA but influenced other program managers to incorporate more mathematical directions into their own programs. Lou's extended vision of the role of a mathematics program manager lives on as a guiding principle of DARPA's Applied and Computational Mathematics Program and is one which I, as a current DARPA program manager, try to emulate.

Lou's research interests and collaborations in recent years were extremely diverse. Lou's outlook is exemplified by the fresh, original approaches that characterized his research, in collaboration with several others, on the Fourier transforms. Lou was convinced of the significant role that core mathematics should play in the design of computational algorithms. To elaborate, he once stated that the almost endless capability that mathematics provides to reformulate problems and solutions should be exploited in seeking new algorithms. He observed that mathematicians are often surprised that mathematically equivalent formulations can have radically differing computational properties. This duality of pure math and computational applications is beautifully presented in Lou's AMS *Bulletin* article [5] with R. Tolimieri on the Fourier transform, which additionally enticed many young mathematicians into harmonic analysis. He was involved in a long-term effort to investigate how the algebraic structure of Fast Fourier Transform (FFT) algorithms could be exploited to automatically implement optimized FFT algorithms. The mathematical culmination of Lou's interest in this subject was a group representation theoretic result obtained jointly with J. R. Johnson and R. W. Johnson shortly before Lou's death, in which "all" possible additive FFT algorithms are characterized mathematically [7]. Although the full implications of this result will take some time to realize, it has already led to multidimensional FFTs that have significantly improved computational properties.

Lou left a rich legacy of professional contributions to mathematics. In addition, he gave those of us who had the opportunity to know him as a friend and colleague may wonderful memories of his warmth, generosity, and wisdom.

Thomas Kailath

Coordinator's Note: This segment is a lightly edited version of an electronic message sent by Thomas Kailath to "Friends in the Stanford Manufacturing Group" shortly after Lou Auslander's death.

Not all of you may have heard that Lou Auslander passed away last week. This sad news, which I received while traveling, was especially poignant because Lou was going to be visiting the Bay Area later this month.

Lou, as some of you know from direct experience, was a very unusual man. He won a fine reputation in several different fields of mathematics before turning in the last dozen years or so to the study of multidimensional Fourier transforms and to the design of signal sets for communications and radar. These areas bring difficult mathematical challenges, but they also got Lou very interested in applications. There are mathematicians who have difficulty coping with the informal way in which engineers often handle mathematical discussions, but not Lou. I remember first meeting him at some signal processing workshop in the mid-1980s. He seemed to enjoy the meeting and had discussions with a variety of people. Lou was then a consultant for the mathematics department of IBM Research, whose director, Shmuel Winograd, had charged me with putting together a summer program on the Mathematics of Signal Processing for the Institute for Mathematics and its Applications in Minneapolis. Seeing Lou in action led me to invite him to be on the organizing committee, of which he soon became a dominant member, expressing himself quite freely and caustically, which will not surprise many of you. However, Lou had many good ideas, several of which we adopted.

A couple of years later he landed himself at DARPA as program manager for Mathematics. [How this came about is a story in itself — briefly (and perhaps not completely accurately), a few years earlier Lou had taken it upon himself to complain directly to the director of DARPA that the value of mathematics was not adequately recognized by DARPA. His complaint worked, but the program that was launched was floundering after a while, so the director apparently insisted that Lou come and fix the problems.] However, by the time Lou arrived at DARPA, there was no money left in the Mathematics budget; moreover the program had found itself in the Materials (later Defense) Science Division. Undaunted, Lou began to adapt to this new environment. Exposure to various discussions and seminars convinced him that though there was a lot of interest in the manufacture of various new types of materials, the tools of control, optimization, signal processing, and simulation were not much used by the materials scientists working on these problems. Lou called me up to discuss the issues and then to suggest that we take a look at filling this gap. While I agreed that our tools could help, as a theoretical engineer who had never worked with real equipment, I was reluctant to get involved. "I only write papers," I said, "while here it looks as if you really want something done." However, Lou persisted, with the promise (possible only by DARPA managers, or perhaps usually only dared to be made by them) of freedom to explore whatever we found to be best, backed up by reasonably generous funding. He added that it was OK if we failed. Put that way, it was an offer we couldn't refuse.

As you know, thanks to our environment of great students and cooperative colleagues, we were able to rise to Lou's challenge and to vindicate his vision of the importance of control and signal processing in manufacturing. Lou was as pleased as we were when one of our efforts won the 1994 Outstanding Paper Prize of the *IEEE Transactions on Semiconductor Manufacturing*, a journal we had hardly been aware of a few years ago. Lou's successor at DARPA, Jim Crowley, built on Lou's initiative by winning approval for a much larger MURI (Multidisciplinary University Research Initiative) program in modeling, simulation, and control of materials manufacturing processes, now under way with six university teams. Some technology

Thomas Kailath is Hitachi America Professor of Engineering at Stanford University. His e-mail address is kailath@ee.stanford.edu.

transfer has already taken place, and I have no doubt that even in the relatively conservative semiconductor manufacturing industry we shall see increasing use of these tools.

However, theory in manufacturing was only one of Lou's initiatives at DARPA. Other major ones were on wavelets (with both classified and unclassified applications), advanced radars (one of his personal research areas), matrix-oriented computing architectures, and several others far beyond my ken.

Our project, and the related ones in industry, gave me the pleasure of many discussions with Lou. He was always available as a source of advice on a variety of issues, including some very prickly ones. He attributed a lot of his attitudes and personality to his grandmother and mother, early immigrants from Eastern Europe whose intelligence, determination, and common sense made them successful despite their lack of formal education. In fact, one of Lou's epitaphs might well be "He was a 'streetwise' mathematician". But that is only one of them. He was too rich a personality, and his range of contributions is too wide to be captured in a single phrase.

We shall really miss him, a thought that might bring a chuckle to his spirit, wherever and whatever it is now—perhaps, in Shelley's words, "an unbodied joy whose race is just begun."

References

[1] L. Auslander, *On curvature in Finsler geometry*, Trans. Amer. Math. Soc. **79** (1955), 378–388.

[2] L. Auslander, L. Green, and F. Hahn, *Flows on homogeneous spaces*, Ann. Math. Stud., No. 53, Princeton Univ. Press, Princeton, NJ, 1963.

[3] L. Auslander and C. C. Moore, *Unitary representations of solvable Lie groups*, Mem. Amer. Math. Soc., No. 62, 1966.

[4] L. Auslander and B. Kostant, *Polarization and unitary representations of solvable Lie groups*, Invent. Math. **14** (1971), 255–354.

[5] L. Auslander and R. Tolimieri, *Is computing with the finite Fourier transform pure or applied mathematics?*, Bull. Amer. Math. Soc. (N.S.) **1** (1979), 847–897. MR 81c:42020.

[6] L. Auslander and A. Tsao, *On parallelizable eigensolvers*, Adv. Appl. Math. **13** (1992), 253–261. MR: 93-F:65098.

[7] L. Auslander, J. R. Johnson, and R. W. Johnson, *Multidimensional Cooley-Tukey algorithms revisited*, Adv. Appl. Math. **17** (1996), 477–519. MR 97k:65301.

[8] G. W. Mackey, *The theory of unitary group representations.* [Based on notes by James M. G. Fell and David B. Lowdenslager of lectures given at the University of Chicago, 1955.] Chicago Lectures in Math., Univ. of Chicago Press, Chicago, 1976.

[9] M. Vergne, *Représentations unitaires des groupes de Lie résolubles*, Séminaire Bourbaki, Vol. 1973/74, 26ème année, Exp. 447, pp. 205–226.

Book Review

The Pleasures of Counting

Reviewed by Brian E. Blank

The Pleasures of Counting
T. W. Körner
Cambridge University Press
534 Pages
Hardcover (1996) $85.00
Paperback (1997) $34.95

For more than two thousand years some familiarity with mathematics has been regarded as an indispensable part of the intellectual equipment of every cultured person. Today the traditional place of mathematics in education is in grave danger. Unfortunately, professional representatives of mathematics share in the responsibility. The teaching of mathematics has sometimes degenerated into empty drill in problem solving. Applications and connections with other fields have been neglected. Teachers, students, and the educated public demand constructive reform. The goal is genuine comprehension of mathematics as a basis for scientific thinking and acting.

The reader has no doubt heard words to this effect many times in the last decade. These ideas, however, were not spawned by the current debate over the college mathematics curriculum. In fact, the first paragraph is a lightly edited extract from the preface of *What Is Mathematics?* [1], written by Richard Courant and Herbert Robbins in 1941. In writing their text, Courant and Robbins sought to acquaint their readers with the "content of living mathematics." Although they cautioned against "the dangerous tendency toward dodging all exertion," they considered their book to be popular in that it required only "a good high school course" by way of background.

And it was a popular book. I remain very fond of it for reasons that are personal as well as objective. As a high school student I had access to numerous algebra and trigonometry books that those of a certain age and British Commonwealth lineage would associate with the style of *Hall and Knight*—unremitting drill, for those who have not shared the experience. But *What Is Mathematics?* was the only book in my high school library that suggested the *depth* of mathematics. Here was a book, after all, that discussed the Prime Number Theorem in the first chapter. I suspect that I am not the only one who learned from Courant and Robbins that the trees actually make up an interesting forest.

For better and for worse, times do change. Certainly the direction of mathematics is constantly shifting as new fields find favor while others fall by the wayside. One might expect Courant and Robbins to choose their topics differently were they writing their book today. Linkages and Mascheroni compass constructions might be dispensed with, continued fractions and projective geometry curtailed. But an even more fundamental dynamic would necessitate another approach: a good high school course is not what it used to be. Reading the precise definition of continuity and then using it to prove the Intermediate and Extreme Value Theorems requires an intellectual discipline that is no longer within the proximate reach of the high school graduate. It is very difficult nowadays to imagine sending a good college freshman to Courant and Robbins to find out what

Brian E. Blank is associate professor of mathematics at Washington University in St. Louis. His e-mail address is `brian@math.wustl.edu`.

mathematics is about. Nor have many alternatives been written: one can envision the difficulties.

In the preface of his new book, *The Pleasures of Counting,* T. W. Körner writes "This book is meant, first of all, for able school children of 14 and over and first year undergraduates who are interested in mathematics and would like to learn something of what it looks like at a higher level....the aim is so worthwhile and the number of such books so limited that I feel no hesitation in adding one more." There will be little hesitation among the readership of the *Notices* in welcoming a book that achieves the stated aim as engagingly as *The Pleasures of Counting* does. There remains little for the reviewer to do but to convey some of the topics that Körner has selected.

The first part of *The Pleasures of Counting* is concerned with the use of abstraction. Several historical problems have been selected as subjects of mathematical analysis by way of example. When, for instance, repeated epidemics of cholera ravaged Europe in the mid-nineteenth century, both the practice of medicine and the practice of statistics were in their infancy. Various theories were advanced to explain the spread of the disease, but medical science was not then able to validate any hypothesis. In 1849 Dr. John Snow proposed that the agent of the deadly illness was spread through contaminated drinking water. What distinguished Snow's conjecture from the others was not so much that it was the correct one, but that he undertook the collection of data to support it.

Conditioned as we now are to this simple act of counting, we will only with difficulty appreciate the underlying abstraction. Consider that statistical argument is only about two hundred years old, even though it might have originated at any time in the history of modern man. In the face of real monetary expenditure, Snow's argument must have seemed very abstract indeed. Incontrovertible statistical evidence was not enough, immediately, to justify the expense of water treatment. Response was predictably slow. When a virulent outbreak of cholera struck London in 1866, Snow was again able to trace the source to tainted water despite the denials of water company officials. Tightwads in Hamburg were even slower to react. That city was the site of the last major European cholera epidemic over a century ago.

This compelling case study gets Körner's book off to a fine start. Unfortunately it does little to illustrate the statistician's practice. So overwhelming are Snow's data that the need for statistical inference does not really arise. The next of Körner's case studies concerns the efficacy of aspirin, streptokinase, and the genetically engineered drug tPA as agents for the treatment of blood clots. It offers a greater opportunity to clarify the role of the statistician. One therefore regrets that the misconception of the statistician as a collector (as opposed to an analyzer) of data is not dispelled. That is my only criticism of the section. The more advanced reader might have already found in Körner's *Fourier Analysis* [3] an extended statistical exposure of Sir Cyril Burt's fraudulent IQ data. The reader who is disappointed with the much shallower discussion of statistics in the work under review should remember Körner's targeted audience. To his credit, Körner resists the temptation to dazzle. His goal is to coax the interested freshman into a deeper study of mathematics. Some restraint is properly brought to the task.

If this review is to serve as any kind of guide, then I am obliged to acknowledge that Körner had an ulterior motive when he chose to analyze thrombolytic agents. There are villains in his story—the profit motive of the drug company producing the expensive drug tPA and the biased coverage of the financial press. Here, as in many other parts of his book, Körner has an opinion. It is not his style to serve up a dispassionate analysis. Although his point of view often comes across unmistakably, it is not expressed in a heavy-handed fashion (excepting, perhaps, in his insistent use of "she" as the default third-person pronoun). Nonetheless, it is undeniable that the statement of an opinion is sure to provoke hostility among some readers. I can only counsel those who know themselves to be intolerant of opinion to seek out blander writing elsewhere.

The application of statistics to medicine behind him, Körner turns his attention to the uses of calculus in war. Consider, for example, the policy of convoying cargo ships as a defensive measure against submarine warfare. There are some obvious advantages to the strategy, but there are also several strong counterarguments: one has only to picture a large group of targets moving en masse no faster than its slowest component.

How does one decide if convoying is beneficial? The statistician, no doubt, would be able to devise some controlled experiments. The Admiralty, on the other hand, wanted an answer before all the data came in. The analysis of the convoy problem provides a wonderful introduction to mathematical modeling. It is at this early point in his book that Körner might begin to lose that fourteen-year-old mentioned in his preface. After a general discussion of considerable interest, the payoff, in the form of a differential equation, is shunted into an exercise. Körner plainly does not want his reader to dodge all exertion. The advantage of his approach is that he does not have to bring the level of his book down to that of the least-prepared reader. Instead, he uses his preface to caution the budding mathematician to expect some difficulties ahead. Were professional mathematicians to understand everything in a mathematics book, he explains, they would suspect that the material was too easy to be worthwhile. This is an important pedagogical point. If it were more forcefully made as part of the orientation of entering university students, then the responsibilities of mathematicians as educators would not be so misunderstood.

The second section of *The Pleasures of Counting* is called "Meditations on Measurements". The name is appropriate, both for its reference to the central theme of measurement and for the indication that more than hard science will be involved. Measurements, it must be admitted, often contradict fine theories. Biologists have long recognized that metabolic rate does not behave the way that it should. Specifically, as mammalian surface area and volume grow according to second and third power laws respectively, the relation between metabolic rate R and mass M should take the form $R \propto M^{2/3}$. How embarrassing, then, that a plot of $\log(R)$ as a function of $\log(M)$, the famous "mouse to elephant plot", yields a line of slope $3/4$. The $3/4$-power law remains a mystery. Although Körner convincingly argues that a $2/3$-power law might be too simple-minded, I do not see anywhere in his explanation why the no less simple-minded $3/4$-power law seems to be so effective a model. Moreover, when the author steps out from his role as mathematician, his expertise may be questioned. In discussing variation in design, Körner asserts that "there are no small mammals in arctic regions." One looks to the marmot, the tundra vole, and the lemming for counterexamples. Even the arctic fox is small, presumably as an adaptation to its environment. But never mind. The scaling arguments that Körner passes on are generally convincing. One learns, for example, why whales are so large, why squirrels climb with so little effort.

It is not a very great leap from scaling in biology to dimensional analysis in the physical sciences, and Körner does not disappoint. The power of dimensional analysis cannot fail to impress the student who encounters the method for the first time. Unfortunately, it is a method that is egregiously absent from standard courses in mathematics and physics. At the heart of the matter is the rarely explicated Buckingham π Theorem. Although a good treatment may be found in the excellent text of Logan [4], Körner's primary reference, few students will find their way to it there. Körner is therefore to be applauded for including a lengthy discussion that is supported by several examples. As is typical in this book, the examples have been chosen both for their importance and for their entertainment value. In one application after another, through dimensional arguments alone, we learn why helicopter blades are long, why fatty deposits on coronary arteries eventually become dangerous, and why the nationality of tanker crews influence the design of tanker engines.

The discussion of dimensional analysis is a handy gateway to an issue that the reviewer ought to at least feebly bring up. There are rather a lot of minor errors in the review copy. The dimensional analysis of the simple pendulum, for example, is marred by incorrect formulae. In fact, the thinking student will be able to use dimensional analysis to deduce that the formulae presented must be wrong. These errors, and an impressive list of others, are corrected on a Web page that Körner maintains. The URL is `www.dpmms.cam.ac.uk/home/emu/twk/.my-book-cor.html`. One supposes that later printings will correct the errors. Until then I suspect that very few readers will be seriously inconvenienced by these minor mistakes. Indeed, the list of errors speaks to the attentiveness of the book's readership.

Körner concludes his meditations on measurement with an extended account (two chapters totalling 68 pages) of the life and work of Lewis Fry Richardson, 1881–1953. This is one of the best parts of the book, amply justifying the lavish treatment of its subject. As a student Richardson studied mathematics, physics, chemistry, botany, and zoology. His eclectic student interests would be a harbinger of his diverse scientific output. In early positions Richardson was employed as both a chemist and a physicist. In 1912 he patented an early sonar device. The next year Richardson joined the Meteorological Office. There he became a pioneer in using mathematics to predict the weather, publishing *Weather Prediction by Numerical Process* in 1922. He later made important contributions to the study of atmospheric turbulence. The "Richardson number", a fundamental meteorological constant, is named after him. Richardson also applied mathematics to study the causes of war, publishing the *Statistics of Deadly Quarrels* in 1950. *The Pleasures of Counting* contains an introduction to all that I have described and more. Körner has done a great service in bringing the mathematical work of this exceptional scientist to wider notice.

The third part of *The Pleasures of Counting* is concerned with "The Pleasures of Computation". It is more conventional. The contents include the Euclidean algorithm, the Fibonacci numbers, Turing's Theorem, and an excellent discussion of the sorting problem (the Knock-Out Method, specifically). But there are less familiar things as well. The "Railroad Problem" or "Max-Flow Problem" asks how to get the maximum number of trains between two points on a network. The Ford-Fulkerson algorithm that solves the problem is given in detail. Nonspecialists who have not kept up with their graph theory might learn for the first time the relatively recent Braess Paradox: adding links in a congested network can be counterproductive.

The chapter that concludes with Turing's Theorem is called "Deeper Matters" and begins with the section "How safe?". It deserves special attention. Körner recounts the cautionary tale of the London Ambulance Service's computerized dispatch system. Designed to have ambulances reach 95%

of emergencies within fifteen minutes, the system did not reach the 20% mark on its first day of operation and only got worse thereafter. The situation improved after management switched to a semicomputerized system, but that soon crashed: errant code left over from a previous patch caused a memory leak of fatal proportions. The £1.5 million system had to be abandoned.

I have used the term "cautionary", as did Körner, but of course the tale of the London Ambulance Service is no such thing. If it were cautionary, we would not have had the Denver International Airport baggage fiasco only a few years later. As you might recall, a \$200,000,000 computerized baggage-handling system was designed using 300 computers to guide 4,000 cars around 21 miles of track. In theory it was a marvel. In practice it not only destroyed the baggage it carried but also its own telecars and even its own tracks. As for errant code left over from an earlier software overhaul, we have a recent ghastly example. In August 1997 the veteran pilot of Korean Air Flight 801, in full control of his aircraft, flew into a hillside in Guam. Two hundred and twenty-six on board were killed. As of this writing no official cause of the accident has been released. But we do know of one reason why the crash was not prevented. The Radar Minimum Safe Altitude Warning system was intended to work when the distance r of the aircraft from Guam International Airport was less than or equal to 55 miles. Due to a software error it actually worked only for $54 \leq r \leq 55$.

Not every software problem is the programmer's fault. The Venus probe, Mariner 1, had to be destroyed a few minutes after launch. Mathematicians had designed its tracking system to employ readings of Mariner's *average* velocity $\overline{v}$. Someone along the chain of transmission left out the bar over the v. The programmer then coded v according to instructions. The use of actual velocity instead of smoothed velocity set in motion a series of "corrections" that resulted in a classic negative feedback loop. That feedback loop, and nothing else, caused the erratic path and eventual destruction of the rocket and probe.

The software problem is one of human fallibility, and Körner can give no solution. What he has to say, though, is worth reading. Since the one real exercise in the section, Exercise 12.1.1, is weak, let me add my own. A program is written to control a system of high-speed elevators in a skyscraper. Included in the system are sensors that detect the number of persons in each elevator and the number of persons that await the elevator at each of its potential stops. To improve efficiency, the elevator is instructed to bypass any floor with more persons waiting than the elevator can accommodate. The next available elevator with adequate capacity is sent instead. Such a system was designed and coded by a leading engineering company. The fatal operational flaw of the system was discovered only in simulation (but at least before the system was put into service). Exercise: (i) What was that flaw? (ii) Redesign the system to fix the problem. (iii) Identify all the new errors that you have introduced in doing so. Fix those and repeat the cycle.

Part IV of *The Pleasures of Counting* is titled "Enigma Variations" and is concerned with cryptography. The title stems not from music but from the German enciphering-deciphering machine used during World War II. By now you will have noticed that Körner's tastes are very wide-ranging—I must confess, more so than my own. I found the material on ciphers old-fashioned and somewhat tedious; the modern RSA algorithm, discussed at some length in [3], is consigned to an exercise here. At least the historical path Körner takes passes through some combinatorial probability theory. (I think it possible that the average mathematician, on seeing the word "counting" in the title, might have expected to find more discrete mathematics in the book.) Part IV gains momentum with the introduction of Shannon's Theorem and concludes well with a long exercise on Hamming error-correcting codes. If this material whets the appetite of the student, then it has done its job; Körner appropriately refers the interested reader to the books of Koblitz [2] and Thompson [6] for more thorough discussions.

The last part of *The Pleasures of Counting* is called "Pleasures of Thought". It is not especially apparent why this section (and not any one of the preceding four) is so named, perhaps because it contains the least amount of mathematics and concludes with a philosophical discussion patterned after Plato's dialogues. Here is a quick summary of the mathematical content. The disappearance of surnames—that is, the dying out of the male line—is the point of departure for a brief excursion that will prepare the student for a later course on Markov chains. It is followed by the logistic differential equation and another, more sophisticated model for the spread of disease. As the last mathematical topic this neatly brings us full circle to modern versions of the cholera epidemic. Quite a lot is left to the exercises in all of this.

There is not enough space in a review such as this even to hint at all the topics that *The Pleasures of Counting* touches. But there are also pleasures to be found that are not mathematical. This is a very entertaining, well-written book that is filled with good humor. Do not miss the note on the national traits of technological disasters; it follows in the best tradition of Flanders and Swann's *A Song of Patriotic Prejudice*. The professional mathematician will appreciate the frequent anecdotes, often found in the side notes. (Do you know why the so-called Professor So-Called Adams was so-called?)

When it comes to criticism, every savvy author is wise to make use of the natural head start he or she is afforded, anticipating possible criticism and deflecting it before the critic comes to the plate. To this end Körner quotes Montaigne: "Some may assert that I have merely gathered here a big bunch of other men's flowers, having furnished nothing of my own but the string to hold them together." Trumped from the outset in my role as critic, I have little to add but the observation that very few readers will have encountered all of these flowers on their own. We may be grateful to Körner for bringing them to our notice. We might not have picked all the same flowers, but surely the author is allowed his choice. It is true that other gardens might have been visited, but the bouquet is already full. Is there nothing else to criticize? Flitting about, from one topic to the next, one does get the impression that some discussions are too superficial. This complaint, however, is not too serious. *The Pleasures of Counting* serves as a mathematical anthology accompanied by a bibliography of 259 items. Detailed notes allow the interested reader ample opportunity for follow-up. Although the bibliography is a valuable resource, from time to time one feels that the references might be better judged. Körner, for example, is very fond of Knuth's *The Art of Computer Programming.* It is far and away the best reference for the experienced mathematician. We might do better, however, to send our students to the book written by Knuth's student (*Algorithms*, by Robert Sedgewick [5]).

It is up to the author to state for whom he is writing his book, and I have already let Körner have his say. As the reviewer I have the less humble task of stating who I think should read the book. I will get to that after allowing Körner one last word. Writing of books that *he* recommends, Körner states "Any book that you can learn from is a good book." By that criterion I feel sure that *The Pleasures of Counting* will be deemed a good book by nearly everyone who picks it up. Although I would not be so presumptuous as to state that all mathematicians should read it, I can at least recommend it to them unreservedly. I especially think that mathematicians with limited applied mathematics experience would benefit from its study. I count myself in that group. On those few occasions in which I have had a little involvement in an application of mathematics, I went blundering in with the misconceptions of a pure mathematician. One example will be enough to illustrate.

Any collision avoidance system might generate two kinds of error. These are usually called type I and type II errors in statistics texts, but let us refer to them by the more suggestive names of false positives and false negatives. A standard strategy in statistics is to consider only decision-making procedures that ensure one (specified) type of error is held to an acceptably low level. From within that class the statistician tries to find a procedure that best controls the remaining type of error. Given the catastrophic consequences of a false negative in an aircraft's collision avoidance system, the mathematician will naturally insist that the radar system be designed so as to have an infinitesimal chance of a false negative. But hold on! The system just described will generate a large number of false positives. The mathematician answers, "True, but so what? They are harmless." Not so: the mathematician is not the one flying the plane. Military aviation experience (and even some tragic commercial experience) reveals that pilots simply turn off devices that produce too many false alarms. (The radar failure in Guam that I mentioned earlier was apparently introduced in an effort to reduce the number of false alarms.) A particular strength of Körner's book is that it reveals not only the rich vein of problems encountered in applied mathematics but also a human side of mathematics that is often absent from pure research.

I find myself at the end of my review, and I have not yet addressed Körner's targeted readership. That must be *your* assignment, for that readership will not see this review. If you anticipate being in the position of influencing a talented student considering mathematics as a career, then I urge you to read this book so that you can refer it to the student with authority. Make sure to recommend it to your local high school library. If they are slow to purchase it, then donate a copy. The mathematics shelves at bookstores are brimming with books titled *Fractal This* and *Chaos That.* Körner has given us a popular text that lacks a glitzy title but which is rich in substance. Let us do our best to make sure that it is read. I was not alive when Courant and Robbins wrote the words with which I opened this review, but I cannot believe that they were truer then than now. There has been a pressing need for a lively, accessible book that will answer the modern student who asks, "What is mathematics?" *The Pleasures of Counting* fits that bill.

References

[1] Richard Courant and Herbert Robbins, *What is mathematics?*, Oxford University Press, 1941.

[2] N. Koblitz, *A course in number theory and cryptography*, Springer-Verlag, Berlin and New York, 1987.

[3] T. W. Körner, *Fourier analysis*, Cambridge University Press, 1988.

[4] J. David Logan, *Applied mathematics*, Second Ed., Wiley, New York, 1997.

[5] Robert Sedgewick, *Algorithms*, Addison-Wesley, Reading, MA, 1988.

[6] T. M. Thompson, *From error correcting codes through sphere packings to simple groups*, Math. Assoc. Amer., Washington, DC, 1983.

Life after Academia: How a Mathematician Found a New Career

Dana Mackenzie

Last year I wrote a series of articles for the Young Mathematicians' Network newsletter[1] that recounted how I tried—and failed—to obtain tenure at a small liberal arts college in Ohio. A number of readers have commented on how much they learned from my experience, and many begged for an epilogue: What happens to a mathematician after the tenure door slams shut?

"Whenever a door shuts, a window opens," goes a comforting adage, which I heard more than once during my tenure battle. For me the window has opened into a new career as a freelance mathematics and science writer. I will tell the story in two parts: how I found a life after academia, and how my career in writing was born.

Finding a Direction

When it was clear that I had my teaching job for only one more year, I started reading two or three books about career-search strategies. All of them stressed the importance of taking an "inventory" of my interests and skills in order to come up with a clear objective. However, I have never been very good at following advice, and most of the inventory techniques struck me as too gimmicky to be worth the trouble. It was more seductive to peruse the thousands of job listings on the World Wide Web, to post my résumé to the various online job services, and dream about finding the perfect job without even leaving home.

In fact, my online résumé did attract one job "nibble", which seemed like a sure thing in December, but then mysteriously slipped off the hook in February. By then over half a year had passed since I began my job search, and I still hadn't finished step one—figuring out what I really wanted to do.

It was time to gear up my job search in earnest, and I decided to try a different tack. Because somewhere around 95 percent of the jobs posted on the Internet are for computer experts, I figured that there would be jobs for the taking if I just added a master's degree in computer science to my mathematics Ph.D. I had already missed some deadlines, but still had time to apply to three universities in the southeast. I also managed to dig up my seventeen-year-old GRE scores, breathing a sigh of relief that the Educational Testing Service had kept them that long!

Meanwhile I kept my eyes open for other opportunities. In mid-March the Internet redeemed itself for leading me astray earlier. One day, on the Web site of the American Association for the Advancement of Science, I saw a link to "New Niches", a guide to nontraditional careers in science.[2] I clicked on the first of the "new niches", science writing, and found profiles of four graduate programs: Johns Hopkins, Boston University, New York University, and the University of California at Santa Cruz. True to form, I had already missed the deadline to apply to three of them. But the UCSC deadline was May 1—there was still hope.

Reading the Web page of the UCSC Science Communication Program[3] was my "Eureka" moment. For years I had toyed with the idea of writing about mathematics. I had even contacted several popular writers of mathematics, including my idol Martin Gardner, to ask how they had gotten started. But the advice of the writers always seemed to boil down to this: Just start writing. While I was still

Dana Mackenzie is a freelance science writer who resides in Santa Cruz, CA. His e-mail address is `mackenzi@cruzio.com`.

[1]*See* `http://www.math.usouthal.edu/~brick/ymn/archive.html`, *issues 4.29–4.32.*

[2]*For anyone contemplating a nonacademic career I recommend going to this Web site right now. Start at* `http://nextwave.org/` *and follow the links.*

[3]*See* `http://natsci.ucsc.edu/acad/scicom/SciWriting.html`.

on the tenure track, I had never mustered up enough gumption to do it. Now, it seemed, there was another way. You could learn how to write about science in the security of an academic classroom.

The moment of truth came in late April, when acceptances started coming in from the computer science grad schools. (Yes, thanks to those prehistoric GRE scores, all three of them accepted me.) Should I go for the M.S. in computer science and the likely prospect of an $80,000 job in a couple of years? Or should I take a chance on the uncertainty of a career in science writing and earn $25,000 if I was lucky? One of my e-mail correspondents wrote, "Think of what you wanted to do when you were a child, and try to make that happen." That was easy. When I was a child, long before I ever knew there was such a thing as a mathematician or a computer scientist, I had wanted to be a writer. Fortunately my wife was willing to let me choose satisfaction over dollars, and she was excited about moving back to California. When John Wilkes, the director of the UCSC program, offered me the tenth and last slot in the class of 1997, my direction became clear. It was time to give the childhood dream a chance to come true.

Becoming a Writer

The Science Communication Program at UCSC lasts one year and leads to a certificate, not a degree—appropriately, in my opinion, because the practical experience one gains in the program outweighs any diploma. The academic part of the program is organized by genre: news writing in the fall, feature writing (the in-depth articles one typically sees in magazines) in the winter, and essay writing in the spring. All students are also required to complete two part-time internships during the school year and a full-time internship in the summer.

The students in my class formed a wondrously talented cross section of the sciences, with five biologists, a geologist, an environmental scientist, a physicist, and an engineer. Wilkes, who handpicks each year's class, attempts to balance the specialties represented. Being a mathematician certainly helped me get in: I was the first Ph.D. in math ever to enter the program and probably the first ever to apply. The class was diverse in age as well, ranging from a twenty-two-year-old physics student who had just graduated from college to a geologist in his mid-fifties who had taken early retirement when his company disbanded its research division.

Before classes started I wondered if this program could possibly be as intense as graduate school in mathematics had been. I started getting my answer right away. For our first assignment the class reported on a lecture by an astronomer who had discovered eight new planets orbiting distant stars. After the lecture we went straight to the newsroom of the Santa Cruz *Sentinel* (where our teacher was the city editor) and filed stories, just as if we had been regular reporters. We were not supposed to leave until we had finished, and the teacher did not want to wait around all night either. We were learning the first lesson of news writing: the importance of meeting deadlines.

I quickly realized that writing for a popular audience differs from academic writing in many ways. Not only does timeliness count, but so does brevity. Usually the writer has a fixed number of words or pages or column inches or minutes of air time, and if the story doesn't fit, the writer has to chop it until it does. (Otherwise, the editor will.) Once, we were assigned to write an explanation of how something works in under a page. I interviewed a bronze sculptor and wrote an elegant one-page treatise on the process of lost-wax casting. I brought it proudly to the next class. Imagine my chagrin when the teacher told us our next assignment: "Now cut your description down to one sentence!" The moral was clear, if painful: journalists must be able to condense any subject into a nutshell.

Most of the students in the class, including me, had not come to UCSC with the intention of becoming newspaper writers. I struggled with the "AP news style" with its "inverted pyramid" format, in which the most important information in the story must come right at the outset, leaving all the explanation, qualification, and context for later. It violated all my training in mathematics, where you start out by making all your terms clear and gradually build up to the main result. But even if we hated it at times, the program broke us of our old writing habits. Our verbs sprang to life, and passive constructions were consigned to the dustbin. Our stories had people in them, and the people said things. Our stories *were* stories, or at least they had stories in them. As we moved into feature and essay writing, the restrictions on length and form eased, but the good writing habits remained.

Before I started at UCSC my idea was to be a mathematics writer, but in my courses and internships I found myself writing about all sorts of different things: distant planets, bronze casting, AIDS, archaeology,... In fact, I often found that it was easier for me to write about subjects that were not mathematical. When the subject was math, my writing would sink like a soufflé as soon as I started explaining technical niceties, such as what it means for a series to converge. My classmates—even though they were all scientists, most with doctorates—would begin to fidget when they got to those parts or skip over them entirely. If even highly educated readers did not have the patience to read about the convergence of an infinite series, how could I expect a general audience to? Slowly and painfully I realized I had to change my expectations. The goal of expository writing is not the same as the goal of a textbook. I might not be able to teach the readers exactly what a convergent series is, but I could show them—in some imperfect way—how mathematicians think, who mathematicians are, or why mathematics has something to do with the world.

The internships may have been even more important than the classes in getting me to change my frame of reference from a mathematician's to a writer's. My winter internship, at the Salinas *Californian*, gave me the experience of "turning a story around" in a day and provided me with lots of "clips"—published articles, which to a writer are more important than a résumé. I learned also how newspapers get stories, often through press releases and news conferences. In the spring quarter I moved to the other side of the information conduit, the public information office at NASA-Ames Research Center. There I enjoyed being an "insider", knowing about things before the press does and influencing the way the press covers them. (I wrote part of a press kit on the upcoming Lunar Prospector mission, which the BBC will use as the basis for a documentary.) However, that internship also gave me a taste of the anonymity and frustration of working in a large bureaucracy.

This summer I interned for two months at *American Scientist* as a writer and editor. Editing, I learned, is not just a matter of correcting spelling errors and locating misplaced antecedents. Editors need a sense of good writing. They should understand the material but read it through the eyes of a reader who doesn't. They must have a sense of diplomacy and no ego—because the name that goes on the article is someone else's. Smart editors, like smart criminals, get what they want without leaving any evidence behind. Fortunately I worked with an author who not only tolerated but welcomed my suggestions, and we were both pleased with the outcome.[4]

What Next?

Generally speaking, science writers have three tracks open to them: freelance writing, a job with a periodical (or radio/TV), and a job as a public information officer. I have chosen freelancing, in some ways the most difficult of the three options but in other ways the most attractive. My biggest fear was that I would come home from my summer internship and simply find myself unemployed, lounging around the house in a T-shirt, drinking beer and watching TV. (And I don't even like beer!) But in the short time since I finished my summer internship, freelance writing has been just like a regular job—quite busy at times, not so busy at others—only with some huge advantages. My commute takes thirty seconds, not thirty minutes. I can work with my dog on my lap. And, yes, if I feel like it, I can take a break and watch TV.

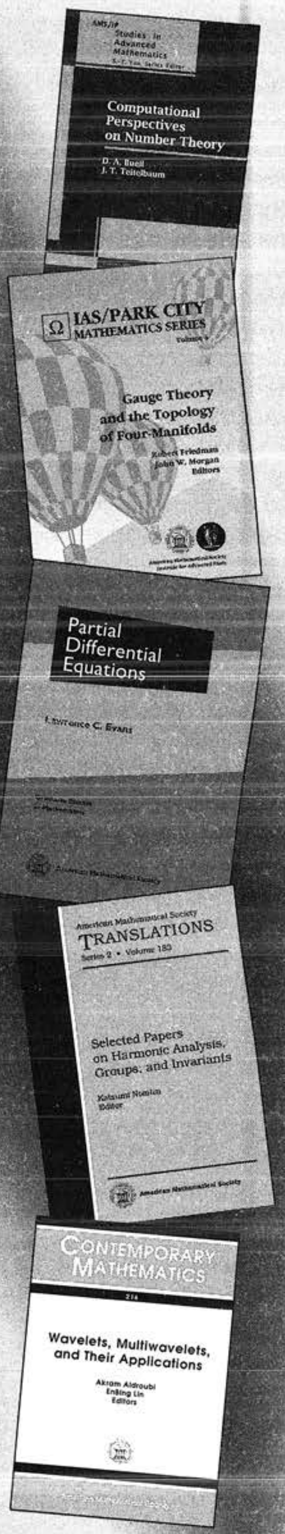
To be successful, a freelance writer has to find a niche—a market or a subject he or she can return to over and over. In my first two months of freelancing, I have done almost all my writing for two publications: *Science* magazine and its Web-based cousin, *Science NOW*. I am greatly indebted to Barry Cipra, who blazed a trail into math writing before I did, for putting me in touch with his editor at *Science* and helping me get my first assignment. My association with *Science NOW* also came through a contact: the editor graduated from the UCSC program the year before me.

I still hope to do quite a bit of writing about mathematics; science editors profess to be eager for more math stories. Meanwhile, I am enjoying the chance to write about other disciplines as well. It is a big world out here, and there are lots of interesting things happening in it. A cartoon I saw tacked to a cubicle in the newsroom of the Salinas *Californian*, expressed the writer's life well. It showed two journalists with a blindfold, a handful of darts, and a bunch of subjects written on the opposite wall: Economy, Crime, International Relations,... One of the writers was saying to the other, "Let's see, what will I be an expert on today?" It's fun to be constantly learning something new, to escape the academic straightjacket of specialization, and not to take myself too seriously.

If You Want to Write

Do you have to change your career and lifestyle if you wish to popularize mathematics? Emphatically not. Some general-science periodicals, such as *American Scientist*, accept feature articles only from scientists and mathematicians, not from journalists. Some mathematicians—Keith Devlin and Frank Morgan come to mind—have taken the plunge of writing regular newspaper or magazine columns while retaining their academic positions. A writer with an academic position enjoys a huge advantage in prestige and credibility over a journalist. Even so, any academic who wants to write for a popular audience should first do a little reading about the "facts of life" in the publishing business. Check out William Zinsser's *On Writing Well* or Deborah Blum and Mary Knudson's *A Field Guide to Science Writing*. Be prepared (alas) to explain your subject without equations. Be willing to accept the fact that the editor might know better than you what the audience wants or is capable of understanding. Remember that things that seem obvious to you do not seem obvious to most readers. And finally, just do it!

[4] *See "Inverse Boundary-Value Problems", by Margaret Cheney, in* American Scientist, *September/October 1997.*



American Mathematical Society

Recently Published Titles from the AMS

Computational Perspectives on Number Theory

Proceedings of a Conference in Honor of A. O. L. Atkin

D. A. Buell, *Center for Computing Sciences, Bowie, MD*, and **J. T. Teitelbaum**, *University of Illinois at Chicago*, Editors

This volume contains papers presented at the conference "Computational Perspectives on Number Theory" held at the University of Illinois at Chicago in honor of the retirement of A. O. L. Atkin. In keeping with Atkin's interests and work, the papers cover a range of topics, including algebraic number theory, p-adic modular forms and modular curves. Many of the papers reflect Atkin's particular interest in computational and algorithmic questions.

AMS/IP Studies in Advanced Mathematics, Volume 7; 1998; 232 pages; Softcover; ISBN 0-8218-0880-X; List $59; All AMS members $47; Order code AMSIP/7RT83

Supplementary Reading

Gauge Theory and the Topology of Four-Manifolds

Robert Friedman and **John W. Morgan**, *Columbia University, New York*, Editors

The lectures in this volume provide a perspective on how 4-manifold theory was studied before the discovery of modern-day Seiberg-Witten theory. One reason the progress using the Seiberg-Witten invariants was so spectacular was that those studying $SU(2)$-gauge theory had more than ten years' experience with the subject. The tools had been honed, the correct questions formulated, and the basic strategies well understood. The knowledge immediately bore fruit in the technically simpler environment of the Seiberg-Witten theory.

Gauge theory long predates Donaldson's applications of the subject to 4-manifold topology, where the central concern was the geometry of the moduli space. One reason for the interest in this study is the connection between the gauge theory moduli spaces of a Kähler manifold and the algebro-geometric moduli space of stable holomorphic bundles over the manifold. The extra geometric richness of the $SU(2)$-moduli spaces may one day be important for purposes beyond the algebraic invariants that have been studied to date. It is for this reason that the results presented in this volume will be essential.

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 4; 1998; 221 pages; Hardcover; ISBN 0-8218-0591-6; List $39; All AMS members $31; Order code PCMS/4RT83

Local Properties of Distributions of Stochastic Functionals

Yu. A. Davydov, *University of Lille I, Villeneuve d'Ascq, France*, **M. A. Lifshits**, *MANCOMTECH Training Center, St. Petersburg, Russia*, and **N. V. Smorodina**, *Radiation Hygiene Institute, St. Petersburg, Russia*

This book investigates the distributions of functionals defined on the sample paths of stochastic processes. It contains systematic exposition and applications of three general research methods developed by the authors.

(i) The method of stratifications is used to study the problem of absolute continuity of distribution for different classes of functionals under very mild smoothness assumptions. It can be used also for evaluation of the distribution density of the functional.

(ii) The method of differential operators is based on the abstract formalism of differential calculus and proves to be a powerful tool for the investigation of the smoothness properties of the distributions.

(iii) The superstructure method, which is a later modification of the method of stratifications, is used to derive strong limit theorems (in the variation metric) for the distributions of stochastic functionals under weak convergence of the processes.

The research methods and basic results in this book are presented here in monograph form for the first time. The text would be suitable for a graduate course in the theory of stochastic processes and related topics.

Translations of Mathematical Monographs, Volume 173; 1998; 184 pages; Hardcover; ISBN 0-8218-0584-3; List $75; Individual member $45; Order code MMONO/173RT83

Recommended Text

Partial Differential Equations

Lawrence C. Evans, *University of California, Berkeley*

This text gives a comprehensive survey of modern techniques in the theoretical study of partial differential equations (PDEs) with particular emphasis on nonlinear equations. The exposition is divided into three parts: 1) representation formulas for solutions, 2) theory for linear partial differential equations, and 3) theory for nonlinear partial differential equations.

Included are complete treatments of the method of characteristics; energy methods within Sobolev spaces; regularity for second-order elliptic, parabolic and hyperbolic equations; maximum principles; the multidimensional calculus of variations; viscosity solutions of Hamilton-Jacobi equations; shock waves and entropy criteria for conservation laws; and much more.

The author summarizes the relevant mathematics required to understand current research in PDEs, especially nonlinear PDEs. While he has reworked and simplified much of the classical theory (particularly the method of characteristics), he primarily emphasizes the modern interplay between functional analytic insights and calculus-type estimates within the context of Sobolev spaces. The book's wide scope and clear exposition make it a suitable text for a graduate course in PDEs.

Graduate Studies in Mathematics; 1998; approximately 712 pages; Hardcover; ISBN 0-8218-0772-2; List $75; All AMS members $60; Order code GSM-EVANSRT83

Selected Papers on Harmonic Analysis, Groups, and Invariants

Katsumi Nomizu, *Brown University, Providence, RI*, Editor

This volume contains papers that originally appeared in Japanese in the journal *Sūgaku*. Ordinarily the papers would appear in the AMS translation of that journal, but to expedite publication the Society has chosen to publish them as a volume of selected papers. The papers range over a variety of topics, including representation theory, differential geometry, invariant theory, and complex analysis.

American Mathematical Society Translations—Series 2, Volume 183; 1998; 143 pages; Hardcover; ISBN 0-8218-0840-0; List $59; Individual member $35; Order code TRANS2/183RT83

Wavelets, Multiwavelets, and Their Applications

Akram Aldroubi, *Vanderbilt University, Nashville, TN*, and **EnBing Lin**, *University of Toledo, OH*, Editors

This volume contains refereed research articles on the active area of wavelets and multiwavelets. The book draws upon work presented by experts in the field during the special session on "Wavelets, Multiwavelets and Their Applications" at the Joint Mathematics Meetings in San Diego (January 1997).

Wavelets were implicit in mathematics, physics, signal or image processing, and numerical analysis long before they were given the status of a unified scientific field in the late 1980s. They continue to be one of the few subjects that have attracted considerable interest from the mathematical community and from other diverse disciplines where they have had promising applications. The topic is in full evolution, with active research efforts emerging from the fruitful interaction of various mathematical subjects and other scientific disciplines.

Contemporary Mathematics, Volume 216; 1998; 175 pages; Softcover; ISBN 0-8218-0793-5; List $49; Individual member $29; Order code CONM/216RT83

All prices subject to change. Charges for delivery are $3.00 per order. For optional air delivery outside of the continental U. S., please include $6.50 per item. *Prepayment required*. Order from: **American Mathematical Society**, P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax (401) 455-4046 or call toll free 800-321-4AMS (4267) in the U. S. and Canada, (401) 455-4000 worldwide. Or place your order through the AMS bookstore at http://www.ams.org/bookstore/. Residents of Canada, please include 7% GST.

Mathematics Opportunities

Short Course on Mathematics and Molecular Biology

The Program in Mathematics and Molecular Biology (PMMB) at the University of California, Berkeley, will conduct an introductory short course on research, training, and career opportunities at the interface between mathematics and molecular biology. Supported by the Burroughs Wellcome Fund Interfaces Program, the course will run June 22–July 3, 1998, at UC Berkeley.

The goal of the short course is to encourage promising students from the physical, chemical, and mathematical sciences to apply their unique knowledge and talents to biological problems. Full support (travel and living expenses) is available for selected students in the physical/chemical/mathematical sciences who are in residence at universities in the United States and Canada. Upper-level undergraduates and graduate students are invited to apply. The short course will include introductory lectures, laboratory and computer experiences, and discussion groups.

The topics and teachers include: Modern Genome Analysis (P.O. Brown, Stanford University; S. J. Spengler, Lawrence Berkeley Laboratory; M. S. Waterman, University of Southern California); Nucleic Acid Structure and Topology (N. R. Cozzarelli, UC Berkeley; L. Kauffman, University of Illinois at Chicago; D. W. Sumners, Florida State University; I. Tinoco, UC Berkeley); Protein Structure and Folding (B. Berger, MIT; C. Brooks, Scripps Research Institute; M. Levitt, Stanford University; J. Onuchic, UC San Diego; A. Sali, Rockefeller University); and Quantitative Analysis of Evolution (T. Speed, UC Berkeley; E. Thompson, University of Washington).

For information and application materials, contact: PMMB, Department of Mathematics, Florida State University, Tallahassee, FL 32306-4510; telephone 850-644-8710; fax 850-644-6612; e-mail: `pmmb@math.fsu.edu`; World Wide Web: `http://www.math.fsu.edu/~pmmb/`. The deadline for receipt of applications is **April 1, 1998**. Women and minorities are encouraged to apply.

—PMMB Announcement

Postdoctoral Grants at Mittag-Leffler

The Mittag-Leffler Institute has announced a number of grants for the year 1998–99. The program of the Institute starts on September 1 and ends on May 31. The grants are intended for recent Ph.D.s or advanced graduate students and amount to 12,000 Swedish crowns (about US$1,550) per month. Preference will be given to applications for longer stays, either for one semester or for the whole year.

The subject for 1998–99 is "Topology and Geometry of Quantum Fields". The following experts have already agreed to take part in the program for an extended period: S. Akbulut, V. I. Arnold, J. Birman, A. Carey, A. Dzhumadildaev, M. Flato, K. Fredenhagen, D. Freed, M.-L. Ge, V. Goryunov, H.-P. Jakobsen, V. Kac, T. Le, G. Mikhalkin, H. Morton, H. Murakami, J. Murakami, T. Ohtsuki, D. Pickrell, M. Polyak, S. Rajeev, J. Råde, G. Thompson, M. Wodzicki. The program committee consists of Jouko Mickelsson, Antti Niemi, Oleg Viro, and Torsten Ekedahl.

In order to be considered for one of these grants, an applicant must fulfill the following conditions: (1) his or her research interest must fall within the area of the program; (2) he or she must be either an advanced graduate student or a recent Ph.D. (no more than 5 (five) years after the degree at the start of the program September 1, 1998); (3) the paper version of his or her application and letters of recommendation *must* reach the Board of the Institute before **March 31, 1998.** Final decisions are made around April 20, 1998.

Inquiries may be directed to any of the following individuals: Kjell-Ove Widman, Mittag-Leffler Institute, Auravägen 17, S-182 62 Djursholm, Sweden, e-mail: widman@ml.kva.se; Jouko Mickelsson, Department of Theoretical Physics, KTH, S-100 44 Stockholm, Sweden, e-mail: jouko@theophys.kth.se; Antti Niemi, Department of Theoretical Physics, University of Uppsala, Box 803, S-751 08 Uppsala, Sweden, e-mail: Antti.Niemi@teorfys.uu.se; Oleg Viro, Department of Mathematics, University of Uppsala, Box 480, S-751 06 Uppsala, Sweden, e-mail: Oleg.Viro@math.uu.se.

For application forms, write to: Mittag-Leffler Institute, Auravägen 17, S-182 62 Djursholm, Sweden. The World Wide Web site for the Institute is found at http://www.ml.kva.se/.

—from Mittag-Leffler Announcement

Maria Mitchell Women in Science Award

The Maria Mitchell Association is establishing an annual award to honor an individual or organization that encourages girls and women to pursue studies and careers in science and technology. Maria Mitchell (1818–1889) was the first woman astronomer and first woman astronomy professor in the U.S.

The award may be given in the natural and physical sciences, mathematics, engineering, computer science, and technology. The winner will be chosen by a national jury of distinguished educators and scientists and will receive a cash award of $5,000. Funding for the award is provided by the Kenan Foundation through the year 2000.

The deadline for submission of nominations is **March 15, 1998.** For further information and a nomination application, contact: Maria Mitchell Association, 2 Vestal Street, Nantucket, MA 02554; telephone 508-228-9198; World Wide Web http://www.mmo.org/.

—from Maria Mitchell Association Announcement

Project NExT 1998–1999

Project NExT (New Experiences in Teaching) is a program for new or recent Ph.D.s in the mathematical sciences who are interested in improving the teaching and learning of undergraduate mathematics. Faculty who are just beginning or just completing their first year of full-time teaching at the college/university level are invited to apply to become Project NExT fellows. The first event for the 1998–1999 fellows will be a workshop, July 13–15, 1998, just prior to the Mathfest, the summer meeting of the Mathematical Association of America (MAA), in Toronto, Canada, July 16–18, 1998.

At this workshop and at Project NExT sessions during the Mathfest, fellows will explore and discuss a broad range of issues that are of special relevance to beginning faculty, including: new approaches to teaching calculus and precalculus; alternative methods of teaching and assessing student learning; using technology in the classroom; perspectives from pedagogical research; writing grant proposals; and balancing teaching and research. The fellows will also have an opportunity to meet and interact with fellows who began the program in previous years.

Invited speakers include: Gerald Alexanderson, Santa Clara University, MAA President; Lloyd Douglas, National Science Foundation; Joseph Gallian, University of Minnesota, Duluth; Anita Solow, DePauw University; Steven Dunbar, University of Nebraska, Lincoln; Glenda Lappan, Michigan State University; and Morton Brown, University of Michigan.

Following the workshop, Project NExT fellows will attend the Mathfest, participating in all the opportunities of that meeting, and choose among special short courses designed for the fellows. During the following academic year, fellows will participate in a network that links fellows with one another and with distinguished teachers of mathematics, special events at the Joint Mathematics Meetings in San Antonio (January 13–16, 1999), and a second workshop in the summer of 1999.

Approximately sixty Project NExT fellows will be selected for the 1998–1999 year. Funding for room and board at the workshop in Toronto and for the short courses at the summer 1998 Mathfest will be provided for participants. Institutions employing the fellows are expected to provide financial assistance for travel and attendance at the national meetings. Limited funds are available to assist those institutions that are unable to afford full or partial support.

Application forms and a letter of support from one's department chair must be sent by **March 27, 1998.** Applicants will be notified by May 15, 1998, whether they have been selected as fellows. (Because the workshop is earlier this year, Project NExT organizers had to make the deadline earlier than in past years. If you would still like to apply and the March 27 deadline has passed, please contact the organizers to see if space is still available.)

Applications and further information may be obtained by writing to: James R. C. Leitzel, Department of Mathematics, University of New Hampshire, Kingsbury Hall, Durham, NH 03824; telephone 603-862-4546; e-mail: jrcl@christa.unh.edu. Project NExT is sponsored by the MAA, with partial support from the Exxon Education Foundation.

—Project NExT Announcement

For Your Information

Statement on the Use of Part-Time Faculty

The leaders of ten professional societies, including the AMS, have issued a 9-page statement on the growing use of part-time faculty. The statement grew out of a conference held in the fall of 1997 that brought together sixty academics from different disciplines to discuss the impact that the use of part-time faculty has had on undergraduate teaching. The AMS representatives at the conference were Committee on the Profession member Annalisa Crannell and Associate Executive Director James W. Maxwell.

While there may be some valid reasons for using part-time faculty, "the terms and conditions of these appointments, in many cases, weakens our capacity to provide essential educational experiences and resources," the statement says. "On behalf of our students and their families, we urge administrators and faculty to avoid excessive or inappropriate reliance on part-time or adjunct faculty."

One part of the statement presents statistics describing the increasing use of part-time and adjunct faculty. For example, the statement notes that the proportion of part-time and adjunct faculty appointments has increased from 22% in 1970 to more than 40% in 1993, with part of the rise reflecting growth in community colleges. There is also a description of the working conditions, which the statement says are "emphatically substandard" for the majority of part-timers.

Sometimes part-timers are needed in order to provide specialized background not present in the permanent faculty, but according to the statement the reliance on part-time faculty far exceeds this need. The drive to save money by appointing temporary rather than permanent faculty is also out of proportion to need, the statement says. "[C]ost-driven reliance on part-time faculty and adjunct, non-tenure-track faculty occurs on a scale so large that it lessens job opportunities in the academic professions and lowers salaries for entering full-time, tenure-track faculty, thereby diminishing the quality of recruits attracted to and retained in undergraduate instruction and the academic profession." The statement also outlines many ways in which overreliance on part-timers weakens the ability of academic departments to provide high-quality education.

The statement ends with a set of policies and guidelines for handling part-time appointments. For example, the guidelines suggest that institutions should recruit and select the best available candidates for part-time positions and consider these people for tenure-track positions for which they are qualified. The statement also advocates long-term appointments, access to benefits, and opportunities for professional advancement. The statement lists a number of actions to be taken that will stimulate the acceptance of these guidelines.

The AMS Committee on the Profession will study the statement and possibly make a recommendation for action to the AMS Council. The entire statement will be published in *Academe*, the magazine of the American Association of University Professors, and may be found on the AMS Web site at `http://www.ams.org/committee/profession/`. For further information on the subject of part-timers, see the article "Changes in Mathematics Faculty Composition, Fall 1990 to Fall 1996", by James W. Maxwell, *Notices*, November 1997.

—*Allyn Jackson*

AMS Web Page for Public Awareness

As this article is being written (November 1997), What's New in Mathematics (WNIM), the public awareness component of e-MATH, is celebrating its first birthday. WNIM aims to have items of interest to both mathematicians and non-mathematicians and has a wide variety of items: articles specially written for WNIM, links to other parts of e-MATH, links to other Web sites, and references to print media.

AMS statistics show that WNIM is one of the most heavily accessed areas of e-MATH. The WNIM home page had just over 4,000 hits last month, and hits to all WNIM pages totalled over 12,500. Pages that attracted the most interest include: Fermat's Last Theorem (a continuing favorite), the PBS program on Fermat's Last Theorem, the "cover" page (which was about the centenary of the death of J. J. Sylvester), "The Bible Code", "science wars", primes, and Math Digest and Math News.

WNIM has a worldwide scope. Countries in addition to the U.S. which recorded at least 100 hits last month were: Australia, Brazil, Canada, France, Germany, India, Italy, Japan, South Korea, Spain, Sweden, and the United Kingdom. Also, as far as can be determined from HTTP statistics, WNIM appears to be achieving its goal of reaching beyond the mathematical community. Domestic hits included 2,377 from domains .edu, 2,790 from domains .com, and 1,376 from domains .net.

WNIM is accessible from the AMS home page or directly at `http://www.ams.org/new-in-math/`.

—Steven H. Weintraub, WNIM Editor

New PBS Series on Mathematics to Air in Spring

Coming to PBS in spring 1998 from WQED Pittsburgh, the series *Life by the Numbers* reveals the important role that mathematics plays in sports, work, education, exploration, chance, technology, and life in general. This exciting series invites public television stations and other organizations to partner in local outreach activities that promote mathematical literacy in our complicated age.

In 1990 after the publication of the mathematics education Standards of the National Council of Teachers of Mathematics (NCTM), WQED set out to see if public television could partner with mathematics teachers to overcome negative student and parent attitudes toward the subject. Building on NCTM's urging that students learn mathematics by engaging in real-world problem solving, WQED looked for ways to show the thousands of aspects of modern life that have mathematics at their core. *Life by the Numbers* is the fascinating result.

Hosted by actor Danny Glover, the series profiles dozens of people who use mathematics everyday—some in mundane ways that we overlook in our own lives, and some in esoteric but intriguing ways. Graphic artists, scientists, astronomers, athletes, artists, businesspeople, pollsters, computer programmers, even a bride planning her wedding—these are just a few of the people who find mathematics to be an indispensable tool.

What follows are brief descriptions of each of the series programs.

"Patterns of Nature": Biological scientists are learning new information about life thanks to new applications of mathematics. This program depicts the relationship between geometry and body size, a mathematical model for animal coat patterns, the application of mathematical knot theory to the study of viruses and DNA, the use of fractals in studying forms in nature, and a computer model for evolution.

"Seeing Is Believing": A major milestone in the connection between mathematics and art was the Renaissance discovery of perspective, which enabled artists to depict depth in paintings. Today mathematics is the basis for a variety of special visual effects that stretch beyond realism. This program describes special effects in movies and the use of mathematics and graphic arts to visualize the birth of the universe, the fourth dimension, and other complex ideas.

"The Numbers Game": Mathematics in sports goes beyond scores, times, and batting averages. Today's athletes, coaches, and trainers are linking up with mathematicians and scientists to fine-tune their performances. This program looks at football teams, ice skaters, sailboat designers, and triathletes, just some of the sports figures who rely on mathematics-based technologies to excel in their events.

"Chances of a Lifetime": What do statisticians, gamblers, pollsters, insurance representatives, and brides have in common? Their reliance on numbers to answer some very important questions. These are not just any numbers, but numbers that help describe risk and probability—the likelihood that something will happen. Just as a gambler bets on the probability that a certain number will turn up on a pair of dice, an insurer banks on the probability that a flood won't happen, and a bride hopes it won't rain on her wedding day.

"Shape of the World": It is impossible to accurately depict a three-dimensional object on a two-dimensional surface. Yet we use maps every day because mathematics enables mapmakers to overcome the distortions. This program briefly describes the history of mapmaking, then shows advanced uses of maps today beneath the sea, in the sky, and beyond.

"A New Age": Computers are reshaping our world. This revolution is based on the simple mathematical logic that is the basis of the computer. This program shows computer software developed to respond to human wishes and explores mathematical applications that help us communicate, understand our needs, and predict our future.

"Making a Difference": For many, memories of math class are of story problems or endless number problems that did not connect with their lives. This program shows some of the fascinating ways educators are making mathematics more relevant and interesting, including a lesson drawn from an Edgar Allan Poe story, an all-girl math class, a teacher-development project, and a program for families.

Nationally, *Life by the Numbers* educational materials are going directly to schools and other organizations to support educational use of the series and to raise awareness of mathematics. High school mathematics teachers will receive a series poster and teaching guide. Such national organizations as Family Math, the National Urban League, Girls Incorporated, and Girl Scouts of the U.S.A. are distributing series Activity Guides to their local affiliates who conduct mathematics-related programs.

In addition, members of organizations like the AMS are invited to participate in local outreach activities designed to enhance the impact of the series and involve children and their parents in events that encourage mathematics education. Two primary activities include "Math Trails", pathways through places with math challenges at stopping points, and "Math Career Awareness Days" events, in which people in math-related careers describe their jobs to young people. AMS members interested in volunteering to help out with such activities should contact the education/outreach director of their local public television station.

More information on the series can be found on the World Wide Web at: `www.pbs.org/math`, `www.mathlife.wqed.org`, `www.ti.com/calc/`. *Life by the Numbers* has been endorsed by the Mathematical Association of America, the American Mathematical Society, and the American Association of School Administrators. Exclusive corporate support for *Life by the Numbers* is provided by Texas Instruments. Major support comes from the National Science Foundation and the Alfred P. Sloan Foundation. Additional support was provided by the McDonnell Douglas Foundation and Alcoa Foundation. Check local listings for broadcast times in your area.

—from Life by the Numbers Announcement

Mathematics Awareness Week 1998

Mathematics Awareness Week (MAW) 1998 will be officially celebrated April 26–May 2. The Joint Policy Board for Mathematics has selected "Mathematics and Imaging" as the 1998 MAW theme.

Mathematics Awareness Week materials, including the MAW poster will be posted on the MAW Web site, `http://forum.swarthmore.edu/maw/`. Additional information can be found and MAW-related activities discussed on MAW-list, the e-mail discussion list. To be included on the list send a message to e-mail: `listserv@enterprise.maa.org`. Leave the subject line blank, and write in the body: subscribe maw.

Institutions and organizations planning MAW activities may wish to post them on MAW-list and on their WWW sites. Links from the postings to the MAW Web site may be arranged with Melissa Dershewitz, e-mail: `dersh@forum.swarthmore.edu`.

To assist in 1998 planning, information on 1996–1997 activities are currently posted on the MAW Web site, with links to many individual MAW Web pages.

—JPBM Announcement

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/profession/employ.html`), 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

AMS Standard Cover Sheet

Last Name ______________________

First Name ______________________

Middle Names ______________________

Address *through June 1998* ______________________

Home Phone ______________________

e-mail Address ______________________

Current Institutional Affiliation ______________________

Work Phone ______________________

Highest Degree and Source ______________________

Year of Ph.D. (optional) ______________________

Ph.D. Advisor ______________________

If the Ph.D. is not presently held, date on which you expect to receive ____________

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.*

____

____

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

University or Company ______________________

Position Title ______________________ Dates ____________

Indicate the position for which you are applying and position posting code, if applicable

____

If unsuccessful for this position, would you like to be considered for a temporary position?

☐ Yes ☐ No If yes, please check the appropriate boxes.

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

List the names, affiliations, and e-mail addresses *of up to four individuals who will provide letters of recommendation if asked. Mark the box provided for each individual whom you have already asked to send a letter.*

☐ ______________________

☐ ______________________

☐ ______________________

☐ ______________________

This form is provided courtesy of the American Mathematical Society.

This cover sheet is provided as an aid to departments in processing job applications. It should be included with your application material.

Please print or type. Do not send this form to the AMS.

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

1998 Frank and Brennie Morgan AMS-MAA-SIAM Prize for Outstanding Research in Mathematics by an Undergraduate Student

The prize is awarded each year to an undergraduate student (or students having submitted joint work) for outstanding research in mathematics. Any student who is an undergraduate in a college or university in the United States or its possessions, or Canada or Mexico, is eligible to be considered for this prize.

The prize recipient's research need not be confined to a single paper; it may be contained in several papers. However, the paper (or papers) to be considered for the prize must be submitted while the student is an undergraduate; they cannot be submitted after the student's graduation. The research paper (or papers) may be submitted for consideration by the student or a nominator. All submissions for the prize must include at least one letter of support from a person, usually a faculty member, familiar with the student's research. Publication of research is not required.

The recipients of the prize are to be selected by a standing joint committee of the AMS, MAA, and SIAM. The decisions of this committee are final. The 1998 prize will be awarded for papers submitted for consideration no later than **March 31, 1998,** by (or on behalf of) students who were undergraduates in December 1997.

Nominations and submissions should be sent to:

Morgan Prize Committee
c/o Robert M. Fossum, Secretary
American Mathematical Society
University of Illinois
Department of Mathematics
1409 West Green Street
Urbana, IL 61801-2975

Questions may be directed to the chairperson of the Morgan Prize Committee:

Martha J. Siegel
Department of Mathematics
Towson State University
Towson, MD 21204-7097
telephone 410-830-2980
e-mail: siegel-m@toe.towson.edu

AMERICAN MATHEMATICAL SOCIETY

Reference

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

Upcoming Deadlines

March 31, 1998: Deadlines for applications for Mittag-Leffler Institute postdoctoral fellowships for the academic year 1998–1999. Information available at the Web site `http://www.ml.kva.se/`. Or write to: Mittag-Leffler Institute, Auravägen 17, S-182 62 Djursholm, Sweden.

April 6, 1998: Deadline for proposals for 1999 NSF-CBMS Regional Research Conferences. For information see Web site `http://www.maa.org/cbms.html`. Or write to Conference Board of the Mathematical Sciences, 1529 18th St., NW, Washington, DC 20036.

April 15, August 15, 1998: Deadlines for applications for NRC Associateship Programs. Information available at the Web site `http://rap.nas.edu/`.

Where to Find It

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

AMS e-mail addresses
October 1997, p. 1118

AMS Ethical Guidelines
June 1995, p. 694

AMS officers and committee members
September 1997, p. 972

Board on Mathematical Sciences and Staff
May 1997, p. 597

Bylaws of the American Mathematical Society
November 1997, p. 1339

Classification of degree-granting departments of mathematics
January 1997, p. 48

Mathematical Sciences Education Board and Staff
May 1997, p. 597

Mathematics Research Institutes contact information
May 1997, p. 598

National Science Board of NSF
November 1996, p. 1380

NSF Mathematical and Physical Sciences Advisory Committee
January 1998, p. 105

Officers of the Society 1996 and 1997 (Council, Executive Committee, Publications Committees, Board of Trustees)
May 1997, p. 593

Program officers for federal funding agencies (DoD, DoE, NSF)
October 1997, pp. 1150–1151

American Mathematical Society

MathSciNet Version 3

Consortia pricing available.*

www.ams.org/mathscinet

30-day free trial for institutions!

MathSciNet—available on the Web by subscription—provides searching of over 55 years of *Mathematical Reviews* and *Current Mathematical Publications*. New features include:

- **Expanded Access to Online Articles**
  In addition to offering links to AMS online journals, MathSciNet now offers links to available articles from other academic publishers.
- **The First of Pre-1980 Reviews Added**
  The AMS has begun to add the reviews from 1940–1979 to the MathSciNet database. As more full-text reviews become available, they will be added in full year increments. By 1999, the full text of all reviews from 1940 to the present will be available on MathSciNet.
- **Marking Records for Display or Download**
  You can select items from a Headline List to display or download in one batch. Choose to display the selected items in the following formats: Reviews in HTML, DVI, or PostScript, Citations in ASCII or BibTeX.
- **Combining Author Identification Results with other Criteria**
  You can now combine an author's name with other search criteria for a more focused search.
- **Searching 5-Year Ranges**
  Using the MR publication year, the database has been divided into 5 year sections beginning with 1940. You can search one 5 year section or a contiguous range.
- **More MathSciNet Mirror Sites**
  There are now five MathSciNet sites. The sites are:
  - Houston, TX USA at http://ams.rice.edu/mathscinet
  - Strasbourg, France at http://irmasrv1.u-strasbg.fr/mathscinet/
  - Bonn, Germany at http://klymene.mpim-bonn.mpg.de/mathscinet/
  - Bielefeld, Germany at http://ams.mathematik.uni-bielefeld.de/mathscinet/
  - Providence, RI USA at http://www.ams.org/mathscinet/
- **Enhancements to Journal Identification**
  - **Now search using ISSN or CODEN** in addition to journal name or abbreviation.
  - **Journal URLs Added**
    If a journal is available electronically, Journal Identification results list the journal's URL and a live link to that journal's web site.

AMS
American Mathematical Society

* For more information, contact the American Mathematical Society, Membership and Customer Services Department at: 1-800-321-4267 or (401) 455-4000, worldwide; fax 401-455-4046; e-mail: cust-serv@ams.org

Mathematics Calendar

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

March 1998

*4-8 **Workshop on Computational Conformal Geometry**, Florida State University, Tallahassee, Florida.

Topics: Computations on Riemann surfaces and algebraic curves.

Participants: E. Bujalance, P. Buser, A. Costa, H. Helling, R. Kulkarni, B. Maskit, G. Rosenberger, K.-D. Semmler, K. Stephenson.

Organizers: J. Denny, S. McNeil, M. Seppala.

Information: `http://klein.math.fsu.edu/~seppala/Symbolic/Workshops/CCGatFSU98/Announcement.html`.

9-13 **Twenty-ninth Southeastern International Conference on Combinatorics, Graph Theory and Computing**, Florida Atlantic University, Boca Raton, Florida. (Dec. 1997, p. 1496)

9-14 **Emerging Applications of Dynamical Systems**, University of Minnesota, Minneapolis, Minnesota. (Sept. 1997, p. 1026)

12-14 **Spring Topology and Dynamics Conference**, George Mason University, Fairfax, Virginia. (Sept. 1997, p. 1026)

14-15 **Knots, Braids, and Mapping Class Groups: A Conference in Low-Dimensional Topology in Honor of Joan Birman's 70th Birthday**, Columbia University/Barnard College, New York, New York. (Sept. 1997, p. 1026)

14-18 **Arizona Winter School 1998: Workshop on Diophantine Geometry Related to the ABC Conjecture**, The University of Arizona, Tucson, Arizona. (Jan. 1998, p. 108)

16-18 **Conference on Complex Hyperbolic Geometry and Discrete Groups**, Okayama University of Science, Okayama, Japan. (Oct. 1997, p. 1056)

20-21 **AMS Southeastern Sectional Meeting**, University of Louisville, Louisville, Kentucky. (Dec. 1996, p. 1560)

Information: R. Cascella, `rgc@ams.org`.

*21-24 **International Conference on Nonlinear Partial Differential Equations and Applications**, Northwestern University, Evanston, Illinois.

Scientific Program: The program will consist of 50-minute plenary talks and 30-minute invited section talks.

Speakers: Invited speakers include: J. Bourgain (IAS), L. Caffarelli* (Austin), A. Chang* (UCLA), P. Constantin* (Chicago), D. Christodoulou (Princeton), C. Dafermos* (Brown), S. Davis (Northwestern), A. Friedman* (Minnesota), J. Glimm* (Stony Brook), D. Hoff* (Indiana), C. Kenig* (Chicago), P. Lax (New York), T.-P. Liu* (Stanford), A. Majda* (New York), J. Moser (ETH), C. Morawetz* (New York), S. Muller* (Leipzig), S. Osher* (UCLA), B. Perthame* (Paris), R. Schoen (Stanford), V. Solonnikov (St Petersburg), G. Talenti* (Florence), and S.-T. Yau* (Harvard). * confirmed

Support: Some funds will be available to help support the participation of graduate students, post-doctoral researchers, and senior researchers who have no grant support. People who belong to currently underrepresented groups (minorities and women) are particularly encouraged to apply. Decisions will be made beginning January 10, 1998.

Sponsors: National Science Foundation, Department of Mathematics and Office of the Vice President for Research and Graduate Studies of Northwestern University.

Organizing Committee: G.-Q. Chen, E. DiBenedetto, T. Ilmanen, and D. Tataru, Department of Mathematics, Northwestern University.

Information: `http://math.nwu.edu/~gqchen/pde98/index.html`. If you have any further questions related to the conference, please contact M. Rubin at 847-491-8035, 847-491-8906 (fax), or `melanie@math.nwu.edu`. To have your e-mail address added to the distribution list, or to contact the organizers, please send a note at `pde@math.nwu.edu`.

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.)

23–25 **DIMACS Workshop on Discrete Mathematical Chemistry**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Sept. 1997, p. 1026)

23–27 **Geometric Stochastic Analysis and Fine Properties of Stochastic Processes**, Mathematical Sciences Research Institute, Berkeley, CA 94720-5070. (Sept. 1997, p. 1026)

23–28 **EC Summer School: Arithmetic Geometry; Part I: Instructional Conference: Current Trends in Arithmetical Algebraic Geometry**, Newton Institute, Cambridge, United Kingdom. (Jan. 1998, p. 109)

23–29 **Japan-U.S. Mathematics Institute Conference and Workshop on Meromorphic Mappings and Intrinsic Metrics in Complex Geometry**, Johns Hopkins University, Baltimore, Maryland. (Nov. 1997, p. 1362)

25–28 **Global Analysis 30 Years Later**, University of Cincinnati, Cincinnati, Ohio. (Nov. 1996, p. 1384)

*25–31 **Calculus of Variations and Related Topics**, Haifa, Israel.
Forum: This conference will commemorate 300 years of the calculus of variations, and will cover topics of current research interest, such as critical point theory (with applications to partial differential equations) and optimal control.
Organizing Committee: A. Ioffe, R. Nussbaum, S. Reich, I. Shafrir, and H. Sussmann.
Speakers: A. Ambrosetti, Z. Artstein, H. Attouch, A. Bahri, E. J. Balder, J. Ball, V. Benci, F. Bethuel, J. Borwein, G. Buttazzo, K. C. Chang, M. Chipot, F. H. Clarke, J.-N. Corvellec, G. Dal Maso, A. V. Dmitruk, A. Dontchev, H. Fattorini, H. Frankowska, L. Freddi, M. Giaquinta, F. Helein, S. Hildebrandt, H. Th. Jongen, D. Kinderlehrer, A. Leizarowitz, P. Loewen, K. Malanowski, M. Marcus, A. Marino, J. Mawhin, A. A. Miljutin, V. Mizel, B. Mordukhovich, L. Nirenberg, R. Nussbaum, N. P. Osmolovskii, P. Rabinowitz, R. T. Rockafellar, J. Rubinstein, E. Schwartzman, S. Simons, H. Sussmann, L. Tartar, J. Taylor, V. M. Tikhomirov, R. Vinter, J. Warga, M. Willem, G. Wolansky, Y. Yomdin, A. Zaslavski, E. Zehnder.
Information: For further information and registration form, contact S. Schur (Secretary), Dept. Math., Technion-Israel Institute of Technology, 32000 Haifa, Israel; fax: 972-4-832-4654; e-mail: `iasm@techunix.technion.ac.il`.

27–28 **AMS Central Section Meeting**, Kansas State University, Manhattan, KS. (Sept. 1997, p. 1027)
Information: W. Drady, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: `wsd@math.ams.org`.

30–April 3 **European Joint Conferences on Theory and Practice of Software (ETAPS), Preliminary announcement and call for satellite events**, Lisbon, Portugal. (Nov. 1996, p. 1385)

30–April 3 **Third Workshop on Randomized Parallel Computing (Call for Papers)**, Orlando, Florida. (Feb. 1998, p. 292)

30–April 4 **EC Summer School: Arithmetic Geometry: Part II: Rational Points**, Newton Institute, Cambridge, United Kingdom. (Jan. 1998, p. 109)

April 1998

4–5 **AMS Eastern Sectional Meeting**, Temple University, Philadelphia, Pennsylvania. (Dec. 1996, p. 1560)
Information: R. Cascella, `rgc@ams.org`.

4–5 **Rivière-Fabes Symposium on Analysis and PDE**, University of Minnesota, Minneapolis, Minnesota. (Feb. 1998, p. 292)

*4–5 **Seventh Southern California Geometric Analysis Seminar**, Mathematics Department, University of California, Irvine, California.
Invited Speakers: S. Donaldson (Stanford - Oxford), J. Escobar (Cornell), N. Hitchin (Oxford), H. Hofer (Courant), Y.-T. Siu (Harvard), C.-L. Terng (Northeastern).
Support: Some support is available for graduate students and postdocs. The SCGAS particularly encourages the participation of women and members of underrepresented groups.
Information: Organizing committee: P. Li, R. Reilly, R. Wentworth, Dept. of Mathematics, University of California, Irvine, CA 92697-3875; `scgas@math.uci.edu`; fax: 714-824-7993. WWW home page: `http://www.math.uci.edu/~scgas/scgas.html`.

14–July 17 **Topology Semester**, Centre de Recerca Matemàtica, Bellaterra, Spain. (Feb. 1998, p. 292)

*16–17 **Models and Numerical Methods in Transport Theory and in Mathematical Physics: An international conference dedicated to V. Boffi on his 70th birthday**, Rome, Italy.
Program: The conference is aimed at bringing together scientists with interest in all fields of mathematical physics and applied mathematics which are related to transport theory. It is structured in a number of invited lectures, each one given by an eminent specialist in the field, about the state of the art and the most recent available results, in order to promote exchange of ideas and methods, as well as dissemination of advanced scientific knowledge, in the interested research community. Both mathematical modeling and numerical techniques will be emphasized. The main lectures will be published in a special issues of the journal "Transport Theory and Statistical Physics".
Organizing Committee: G. Frosali (Firenze), G. Spiga (Parma), R. Spigler (Roma).
Scientific Committee: M. Anile (Catania), A. Belleni-Morante (Firenze), P. Benvenuti (Roma), V. Capasso (Milano), M. Fabrizio (Bologna), G. Frosali (Firenze), R. Monaco (Torino), R. Piva (Roma), L. Salvadori (Trento), G. Spiga (Parma), R. Spigler (Roma), G. Toscani (Pavia).
Invited Speakers: N. Bellomo, C. Cercignani, L. De Socio, J. Dorning, A. Fasano, B. D. Ganapol, C. Marchioro, E. Massa, J. Mika, H. Neunzert, T. Nonnenmacher, P. Podio-Guidugli, J. Pomraning, S. Rionero, R. Scozzafava.
Information: G. Frosali, fax +39-55-471787; e-mail: `frosali@dma.unifi.it` and via WWW at `http://www.dma.unifi.it/~congressi/`.

16–18 **Twenty-Second Arkansas Spring Lectures in the Mathematical Sciences**, Fayetteville, Arkansas. (Sept. 1997, p. 1027)

19–22 **Supporting Educational, Faculty & TA Development Within Departments and Disciplines**, Austin, Texas. (Nov. 1997, p. 1362)

20–23 **International Conference on Interval Methods and their Application in Global Optimization (INTERVAL '98)**, Nanjing, China. (Oct. 1997, p. 1156)

20–24 **International Conference on Theoretical Computer Science in Honour of Professor Manuel Blum's 60th Birthday**, City University of Hong Kong, Hong Kong. (Jan. 1998, p. 109)

20–24 **Workshop on Probability: Theory and Applications**, Nottingham Trent University, Nottingham, England. (Dec. 1997, p. 1496)

25 **Midwest Numerical Analysis Day 1998**, Western Illinois University, Macomb, Illinois. (Jan. 1998, p. 109)

25–26 **AMS Western Sectional Meeting**, University of California-Davis, CA. (Apr. 1997, p. 481)
Information: W. Drady, `wsd@ams.org`.

26–June 27 **Commutative Algebra, Homological Algebra, and Representation Theory**, Italy. (Jan. 1998, p. 109)

*27–28 **DIMACS Workshop on Mathematical Methods for High Performance Data Mining Applications**, Computer Science Dept., Princeton University, Princeton, New Jersey.
Sponsor: DIMACS Center.
Organizers: H. E. Kulsrud (CCR-P/IDA), R. Grossman (Univ. of Illinois at Chicago and Magnify, Inc).
Contacts: H. E. Kulsrud, `laney@ccr-p.ida.org`.
Local Arrangements: S. Barbu, Princeton University, `barbu@cs.princeton.edu`, tel: 609-609-1771.
Focus: Data Mining is the automatic discovery of patterns, associations, changes, and anomalies in data sets. Scaling data mining to massive data sets requires new algorithms and combining techniques from high performance computing and data management with techniques from statistics and machine learning. This workshop will emphasize techniques to scale and parallelize algorithms. Of particular interest is the application of methods to specific types

of problems and the areas of success and failure.

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

27–29 **Conference on Real Numbers and Computers**, Pierre et Marie Curie University, Paris, France. (Sept. 1997, p. 1027)

27–May 1 **Emerging Applications of Dynamical Systems**, University of Minnesota, Minneapolis, Minnesota. (Sept. 1997, p. 1028)

* 28–May 2 **Second Conference on Probabilities and Stochastic Analysis**, Cadi Ayyad University, Faculty of Sciences Semlalia, Marrakech, Morocco.

Program: The program consists of three courses delivered by invited speakers and contributed talks by participants on various topics related to probability and stochastic analysis.

Invited Speakers: I. Gyongy (Univ. of Edinburgh), B. Roynette (Univ. de Nancy), and D. Talay (INRIA, Sophia).

Organizing Committee: M. Eddahbi (secretary), D. Nualart, Y. Ouknine (chairman), and M. Sanz Sole.

Conference Language: The language for all activities of the conference will be English or French.

Information: Y. Ouknine, Departement de Mathematiques Faculte des Sciences, Semlalia B.P. S 15, Marrakech, Morocco; fax: 212-4-43-74-09; e-mail: yo@mbox.azure.net.

29–May 1 **Nonlinear* Problems in Aviation and Aerospace**, Daytona Beach, Florida. (Sept. 1997, p. 1028)

May 1998

* 1–2 **The Duke Mathematics Journal and International Mathematics Research Notices Conference**, Duke University, Durham, North Carolina.

Organizers: R. Hain and J. Wahl.

Information: More information may be obtained from http://www.math.duke.edu/conference/ or by sending e-mail to A. Langen, langen@math.duke.edu.

* 1–2 **Mid-Atlantic Algebra Conference**, James Madison University, Harrisonburg, Virginia.

Scope: This meeting of this continuing series of algebra conferences will be held at James Madison University. Sessions will be held on the afternoon of Friday, May 1, and on both the morning and the afternoon of Saturday, May 2. G. Baumslag will be the principal speaker, giving hour talks Friday and Saturday. The remaining time will be for twenty-minute talks by participants. Attendees who wish to speak should let the organizers know by April 18, 1998.

Organizers: C. Droms, C. Lyons, and G. Peterson.

Information: Contact G. Peterson, e-mail: peterson@math.jmu.edu.

1–3 **Conference on Algebraic Combinatorics and Applications**, Oakland University, Rochester, Michigan. (Dec. 1997, p. 1497)

2–4 **Quadratic Forms and Orthogonal Groups: Conference in Honor of the 70th Birthday of O. Timothy O'Meara**, University of Notre Dame, Notre Dame, Indiana. (Feb. 1998, p. 292)

3–6 **Fourier Analysis and Applications (FAA98)**, Kuwait University, Kuwait. (Jan. 1998, p. 110)

4–8 **NSF-CBMS Regional Research Conference on Wavelet Analysis as a Tool for Computational and Harmonic Analysis**, University of Central Florida, Orlando, Florida. (Jan. 1998, p. 110)

6–8 **Astrophysics and Algorithms: A DIMACS Workshop on Massive Astronomical Data Sets**, Computer Science Dept., Princeton University, Princeton, New Jersey. (Oct. 1997, p. 1157)

7–9 **Fourth SIAM Conference on Control and Its Applications**, Omni Jacksonville Hotel, Jacksonville, Florida. (Oct. 1997, p. 1157)

11–15 **Emerging Applications of Dynamical Systems**, University of Minnesota, Minneapolis, Minnesota. (Sept. 1997, p. 1028)

11–15 **Workshop in Mathematical Population Dynamics**, Gothenburg Stochastic Centre, Chalmers University of Technology, Gothenburg, Sweden. (Oct. 1997, p. 1157)

* 13–15 **The Japan-USA-Vietnam Workshop on Research and Education in Systems, Computation and Control Engineering (RESCCE'98)**, Hanoi, Vietnam.

Scope: The objective of this workshop is to bring together researchers and educators from Japan, the United States, and Vietnam to discuss the integration of research and education in the field of dynamic systems and control engineering.

The control theory and related areas in computations and communications as well as application problems in process control, manufacturing, and mechanical systems will be covered. The workshop should serve as a springboard for initiating a long-lasting cooperation of the three countries as well as neighboring Asian countries on this important subject.

International Program Committee: D. Auslander (USA), P. T. Cat (VN), T. Fukuda (Japan), K. Furuta (Japan), P. M. Ha (VN), S. Hosoe (Japan), S. Kawaji (Japan), T. Mita (Japan), V. N. Phat (VN), R. V. Quoc (USA), N. N. San (VN), S. Sastry (USA), N. K. Son (VN), N. D. Thinh, M. Tomizuka (Japan), T.-C. Tsao (USA).

Potential Invited Speakers: Vietnam: P.T. Cat, P.M. Ha, N.C. Hien, C.T. Huynh, D.C. Khanh, V.N. Phat, N.N. San, N.K. Son, H.D. Tuan, H. Tuy. Japan: M. Akari, T. Fukuda, K. Furuta, S. Kawaji, K. Kosuge, T. Mita, N. Suda, S. Hosoe. USA: D. Auslander, R. V. Quoc, S. Sastry, N. D. Thinh, M. Tomizuka, K. Youcef-Toumi, T.-C. Tsao.

Topics: Research and education in systems, computation and control engineering; infrastructure for control education and research; the role of automation in industrialization; design of control systems: methods and computer tools; control theory and applications: robust control, fuzzy logic control, neural-net control, optimal control, stability and sensitivity of control systems; process control, computer control; real-time software engineering; manufacturing and instrumentation; robotics, mechatronics.

Registration Fee: expected to be 100 USD. Payment to be made on arrival.

Important Dates: February 25, 1998: submission of papers; March 30, 1998: notification of acceptance of contributed papers; April 20, 1998: final version of paper (camera-ready manuscript); May 13-15, 1998: workshop.

Information: Contact: RESCCE'98, V. N. Phat, Institute of Mathematics, P.O. Box 631, Bo Ho 10000, Hanoi, Vietnam; tel: 84-4-8361317; fax: 84-4-8343303; e-mail: vnphat@thevinh.ac.vn.

* 18–22 **Fifth Conference on Probability**, Technical University of Częstochowa, Częstochowa (Poraj), Poland.

Aim: The aim of the conference is to report on and to discuss recent developments and problems in the field of probability theory and its applications.

Organizers: The Fifth Conference is organized jointly by the Institute of Mathematics of Polish Academy of Science, Institute of Mathematics and Computer Science of Technical University of Częstochowa, and Institute of Mathematics of Warsaw University of Technology.

Information: W. Dziubdziela, Institute of Mathematics and Computer Science, ul. Dąbrowskiego 73, 42-200 Częstochowa, Poland; e-mail: probab98@matinf.pcz.czest.pl.

18–23 **Third Conference on Function Spaces**, Southern Illinois University at Edwardsville, Edwardsville, Illinois. (Oct. 1997, p. 1157)

18–24 **Laminations and Foliations in Dynamics, Geometry, and Topology**, Institute for Mathematical Sciences, State University of New York at Stony Brook, Stony Brook, New York. (Jan. 1998, p. 110)

* 20–22 **DIMACS Workshop on External Memory Algorithms and Visualization**, DIMACS Center, Rutgers University, Piscataway, New Jersey.

Organizers: J. Abello, A. Birilis, S. Mahaney, Y. Matias, T. Munzner, W. Sweldens, J. Vitter, K. P. Vo.

Aim: We are witnessing a proliferation of applications that need to process large amounts of information. I/O between main and external memory is becoming an increasingly significant bottleneck. How, where and in what circumstances to involve the user are central questions and

visualization may provide some of the answers. This workshop aims at fostering the cooperation among theoreticians and practitioners in the fields of external memory algorithms and/or visualization.
Deadline: For submissions: February 28, 1998.
Contacts: J. Abello, abello@research.att.com, 973-360-8649 (phone), 973-360-8077 (fax). Local arrangements P. Pravato, DIMACS Center, pravato@dimacs.rutgers.edu, 732-445-5929.
Information: http://dimacs.rutgers.edu/Workshops/Visualization/index.html.

20-23 **Continued Fractions: From Analytic Number Theory to Constructive Approximation**, University of Missouri, Columbia, Missouri. (Feb. 1998, p. 292)

* 21-25 **The 26th Annual Canadian Operator Theory and Operator Algebras Symposium**, University of Alberta, Edmonton, Alberta, Canada.
Invited Speakers: R. Curto (Iowa), K. R. Davidson (Waterloo), G. E. Elliott (Toronto), D. W. Hadwin (New Hampshire), D. Handelman (Ottawa), E. Kaniuth (Paderborn), D. Larson (Texas A&M), G. K. Pedersen (Copenhagen), V. Paulsen (Houston), Z.-J. Ruan (Illinois at Urbana-Champagne), R. R. Smith (Texas A&M).
Information: Please send e-mail to either L.Marcoux@ualberta.ca or tlau@vega.math.ualberta.ca. Information will also be posted to the following website: http://www.math.ualberta.ca/~lmarcoux/spots.html.

24-31 **International Algebraic Conference (Dedicated to the Memory of A. G. Kurosh)**, Moscow State University, Faculty of Mechanics and Mathematics, Department of Algebra, Moscow, Russia. (Jan. 1998, p. 110)

25-27 **The Delft Meeting on Functional Analysis and Nonlinear Partial Differential Equations**, Delft University of Technology, Delft, The Netherlands. (Feb. 1998, p. 293)

25-29 **Conference on Combinatorial and Global Optimization**, Chania, Crete, Greece. (Jan. 1998, p. 110)

26-29 **ICDCS'98, the 18th International Conference on Distributed Computing Systems**, Center of Mathematics and Computer Science (CWI), Amsterdam, The Netherlands. (Oct. 1997, p. 1157)

27-29 **Joint DIMACS-CMU-Georgia Tech Workshop on Large Scale Discrete Optimization**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Oct. 1997, p. 1157)

27-June 2 **Advanced Course on Classifying Spaces and Cohomology of Groups**, Centre de Recerca Matemàtica, Bellaterra, Spain. (Feb. 1998, p. 293)

* 28-30 **First Spanish-Italian Meeting on Financial Mathematics**, University of Almeria, Almeria, Spain.
Sponsors: University of Almeria and Second University of Napoli.
Organizers and Contacts: S. C. Rambaud, e-mail: scruz@ualm.es; and A. G. S. Ventre, e-mail: alventre@unina.it.
Aim: A variety of approaches are possible when working in financial mathematics. One of them is oriented in building theories up to be cast within some general economic paradigm; another, although sensitive to general theories, consists in developing models embodying relevant details of reality. A gap between standard finance theory and the common financial reality must be covered with a bridge. The bricks of the bridge could be (at least partially) provided by a Spanish-Italian Meeting on Financial Mathematics.
Deadline: Papers of a length up to 10 pages should be submitted no later than March 30, 1998.

28-31 **19th Annual Meeting of Canadian Applied Mathematics Society (CAMS/SCMA) and 13th Canadian Symposium on Fluid Dynamics**, Simon Fraser University, Burnaby, British Columbia, Canada. (Sept. 1997, p. 1028)

31-June 6 **Sixth International Spring School "Nonlinear Analysis, Function Spaces and Applications"**, Prague, Czech Republic. (Sept. 1997, p. 1028)

June 1998

June-July **MODELLING '98, 1st IMACS Conference on Mathematical Modelling and Computational Methods in Mechanics and Geodynamics**, Prague, Czech Republic. (Oct. 1997, p. 1157)

1-4 **IASTED International Conference on Computer Graphics and Imaging**, Halifax, Canada. (Dec. 1997, p. 1497)

1-4 **Mathematics and Design 98**, The University of the Basque Country, San Sebastian, Spain. (Dec. 1997, p. 1497)

1-5 **Emerging Applications of Dynamical Systems**, University of Minnesota, Minneapolis, Minnesota. (Sept. 1997, p. 1028)

1-5 **Fifth International Conference on p-Adic Functional Analysis**, A. Mickiewicz University of Poznań, Poland. (Sept. 1997, p. 1028)

1-5 **Fourth International Conference on Mathematical and Numerical Aspects of Wave Propagation**, Colorado School of Mines, Golden, Colorado. (Jan. 1998, p. 110)

1-5 **Model Theory, Algebra and Arithmetic**, Mathematical Sciences Research Institute, Berkeley, CA. (Sept. 1997, p. 1028)

3-6 **Seventh Conference of the International Linear Algebra Society, The Hans Schneider Linear Algebra Conference**, University of Wisconsin-Madison, Madison, Wisconsin. (Nov. 1997, p. 1362)

4-10 **1998 Barcelona Conference on Algebraic Topology**, Centre de Recerca Matemàtica, Bellaterra, Spain. (Feb. 1998, p. 293)

7-19 **NATO ASI—1998 CRM Summer School**, Banff, Alberta, Canada.

* 8-12 **The 1998 Barrett Memorial Lectures: Discrete Conformal Geometry**, University of Tennessee, Knoxville, Tennessee.
Speakers: The principal lecturers are J. Cannon (Brigham Young), J. Heinonen (Michigan), and O. Schramm (Weizmann Institute); each will give a series of three 1-hour talks. There will be additional invited speakers for 1-hour talks, sessions for contributed papers, and a poster/demo session for computational aspects of the topic.
Funding: Some funding is anticipated for those without other support; participation by young researchers and graduate students is particularly encouraged.
Topics: The work of various researchers, prominent among them, Thurston, Sullivan, Gromov, and Cannon, have pointed the way to surprising connections between the "discrete" world of purely combinatorial objects on the one hand and the "conformal" world associated with rigid analytic and geometric structures on the other. Broad examples include tilings and tessellations, the combinatorial Riemann mapping theorem, Alexandrov spaces, discrete notions of hyperbolicity in graph and combinatorial group theory, discrete potential theory, combinatorial proofs in quasiconformal mapping, symbolic dynamics, combinatorial moduli and discrete Teichmuller spaces, Grothendieck's dessins d'enfants, and the discrete analytic structures associated with circle packings.
Goal: This conference is not for specialists in any one area. The goal is to bring together researchers from various areas who are nevertheless uncovering similar links between the discrete and the conformal worlds—to foster interactions across areas by mathematicians who sense some underlying unity and are willing to share their ideas and viewpoints.
Organizer: K. Stephenson.
Information: Visit the Web page at http://www.math.utk.edu/Barrett98/ for latest details on registration, accommodations, funding, deadlines, etc. Send e-mail to barrett98@math.utk.edu for further information.

9-11 **1998 International Conference on Dynamic Systems and Differential Equations**, Shanghai Jiao Tong University, Shanghai, The People's Republic of China. (Sept. 1997, p. 1028)

10-12 **From Erdős to Algorithms: Applications of the Probabilistic Method**, DIMACS Center, Rutgers University, Piscataway, New Jersey (Jan. 1998, p. 111)

12-13 **The Third Biennial Symposium on Mathematical Modeling in the Undergraduate Curriculum**, University of Wisconsin, La Crosse, Wisconsin. (Jan. 1998, p. 111)

* 12–18 **NSF/CBMS Regional Conference in the Mathematical Sciences**, Fort Collins, Colorado.

Topic: Division algebras.

Principal Description: The principal lecturer will give a series of ten one-hour talks on division algebras over a five day period. There will be a small number of additional one-hour talks on this topic.

Information: Contact the conference coordinator: F. DeMeyer, Dept. of Mathematics, Colorado State Univ., Fort Collins CO 80523, e-mail: `demeyer@math.colostate.edu`, or view our web page `http://www.math.colostate.edu/`.

* 13–15 **CMS Summer 1998 Meeting**, University of New Brunswick, Saint John, New Brunswick.

Program: This meeting will feature plenary speakers from a broad spectrum of mathematics by top mathematicians. It will also feature sessions in various areas of mathematics.

Plenary Speakers: K. Davidson (Waterloo), D. Gromoll (SUNY Stony Brook), E. Lutwak (Polytechnic Univ., Brooklyn), S. Schanuel (SUNY Buffalo).

Prize Lectures: The Jeffery-Williams Lecture will be given by G. Elliott, Univ. of Toronto. The Krieger-Nelson Lecture will be given by Catherine Sulem, Univ. of Toronto.

Public Lecture: W. Lawvere, SUNY Buffalo, will deliver a public lecture on Monday, June 15, at 8:00 p.m.

Symposia: There will be symposia in six areas. The session titles and speakers are: *Category Theory*: (Org: R. Wood, Dalhousie Univ.); M. Barr (McGill), M. Bunge (McGill), P. Freyd (Pennsylvania), A. Joyal (UQAM), F. W. Lawvere (SUNY Buffalo), M. Makkai (McGill), S. Niefield (Union), R. Pare (Dalhousie), J. W. Pelletier (York), S. Schanuel (SUNY Buffalo), M. Tierney (Rutgers), W. Tholen (York), R. F. C. Walters (Sydney).

Convex Geometry: (Org: A. C. Thompson, Dalhousie Univ.); L. Batten (Manitoba), T. Bisztriczky (Calgary), J. Bracho (Nat. Univ. Mexico), R. Dawson (SMU), B. Dekster (Mt. Allison), R. Erdahl (Queens), C. Fisher (Regina), R. Gardner (W. Washington), P. Goodey (U. of Oklahoma), E. Grinberg (Temple and Polytechnic Univ.), P. Gruber (Vienna), D. Klain (Georgia Tech.), A. Koldobsky (Univ. Texas, San Antonio), J. D. Lewis (Edmonton), B. Monson (UNB), K. Rybnikov (Queens), R. Schneider (Freiburg, Germany), R. Vitale (U. Conn), A. Weiss (York), E. Werner (Case Western Reserve), G. Zhang (Polytechnic Univ.).

Operator Theory: (Org: H. Radjavi, Dalhousie Univ.); H. Bercovici (Indiana), M. D. Choi (Toronto), R. Curto (Iowa), K. Davidson (Waterloo), D. Farenick (Regina), D. Hadwin (New Hampshire), M. Lamoureux (Calgary), L. Livshits (Colby), V. Lomonosov (Kent State), G. MacDonald (U.P.E.I.), L. Marcoux (Alberta), B. Mathes (Colby), E. Nordgren (New Hampshire), V. Paulsen (Houston), S. Power (Lancaster, U.K.), R. Rosenthal (Toronto), P. Semrl (Maribor, Slovenia), A. Sourour (Victoria).

Relativity and Geometry: (Org: Jacques Hurtubise and Niky Kamran, McGill Univ.); R. Bielawski (Max-Planck Institute, Bonn), C. Boyer (New Mexico), A. Coley (Dalhousie Univ.), A. Dancer (McMaster), P. Ehrlich (Florida), T. Ilmanen (Max-Planck Institute, Leipzig), M. Kossowski (South Carolina), H. Kunzle (Alberta), R. McLenaghan (Waterloo), M. Min-Oo (McMaster), B. Tupper (New Brunswick), J. Wainwright (Waterloo), M. Wang (McMaster), G. Weinstein (Alabama).

Education—Mathematicians Teaching Statistics: (Org: M. Tingley and B. Monson, Univ. of New Brunswick - Fredericton); R. Dawson (SMU), D. Hamilton (Dalhousie).

Combinatorics: (Self-supporting session) (Org: K. Heinrich and B. Alspach, Simon Fraser Univ. and A. Punnen, Univ. of New Brunswick - Fredericton); speakers TBA.

Graduate Student Seminar: (Org: J. Mills, Univ. of New Brunswick - Saint John); A special session is being organized for graduate students. Anyone interested in participating in the organization of this program should contact the meeting director at the following address: `md-s98@cms.math.ca`.

Contributed Papers: Contributed papers of 15 minutes' duration are invited, and **graduate students are particularly urged to participate**. For an abstract to be eligible, the abstract must be received **before March 15, 1998**. The abstract must be accompanied by its contributor's registration form and appropriate fees.

Information: Canadian Mathematical Society, 577 King Edward, Suite 109, POB 450, Station A, Ottawa, Ontario, Canada K1N 6N5; tel: 613-562-5702, fax: 613-565-1539; e-mail: `meetings@cms.math.ca`; WWW: `http://www.camel.math.ca/CMS/Events/summer98/`.

15–17 **Conference on Advances in Applied and Computational Mathematics**, Mathematical Sciences Research Institute, Berkeley, California. (Feb. 1998, p. 293)

* 15–19 **International Conference on Local Differentiable Dynamics and Applications to Bifurcation Theory**, Limburgs Universitair Centrum (L.U.C.), Diepenbeek, Belgium.

Organizers: P. Bonckaert, F. Dumortier.

Scientific Committee: P. Bonckaert, F. Cano, F. Dumortier, R. Roussarie, F. Takens.

Theme: Understanding differentiable dynamics, described by vector fields and diffeomorphisms, and proving rigorous results often require analytical methods such as: linearization, normal forms, desingularization, invariant manifolds and foliations, etc. What is their precise importance in bifurcation and perturbation theory, and how do these fields lead to interesting new questions concerning these analytical methods? Emphasis will be put on the geometric ideas underlying the different techniques and the relations between them. We hope to present a number of survey talks on the subject.

Main Speakers (tentative): G. Belitsky, H. Broer, S. N. Chow, Y. Il'yashenko, H. Kokubu, J. Llibre, M. J. Pacifico, J. Palis, C. Robinson, R. Roussarie, C. Rousseau, C. Simo, J. Sotomayor, F. Takens, M. Viana, J. Yakovenko, J. C. Yoccoz, M. Zhitomirskii.

Information: `http://www.luc.ac.be/Research/DySy/Conference.html`.

15–20 **Second International Conference on Differential Equations and Applications**, St. Petersburg State Technical University, St. Petersburg, Russia. (Oct. 1997, p. 1157)

* 16–19 **Conference on the Theory of Phase Transitions and Free Boundary Problems**, Center for Mathematical Sciences, Zhejiang University, Hangzhou, China.

Scientific Committee: L. Caffarelli (Texas), G. Dong (Hangzhou), A. Friedman (Minnesota), L. Jiang (Shanghai), N. Kenmochi (Japan), T.-T. Li (Shanghai), F. Lin, chair (Chicago).

Organizing Committee: S. Chen, chair (Hangzhou), X. Pan (Hangzhou), S. Zheng (Shanghai).

Scope and Topics: The conference will concentrate on the theory of phase transitions and free boundary problems and their applications. The topics will also include (but not be limited to) phase field equations, sharp interfaces, geometric flows, peak and concentration phenomena, and mathematical superconductivities.

List of Speakers: The following is a tentative list of speakers. An asterisk indicates a confirmed speaker. This list will be updated in a subsequent announcement. *P. Bates (BYU), *L. Caffarelli (Texas), S. J. Chapman (Oxford), S. X. Chen (Shanghai), *X. F. Chen (Pittsburgh), E. DiBenedetto (Northwestern Univ.), *G. C. Dong (Hangzhou), Q. Du (HKUST), *C. Evans (Berkeley), *A. Friedman (Minnesota), *T. Gamba (Texas), Y. Giga (Japan), *Z. C. Guan (Hangzhou), C. F. Gui (UBC, Canada), B. L. Guo (Beijing), K.-H. Hoffmann (Munchen), *J. X. Hong (Shanghai), J. Howison (Oxford), *B. Hu (Notre Dame Univ.), T. Ilemanan (Northwestern Univ.), H. Ishii (Japan), *L. S. Jiang (Shanghai), *S. Jimbo (Japan), *N. Kenmochi (Japan), *T. T. Li (Shanghai), C. S. Lin (Taiwan), *F. H. Lin (Chicago), *K. N. Lu (BYU), S. Luckhaus (Bonn), *M. Mimura (Japan), W. M. Ni (Minnesota), S. Omata (Japan), *T. C. Ouyang (BYU), *X. B. Pan (Hangzhou), *Y. W. Qi (HKUST), T. Riviere (France), *S. Shao (Cleveland), B. Stothe (Bonn), *L. H. Wang (Iowa/UCLA), *X. F. Wang (Tulane), *J. Wu (ARO), *S. P. Wu (Hangzhou), Q. X. Ye (Beijing), *H. M. Ying (Notre Dame Univ.), *S. M. Zheng (Shanghai).

Information: Updated information can be found at the Web site: `http://math.zju.edu.cn/conference.html`. Inquiries concerning the conference should be sent to X. Pan, 1998 PDE Conference, Center for Mathematical Sciences, Zhejiang Univ., Hangzhou 310027, China; or by e-mail to ama_chensp@ema.zju.edu.cn.

17-23 **6th Purdue International Symposium on Statistics**, West Lafayette, Indiana. (Sept. 1997, p. 1028)

* 19-22 **Conference on Control of Distributed Parameter and Stochastic Systems**, Hangzhou, China.

Sponsors: The State Education Commission of China, The National Natural Science Foundation of China, The International Federation for Information and Processing (IFIP), Zhejiang University, Fudan University.

Organizing Committee: S. Chen (Zhejiang Univ.), X. Li (Fudan Univ.), Z. Liu (Univ. of Minnesota at Duluth), G. Yin (Wayne State Univ.), J. Yong (Fudan Univ.), X.Y. Zhou (The Chinese Univ. of Hong Kong).

Advisory Committee: J. Burns (Virginia Tech.), H. F. Chen (Chinese Academy of Science, China), W. H. Fleming (Brown Univ.), I. Lasiecka (Univ. of Virginia), B. Pasik-Duncan (Univ. of Kansas), S. Peng (Shandong Univ., China), T. I. Seidman (Univ. of Maryland at Baltimore County), R. Triggiani (Univ. of Virginia).

Scope and Topics: The conference will concentrate on control of distributed parameter and stochastic systems. The topics will include (but are not limited to) the following: adaptive control, controllability, filtering, identification, manufacturing systems, mathematical finance/insurance, numerical approximation, optimal control, stabilization.

Format: There will be two parallel sessions: distributed parameter systems and stochastic systems. Each speaker will be given 40 minutes for the presentation.

Proceedings: It is expected that the proceedings will be published by either Chapman and Hall or Zhejiang University Press after the conference. Proceedings will include refereed written versions of the talks by the speakers. Detailed instructions will be provided later.

Abstract: To help finalize the organizational matter, each invited speaker is asked to submit a one-page abstract of the presentation to J. Yong by e-mail (TeX or LaTeX files) fax, or airmail by November 1, 1997. The preferred form is the e-mail submission to jyong@ms.fudan.edu.cn; fax: 86-21-65494190; mailing address: J. Yong, Dept. of Mathematics, Fudan Univ., Shanghai 200433, China.

Information: Updated information can be found at the Web site: http://math.zju.edu.cn/conference.html. Inquiries concerning the conference should be addressed to J. Yong or X. Y. Zhou at the following addresses: J. Yong, e-mail: jyong@ms.fudan.edu.cn; fax: 86-21-65494190; X. Y. Zhou, e-mail: xyzhou@se.cuhk.edu.hk, fax: 852-2603-5505.

19-23 **International Interdisciplinary Symposium: Mathematics in the Sciences**, Leipzig, Germany.

Organizers: Adrejewski Foundation and the Max-Planck-Institute for Mathematics in the Sciences (Leipzig).

Goal: The goal of this outstanding symposium is to promote the flow of ideas between mathematics and the sciences in both directions and to open new perspectives for the future.

Lecturers: The following scientists have agreed to give 1-hour lectures: A. Ashtekar, M. Atiyah, J. Ball, R. Bank, A. Connes, S. Edwards, M. Eigen, M. Gromov, H. Hofer, R. James, A. Katok, E. Lieb, B. Schutz, Y. Sinai, L. Tartar, S. Varadhan, J. Wess, S. Yau.

Organizing Committee: J. Jost, S. Mueller, E. Zeidler (MIS), and representing the Adrejewski Foundation, B. Geyer (Leipzig Univ.) and D. Luest (Humboldt Univ., Berlin).

Information: http://www.mis.mpg.de/conferences/symp.98/.

21-24 **LICS'98 (The Thirteenth Annual IEEE Symposium on Logic in Computer Science**, Indiana University Conference Center, Indianapolis. (Sept. 1997, p. 1029)

21-26 **Thirteenth U.S. National Congress of Theoretical & Applied Mechanics**, University of Florida, Gainesville, Florida. (Sept. 1997, p. 1029)

22-26 **The Eighth International Conference on Fibonacci Numbers and Their Applications**, Rochester, New York. (Sept. 1997, p. 1029)

* 22-26 **Mathematical Results in Quantum Mechanics (QMath7)**, Doppler Institute of the Czech Technical University, Prague, Czech Republic.

Organizers: Nuclear Physics Institute of the Czech Academy of Sciences, and Doppler Institute of the Czech Technical University.

Topics: Quantum chaos, quantum dots and waveguides, parameter-dependent Hamiltonians, Schrödinger operators - bound states and scattering, Schrödinger operator spectra and localization properties, solvable models.

Invited Speakers: J. E. Avron (Haifa), J. Bellisard (Toulouse), M. S. Birman (St. Petersburg), G. Casati (Milano), J. M. Combes (Marseille and Toulon), F. Gestesy (Columbia-Missouri), E. H. Lieb (Princeton), L. A. Pastur (Kharkov and Paris), R. Seiler (Berlin), B. Simon (Pasadena), J. Yngvason (Vienna).

Deadline: For abstracts: March 31, 1998.

Related Events: Vienna, Schr. operators ... (first half of June, cf. thoffman@esi.ac.at) and Prague, Quantum groups (June 18-20, cf. burdik@dec1.fjfi.cvut.cz).

Information: e-mail: qmath7@ujf.cas.cz; mail: P. Exner, Nuclear Physics Institute, Academy of Sciences, CZ-250 68 Rez near Prague, Czech Republic. http://www.ujf.cas.cz/~exner/cf98.html; fax: 0420-2-685-7003; phone: 0420-2-6617-3293.

22-26 **Third International Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing**, The Claremont Colleges, Claremont, California. (Oct. 1997, p. 1158)

22-27 **Third Siberian Congress on Industrial and Applied Mathematics (INPRIM-98) dedicated to the memory of S. L. Sobolev (1908-1989)**, Novosibirsk Akademgorodok, Russia. (Sept. 1997, p. 1029)

* 22-July 3 **Mathematics and Molecular Biology: Science for the 21st Century**, University of California at Berkeley, California.

Program: The Program in Mathematics and Molecular Biology (PMMB), with support from the Burroughs Wellcome Fund Interfaces Program, will conduct an introductory short course on research, training and career opportunities at the interface between mathematics and molecular biology. The goal of the short course is to encourage promising students from the physical, chemical and mathematical sciences to apply their unique knowledge and talents to biological problems. Full support (travel and living expenses) is available for selected students in the physical/chemical/mathematical sciences who are in residence at universities in the United States and Canada. Upper level undergraduates and graduate students are invited to apply. The short course will include introductory lectures, laboratory and computer experiences, and discussion groups.

Topics and Teachers: Modern Genome Analysis: P. O. Brown (Stanford Univ.), S. J. Spengler (Lawrence Berkeley Lab.), M. S. Waterman (Univ. Southern California); Nucleic Acid Structure and Topology: N. R. Cozzarelli (U. C. Berkeley), L. Kauffman (U. Illinois at Chicago), D. W. Sumners (Florida State U.), I. Tinoco (U. C. Berkeley); Protein Structure and Folding: B. Berger (MIT), C. Brooks, (Scripps Res. Inst.), M. Levitt (Stanford U.), J. Onuchic (U. C. San Diego), A. Sali (Rockefeller); Quantitative Analysis of Evolution: T. Speed (U. C. Berkeley), E. Thompson (U. Washington).

Information: For information and application materials contact: PMMB, Department of Mathematics, Florida State University, Tallahassee, FL 32306-4510; tel: 850-644-8710; fax: 850-644-6612; e-mail: pmmb@math.fsu.edu; URL: http://www.math.fsu.edu/~pmmb/.

Deadline: For receipt of applications: April 1, 1998. Women and minorities are encouraged to apply.

* 22-August 28 **Astrophysical and Geophysical Flows as Dynamical Systems, GFD Summer Study Program**, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Focus: Many problems in the astrophysical and geophysical sciences surround fluid flows of a very complicated nature. In most situations, the flows are turbulent, and often the problems of interest are complicated further by other physical effects such as rotation, magnetic fields, and chemical and phase changes. Over the last decades, dynamical systems techniques have been fashioned and usefully applied to a variety of relatively simple systems. Attempts have also been made to apply these techniques to the much more complicated problems in astro- and geophysics. Yet how far can this kind of approach be taken?

In the 1998 summer study program, the focus will be on the application of dynamical systems techniques in astro- and geophysical flows. The techniques will be described in detail, and the successes to date in applying them to various problems will be explored. A major, provocative theme of the summer will be whether these techniques allow us anything more than a light, qualitative explanation of the phenomena we see.

The introductory lectures will consist of a discussion of astrophysical and geophysical problems by A. Provenzale, paralleled with tutorials on dynamical systems by C. Tresser and J. D. Crawford.

Fellowships: Up to ten competitive fellowships are available for graduate or postdoctoral students. Successful applicants will receive stipends of $3,900 and an allowance for travel expenses within the United States. Fellows are expected to be in residence for the full ten weeks of the program. The application deadline is February 14, 1998. Awards will be announced by April 1, 1998. We particularly encourage applications from women and members of underrepresented groups.

Information: Application forms may be obtained from: Education Office, Clark Laboratory, MS #31, Fellowship Committee, Woods Hole Oceanographic Institution, 360 Woods Hole Road, Woods Hole, MA 02543-1541; tel: 508-289-2219; e-mail: `lcampbell@whoi.edu`; fax: 508-457-2188. Further information and an electronic application form for student fellowships are available online at `http://www.whoi.edu/gfd/`. Prospective senior visitors, please contact N. Balmforth, the Program Coordinator, by email at `njb@hank.ucsd.edu`.

24-26 **Centennial Congress on M. C. Escher (1898-1972)**, University of Rome "La Sapienza", Rome, Italy. (Feb. 1998, p. 293)

24-27 **Thirteenth Summer Conference on Topology and Its Applications with Workshops on Set-Theoretic Topology and Topological Groups**, Universidad Nacional Autónoma de México (UNAM), Mexico City, D.F. Mexico.

Organizing Committee: S. García-Ferreira (UNAM), I. Puga (UNAM), M. Sanchis (Jaume I), A. Tamariz (UNAM), V. Tkachuk (UAM), J. Trigos-Arrieta (Cal. State Bakersfield), R. G. Wilson (UAM).

Invited Speakers: A. V. Arhangelskii (Moscow State and Ohio), A. Bella (Catania), A. García-Máynez (UNAM), A. Illanes (UNAM), R. Kopperman (CCNY), K. Kunen (Wisconsin), R. McCoy, (V. P. I.), T. Nogura (Ehime).

Workshop Lecturers: I. Juhasz (Hungarian Academy of Sciences) and M. Tkačenko (UAM).

Special Sessions: There will be special sessions on Continuum Theory (coordinated by S. B. Nadler Jr., West Virginia, and W. Charatonik, UNAM), Set-Theoretic Topology (A. Dow, York), Topological Algebraic Structures (W.W. Comfort, Wesleyan, and O. Okunev, UNAM) and Uniform and Quasi-uniform Structures (H. Kunzi, Berne, and S. Romaguera, Politécnica de Valencia). Additionally, there will be a special lecture by D. B. Shakhmatov (Ehime) dedicated to A. V. Arhangelskii on the occasion of his sixtieth birthday.

Topics: All areas of topology-related mathematics, especially set-theoretic topology, continuum theory, geometric topology, and applications of topology to computer science and other areas of mathematics.

Call for Papers: Please send abstracts for contributed papers by June 1, 1998, to `top8@xanum.uam.mx`.

Information: Contact `top8@xanum.uam.mx`, or see the conference home page at `http://www.iztapalapa.uam.mx/summer98/`, or write to R. G. Wilson, Apartado Postal 84-004, 10580 Mexico D.F., Mexico.

25 **LICS'98 Workshop on Formal Methods and Security Protocols**, Indianapolis, Indiana. (Jan. 1998, p. 111)

25 **LICS'98 Workshop on Logic and Diagrammatic Information (LDI'98)**, Indianapolis, Indiana. (Jan. 1998, p. 111)

25-27 **International Conference on Scientific Computing and Mathematical Modeling IMACS'98**, Alicante, Spain. (Jan. 1998, p. 111)

28-July 2 **Pacific Rim Geometry Conference**, Univeristy of British Columbia, Vancouver, British Columbia. (Dec. 1997, p. 1498)

28-July 3 **Conference on Computer-Aided Verification (CAV'98)**, Vancouver, British Columbia. (Jan. 1998, p. 111)

28-July 3 **The Third St. Petersburg Workshop on Simulation**, St. Petersburg, Russia. (Jan. 1998, p. 112)

29-July 1 **Parallel Computing and Algorithms in Economics and Finance (Call for Papers)**, University of Cambridge, Cambridge, United Kingdom. (Feb. 1998, p. 293)

* 29-July 2 **The First International Conference on Functional Differential Equations (FDE1)**, The Research Institute, The College of Judea and Samaria, Ariel, Israel.

Organizing Committee: L. Berezanskii, A. Domoshnitsky, Y. Goltser, G. Kresin, E. Litsyn (chair), and E. Merzbach.

Information: E. Litsyn, `elenal@black.wisdom.weizmann.ac.il`.

* 29-July 2 **International Workshop on Orthogonal Polynomials: Numerical and Symbolic Algorithms**, Madrid, Spain.

Aim: The main aim of the next edition of the workshop is that a reduced number of invited mathematicians discuss and review recent progress in the theory of orthogonal polynomials, with special emphasis on the numerical applications and symbolic algorithms.

Topics: To be considered will be: quadrature formulas, spectral methods in boundary value problems, numerical linear algebra, symbolic algorithms and software, combinatorics.

Contributions: It will be possible for participants who are interested to present their own contributions in the above-mentioned areas. Because of the reduced numbers of short communications, we ask such participants who want to present their work to send as soon as possible (April 30, 1998) the abstract (no more than one page). Priority will be given to those talks closely related to the main subject of the workshop. For online registration visit the WWW page site at `http://dulcinea.uc3m.es/users/workshop/iwop98.html`.

Invited Speakers: W. Gautschi (Purdue Univ.), G. Golub (Stanford Univ.), W. Koepf (Hochschule für Technik), Y. Maday (Univ. Pierre et Marie Curie), M. Petkovsěk (Univ. of Ljubljana), D. Zeilberger (Temple Univ.).

Organizing Committee: M. Alfaro, R. Àlvarez-Nodarse, J. Arvesú, F. Marcellán (chair).

Information: Contact: R. Àlvarez-Nodarse (`nodar@math.uc3m.es`) or F. Marcellán (`pacomarc@ing.uc3m.es`), Departamento de Matemáticas, Escuela Politécnica Superior, Universidad Carlos III de Madrid, Butarque 15, 28911, Leganés, Madrid, Spain; fax: 34-1-624-94-30.

29-July 3 **Arakelov Theory, Values of *L*-Functions**, Newton Institute, Cambridge, United Kingdom. (Jan. 1998, p. 112)

29-July 3 **Second International Conference on Bifurcation Theory and its Numerical Analysis**, Xi'an Jiaotong University, Xi'an, P.R. China. (Dec. 1997, p. 1498)

July 1998

* 3-6 **International Conference on the Teaching of Mathematics**, Village of Pythagorion, Samos, Greece.

Scope: The objective of this international conference is to examine new ways of teaching undergraduate mathematics. It will provide a unique and centralized forum and bring together faculty members from various countries who are committed to introducing and using innovative teaching methods. The conference will be of great interest to mathematics faculty as well as to anyone involved in the teaching and learning process of undergraduate mathematics.

Topics: Educational research, technology, innovative teaching formats, distance learning, reform on specific courses, connections with other disciplines.

Invited Speakers: A. Gleason (Harvard Univ.), C. Laborde (Univ. Joseph Fourier), S. Negrepontis (Univ. of Athens), J. Persens (Univ. of the Western Cape), D. Tall (Warwick Univ.), J. Uhl (Univ. of Illinois), B. Waits (The Ohio State Univ.), E. C. Wittmann (Univ.

Dortmund).

Call for Papers: Contributed papers and poster session submissions are invited for the conference.

Contributed Papers: Contributed paper sessions will consist of several 20-minute presentations. Such presentations should concern original work which has not been published elsewhere. Poster sessions will consist of poster displays scheduled at specific times during the conference. Proposals for papers and displays should contain: an identification of the proposal as a paper or a display, title of the proposal, the name(s) of the author(s) and preferred address and e-mail address of the contact person for the proposal, an extended abstract of 1-1/2 pages double spaced, an identification of the conference topic under which the proposal fits. Please submit your proposal by e-mail (ASCII files only): (if you do not have access to e-mail, send three (3) copies to): W. Barker, Dept. of Mathematics, Yale University, P.O. Box 208283, New Haven, CT 06520-8283; tel: 203-432-7055; fax: 203-432-7316; e-mail: bbarker@math.yale.edu.

Information: Contact: J. Baldwin, Dept. of Math. and Comp. Sci., Capital Univ., Columbus, OH 43209; e-mail: jbaldwin@capital.edu. For information on local arrangements (only): D. Kandilakis, Dept. of Math., Univ. of Aegean, Samos, Greece; e-mail: dkan@aegean.gr; http://icg.fas.harvard.edu/~samos98/.

5-9 **1998 New Zealand Mathematics Colloquium**, Victoria University of Wellington, New Zealand. (Dec. 1997, p. 1498)

5-10 **15th International Conference on Automated Deduction (CADE-15)**, Lindau, Germany. (Jan. 1998, p. 112)

6-10 **International Conference on Ordered Algebraic Structures and Related Areas (OAS '98)**, The Center for Chinese and American Studies, Nanjing University, Nanjing, P. R. China. (Jan. 1998, p. 112)

6-10 **Twenty-Third Australasian Conference on Combinatorial Mathematics and Combinatorial Computing**, The University of Queensland, Brisbane, Australia. (Sept. 1997, p. 1029)

6-17 **Mathematical Models in Population Biology and Epidemiology: From Elementary to the Frontier**, University of Wyoming, Laramie, Wyoming. (Jan. 1998, p. 112)

7-9 **Thirteenth International Conference on Artificial Intelligence in Engineering (AIENG 98)**, Galway, Ireland. (Dec. 1997, p. 1498)

7-11 (Note: NEW DATE) **The 1st IMACS Conference on Mathematical Modelling and Computational Methods in Mechanics and Geodynamics Modelling '98**, Prague, Czech Republic. (Oct. 1997, p. 1157)

7-11 **Chance Workshop**, Dartmouth College, Hanover, New Hampshire.

Aim: Chance is a new introductory quantitative literacy course which teaches basic concepts from probability and statistics in the context of current issues in the news such as medical trials, opinion polls, weather prediction, and the use of DNA fingerprinting in the courts. The aim of the course is to make students better able to understand and critically analyze chance news. The Chance course makes significant use of group learning and activities. The workshop will allow college teachers to experience a brief version of the Chance course and to learn how it is taught.

Applications: Applications can obtained from the Chance web site or by e-mailing to jlsnell@dartmouth.edu or writing to J. L. Snell, Department of Mathematics, Dartmouth College, 6188 Bradley Hall, Hanover NH, 03755-3551. The deadline for applications is March 15, 1998.

Support: This workshop is supported by the NSF.

Information: More information about the Chance course can be found at the Chance web site: http://www.dartmouth.edu/~chance/.

7-17 **Emerging Applications of Dynamical Systems**, University of Minnesota, Minneapolis, Minnesota. (Sept. 1997, p. 1029)

8-10 **4th International Conference on Lattice Paths Combinatorics and Applications**, University of Vienna, Vienna, Austria (Dec. 1997, p. 1498)

8-11 **IFAC-LSS '98, Symposium on Large Scale Systems: Theory and Applications**, Patras, Greece. (Oct. 1997, p. 1158)

9-10 **Workshop on New Methods in Applied and Computational Mathematics (NEMACOM'98)**, Hervey Bay, Queensland, Australia. (Feb. 1998, p. 294)

12-August 1 **IAS/Park City Mathematics Institute**, Park City, Utah. (Jan. 1998, p. 113)

13-17 **International Colloquium on Automata, Languages, and Programming (ICALP'98)**, Aalborg, Denmark. (Jan. 1998, p. 113)

13-17 **1998 SIAM Annual Meeting**, University of Toronto, Toronto, Ontario, Canada. (Jan. 1998, p. 113)

19-24 **International Symposium on Optical Science, Engineering, and Instrumentation, Vision Geometry VII (SD91)**, San Diego, California. (Jan. 1998, p. 113)

*19-25 **IV International Conference on Non-Associative Algebra and Its Applications**, Institute of Mathematics and Statistics, University of Sao Paulo, Sao Paulo, Brazil.

Organizers: The Institute of Mathematics and Statistics (USP) in conjunction with the Institute for Advanced Studies (USP), the Institute of Physics (USP) and the Institute of Theoretical Physics (UNESP).

Program: The program consists of conferences delivered by invited speakers and contributed short talks by participants on various topics related to the field of non-associative algebra and its applications.

Organizing Committee: R. C. F. Costa (chairman), A. Grishkov, H. Guzzo Jr., L. A. Peresi.

Information: Please visit the conference's home page at http://www.ime.usp.br/~ivnonalg/or contact the organizing committee by e-mail ivnonalg@ime.usp.br.

19-August 2 **7th Workshop on Stochastic Analysis**, Didim, Turkey. (Sept. 1997, p. 1029)

20-25 **Exactly Solvable Models in Mathematical Physics**, Chelyabinsk University of Technology, Chelyabinsk, Russia (Feb. 1998, p. 294)

24-25 **Second International Conference on Matrix-Analytic Methods in Stochastic Models**, Winnipeg, Manitoba, Canada. (Sept. 1997, p. 1029)

*26-31 **III Iberoamerican Congress of Mathematics Education (III CIBEM)**, Universidad Central de Venezuela, Caracas, Venezuela.

Aim: The I Iberomerican Congress of Mathematics Education was held at the University of Sevilla, Spain, in 1990. From then on they have been held every four years. The aim of the CIBEM is to promote the interchange of research and development of relevance for the Iberoamerican region in the field of mathematics education.

Call for Contributions: To the Scientific Program: deadline January 31, 1998.

Information: W. Beyer, Coordinator, Scientific Program Committee, Apartado Postal 54087, UCV 1053-A, Caracas, Venezuela; e-mail: iiicibem@sagi.ucv.edu.ve, asovemat@sagi.ucv.edu.ve.

26-August 1 **XV Escola de Algebra**, Canela, Rio Grande do Sul, Brazil. (Feb. 1998, p. 294)

27-August 7 **SMS-NATO ASI: Nonlinear Analysis, Differential Equations, and Control**, Université de Montreal, Montreal, Canada (dec. 1997, p. 1498)

29-August 7 **Frontiers of Combinatorics**, Los Alamos National Laboratory, Los Alamos, New Mexico. (Feb. 1998, p. 294)

August 1998

August-December **The Fields Institute for Research in Mathematical Sciences Program in Probability and Its Applications**, The Fields Institute, Toronto, Ontario, Canada. (Sept. 1997, p. 1029)

*3-7 **Art and Mathematics Conference (AM98)**, University of California at Berkeley, Berkeley, California.

Speakers: J. Conway, H. Ferguson, D. Hoffman, and W. Thurston.

Information: Contact N. Friedman, Dept. of Math., Univ. at Albany-SUNY, Albany, NY 12222; tel: 518-442-4621, fax: 518-442-4731; artmath@math.albany.edu; or C. Sequin, EECS, CS Div., Univ. of California, Soda Hall, Berkeley, CA 94720-1776; tel: 510-642-5103, fax: 510-642-5775; sequin@cs.berkeley.edu or visit http://http.cs.berkeley.edu/~sequin/AM98/index.html.

3-7 **Conference on Lattices and Universal Algebra**, JATE Bolyai Institute, Szeged, Hungary. (Oct. 1997, p. 1158)

3-7 **XI - Brazilian Meeting of Topology**, Departamento de Matematica do Instituto de Geociencias e Ciencias Exatas da UNESP - Rio Claro, Sao Paulo, Brazil. (Dec. 1997, p. 1499)

*3-21 **Mathematical Geophysics Summer School**, Department of Mathematics, Stanford University, Stanford, California.
Program: MGSS is a five-year NSF-funded program organized by Stanford Mathematics. Its purpose is to attract the attention and interest of theoreticians to the many interesting and important problems in geophysics, as well as to define mathematically, address and solve some of these problems. Topics include Seismic Imaging (August 3-21, 1998), Geophysical Tomography (August 1999), and Waves and Heterogeneous Media (2000). The 3-week program will be divided into three roughly equal parts covering applications, theory and computation. There will be daily introductory lectures in the mornings. More specialized lectures (for smaller groups) and seminars will be scheduled in the afternoons.
Information: For more information and application form: http://cartan.stanford.edu/mgss/, or MGSS@math.stanford.edu, or W. Perez, Dept. of Mathematics, Stanford Univ., Stanford, CA 94305-2125.

*4-15 **Summer School on Low Dimensional Topology**, Budapest, Hungary.
Organizing Committee: K. Böröczky Jr. (Math. Inst. Acad, Budapest), A. Némethi (Ohio State Univ.), R. Rimányi (Eötvös Univ., Budapest), A. Stipsicz (Eötvös Univ.), A. Szűcs (Eötvös Univ.).
Speakers: M. Davis (Ohio State Univ.): Nonpositively curved spaces; A. Nèmethi (Ohio State Univ.): The link of surface singularities; W. Neumann (Univ. of Melbourne, Australia): Geometry of 3-manifolds; R. Stern (Univ. of California, Irvine): Differential topology of 4-dimensional manifolds.
Information: The level of the lectures is of a 2nd year PhD course. The lecture series will be accompanied by tutorials. We hope to provide accomodation for the participants. Abstracts and updated information is available at http://www.math-inst.hu/~carlos/difftop.html. For registration or any questions, contact K. Böröczky Jr. at carlos@math-inst.hu. Deadline for application: March 1, 1998.

7-10 **European Summer School: Markov Chain Monte Carlo Methods**, Rebild, Denmark. (Feb. 1998, p. 294)

*9-11 **The Fourth International IMACS Conference on Applications of Computer Algebra**, Czech Technical University, Prague, Czech Republic.
Program Chairs: V. Edneral (edneral@theory.npi.msu.su), W. Kuechlin (kuechlin@informatik.uni-tuebingen.de), R. Liska (liska@siduri.fjfi.cvut.cz).
Organizing Committee: S. Steinberg, M. Wester.
Local Arrangements: J. Limpouch, M. Sinor, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical Univ.
Scope: 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.
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 chairs. All paper submissions must be directed to an organizer of an appropriate special session, which will be listed at the Web sites.
List of Sessions (preliminary): Mechanics; ODEs; problem solving environments; high energy physics; PDEs and symmetries; symbolic-numeric interfaces; general relativity; Hamiltonian systems; seminumerical methods; robotics; geometry; automatic differentiation; control theory; grand challenges; interval arithmetic; industrial applications; software integration; education.
Information: For more information see http://www-troja.fjfi.cvut.cz/aca98/ (or the US mirror http://math.unm.edu/ACA/1998/index.html) or send e-mail to aca98@siduri.fjfi.cvut.cz.

9-15 **Conference on Geometry and Topology**, University of Aarhus, Aarhus, Denmark. (Dec. 1997, p. 1499)

10-13 **Integral Methods in Science and Engineering '98**, Michigan Technological University, Houghton, Michigan. (Dec. 1997, p. 1499)

10-14 **From Individuals to Populations**, Ceske Budejovice, Czech Republic. (Sept. 1997, p. 1030)

10-17 **The 4th International Conference on Theory of Groups (GROUP-KOREA 1998)**, Pusan National University, Pusan, Korea. (Feb. 1998, p. 294)

*13-15 **International Symposium on Symbolic and Algebraic Computation (ISSAC'98 Rostock)**, Universität Rostock, Rostock, Germany.
Sponsor: GI, in cooperation with ACM-SIGSAM.
Forum: ISSAC is a yearly international symposium that provides an opportunity to learn of new developments and to present original research results in all areas of symbolic mathematical computation.
Topics: Include, but are not limited to: algorithmic mathematics, computer science, applications.
Activities: The planned activities include invited presentations, research and survey papers, poster sessions, tutorial courses, vendor exhibits, and software demonstrations. Proceedings will be distributed at the symposium.
Proposals for workshops, tutorial courses, demonstrations, panel discussions, or related activities are welcomed. User-groups, editorial boards, or other associations desiring meeting space during the course of the symposium are encouraged to contact the conference organizers.
Important Dates: January 20, 1998: Submitted papers must be received. March 24, 1998: Notification of acceptance. April 28, 1998: Camera-ready papers must be received.
Information: http://wwwteo.informatik.uni-rostock.de/ISSAC98/.

*13-16 **Conference on Commutative Algebra in Honour of David Rees's 80th Year (a satellite conference of ICM-98)**, Exeter, United Kingdom.
Program: The conference, which is supported financially by the London Mathematical Society and is open to all interested mathematicians, is expected to concentrate on recent and current research in aspects of commutative algebra related to the work of David Rees, including reductions and integral closures of ideals, Rees rings and algebras, uniform Artin-Rees theorems, mixed multiplicities, and Hilbert functions.
Invited Speakers: Among those who have already accepted invitations to speak are C. Huneke (Purdue), D. Katz (Kansas), D. Kirby (Southampton), L. O'Carroll (Edinburgh), N. V. Trung (Hanoi), G. Valla (Genoa), and J. K. Verma (Bombay).
Organizers: R. Y. Sharp (Sheffield) and P. Vámos (Exeter).
Registration Fee: Participants from developed countries will be expected to pay a registration fee of £35.
Information: e-mail: car-meet@maths.ex.ac.uk; conference Web site: http://www.maths.ex.ac.uk/conf_rees.html.

13-17 **Seventh International Colloquium on Numerical Analysis and Computer Science with Applications**, Plovdiv, Bulgaria. (Sept. 1997, p. 1030)

15-23 **International Workshop on Nonlinear and Improperly Posed Problems**, Kocaeli, Turkey. (Feb. 1998, p. 294)

16-21 **1998 IEEE International Symposium on Information Theory**, Massachusetts Institute of Technology, Cambridge, Massachusetts. (Sept. 1997, p. 1030)

*17-September 2 **XXVIIIth Probability Summer School**, Saint-Flour, Cantal, France.
Invited Speakers: M. Emery (C.N.R.S.), A. Nemirovski (Technion-Israel Inst. of Tech.), D. Voiculescu (Univ. of California, Berkeley).
Inscriptions and Information: P. Bernard, Université Blaise Pascal, Mathématiques Appliquées, F63177 Aubiere Cedex; tel:

04-73-40-70-52 or 04-73-40-70-50; fax: 04-73-40-70-64; e-mail: bernard@ucfma.univ-bpclermont.fr.

18-23 **Ninth International Colloquium on Differential Equations**, Plovdiv, Bulgaria. (Sept. 1997, p. 1030)

18-27 **International Congress of Mathematicians (ICM98)**, Berlin, Germany. (June 1996, p. 702)

19-21 **20th Anniversary of Boundary Elements Conference (BEM 20)**, University of Central Florida, Orlando, Florida. (Dec. 1997, p. 1499)

19-23 **4th International Conference on Numerical Methods and Applications**, Sofia, Bulgaria. (Dec. 1997, p. 1499)

24-29 **Fields Institute Workshop on Mathematical Physics of Polymers and Percolation**, The Fields Institute for Research in Mathematical Sciences, Toronto, Ontario, Canada. (Feb. 1998, p. 294)

* 27-31 **ICDEA98 Fourth International Conference on Difference Equations and Applications**, Institute of Mathematics, Poznan University of Technology, Poland.
Topics: General theory of difference equations, asymptotic behaviour, oscillation theory, stability theory, chaos, discrete dynamical systems, discrete transformations, discrete inequalities, numerical methods, approximation theory, control theory, stochastic processes, applications in industrial mathematics and engineering, discrete models in natural sciences, biology, economy etc., miscellaneous.
Main Speakers and Invited Lectures: R. Agarwal (Singapore), K. Aomoto (Japan), O. Arino (France), H. Brunner (Canada), S. Elaydi (USA), L. Erbe (Canada), S. S. Cheng (Taiwan), J. Graef (USA), I. Gyori (Hungary), T. Kaczorek (Poland), I. Kiguradze (Georgia), P. Kloeden (Australia), A. Lasota (Poland), A. Peterson (USA), T. Sauer (USA), A. N. Sharkovsky (Ukraine), B. G. Zhang (China). There will be an open problem session by G. Ladas (USA).
Information: For registration and further information contact: ICDEA98 secretary: A. Marlewski, icdea98@math.put.poznan.pl. For the information on the World Wide Web: http://www.tup.edu.pl/hypertext/put/mm/ICDEA98.html.

* 28-September 3 **Fractal Geometry and Stochastics II**, Univ of Greifswald, Greifswald, Germany.
Topics: Fractal sets and measures, geometric measure theory, stochastic processes and random fractals, connections with dynamical systems, harmonic analysis on fractals.
Invited Speakers: Fukushima, Kahane, Lyubich, Mandelbrot, Moran, Olsen, Peres, Preiss, Solomyak, Taqqu.
Organizers: C. Bandt (Greifswald), S. Graf (Passau), M. Zähle (Jena). Sponsored by Deutsche Forschungsgemeinschaft.
Information: http://www.math-inf.uni-greifswald.de/~fgs2/; e-mail: frac@uni-greifswald.de; fax: +49-3834-864615.

* 30-September 4 **XII Conference on Analytic Functions**, Lublin, Poland.
Organizers: J. G. Krzyz, J. Lawrynowicz, J. Siciak, J. Szynal, E. Zlotkiewicz.
Topics: Conformal and quasiconformal mappings, polynomials, complex dynamics, complex analysis in C^n, Clifford analysis.
Call for Papers: Abstracts of contributed papers of one page at most should be submitted before June 30, preferably by e-mail (using AMS-TEX), to the organizers. The proceedings of the conference will be published as a carefully refereed special issue of the *Annales Universitatis Mariae Curie-Sklodowska* Sect. A.
Fees: The conference fees are US$150 (if paid by June 30) or US$200 (if paid at the conference). The fees cover conference materials, refreshments, and lunch (Monday to Friday).
Information: XII Conference on Analytic Functions, Department of Mathematics, M. Curie-Sklodowska Univ., Plac M. Curie-Sklodowskiej 1, 20-031 Lublin, Poland; e-mail: nowakm@golem.umcs.lublin.pl. Updated information about the conference will be available on our WWW homepage: http://golem.umcs.lublin.pl/~funal/.

30-September 5 **Algebraic Number Theory and Diophantine Analysis**, Graz, Austria. (Sept. 1997, p. 1030)

31-September 4 **Conference on Functional Analysis, Partial Differential Equations and Applications, in honor of V. Mazya**, Rostock, Germany. (Dec. 1997, p. 1500)

31-September 6 **International Conference on Mathematics and Applications Dedicated to the 90th Anniversary of L. S. Pontryagin**, Steklov Mathematical Institute and Moscow State (Lomonosov) University, Moscow, Russia. (Sept. 1997, p. 1030)

September 1998

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

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

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

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

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

* 17-29 **Ninth Crimean Autumn Mathematical Symposium on Spectral and Evolutionary Problems**, Crimea, Ukraine.
Deadline: May 15, 1998.
Organizers: Simferopol State University, Mathematical Foundation of Crimea.

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

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

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

October 1998

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

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

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

* 14-17 **Trends in Mathematical Physics**, University of Tennessee, Knoxville, Tennessee.
Aim: The UTK Departments of Mathematics and Physics are jointly hosting a conference in mathematical physics, to bring together researchers with various backgrounds in mathematics and/or in physics for a series of expository lectures on selected areas in mathematical physics. The aim is to explore the common features shared by various fields of mathematical physics and the underlying mathematics and to create links between researchers across discipline boundaries.
Topics: The conference will consist of a series of plenary lectures on selected topics, both theoretical and computational, including: dendritic growth/pattern formation, mean curvature flow, lattice gauge theory, gauge-theoretic invariants/topology, gravitation/cosmology, fermion dynamical symmetries/Lie algebras.
Speakers: The following speakers have accepted an invitation to give three hour-long lectures each: M. Glicksman (RPI), G. Huisken (Tubingen), C. Michael (Liverpool), C. Taubes (Harvard), C.-L. Wu (Taiwan). Additional speakers are expected.
Funding: Some funds are available to provide financial assistance to graduate students and postdoctoral fellows wishing to attend.
Information: Additional info and updates at the conference Web site: http://ares.math.utk.edu/maphya/.

22-23 **SIAM Workshop on Mathematical**

Foundations for Features in CAD, Engineering, and Manufacturing, Somerset Inn, Troy, Michigan. (Jan. 1998, p. 113)

24-25 **AMS Eastern Sectional Meeting**, Pennsylvania State University, State College, PA. (Sept. 1997, p. 1031)

Information: R. Cascella, `rgc@ams.org`.

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

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

November 1998

* 2-7 **International Conference on Potential Analysis**, Hammamet, Tunisia.

Organizing Committee: D. Feyel (Evry), E. Haouala (Tunis), F. Hirsch (Evry), M. Hmissi (Tunis).

Scientific Committee: Honourary member: G. Choquet (Paris). Members: A. Ancona (Orsay), D. Bakry (Toulouse), P. J. Fitzsimmons (San Diego), M. Fukushima (Osaka), W. Hansen (Bielefeld), L. I. Hedberg (Linkoping), T. Lyons (London), G. Mokobodzki (Paris), D. Nualart (Barcelone), M. Roeckner (Bielefeld) H. Ben Saad (Tunis).

Topics: The themes to be dealt with are those of the journal *Potential Analysis*, devoted to the interactions among potential theory, probability, geometry, and functional analysis. The topics include classical potential theory and its applications to PDEs; nonlinear generalizations; operators, semi-groups, harmonic spaces, Dirichlet spaces; probabilistic interpretations and applications; Markovian stochastic differential equations and diffusion processes; connections with other theories such as harmonic analysis, dynamical systems, martingale theory and stochastic integration; geometry and diffusions on manifolds.

Official Languages: English and French.

Venue and Accommodations: The conference will take place in Hammamet, in one of its beautiful hotels. Hammamet is a well-known touristic city of Tunisia. It is located on the shores of the Cap Bon and right on the sea.

Information: Departement de Mathematiques, Facult des Sciences de Tunis, 1060 Le Belvdre. Tunis, Tunisia; fax: 216-1-885350; e-mail: `ezdine.haouala@fst.rnu.tn`.

14-15 **AMS Western Sectional Meeting**, University of Arizona, Tucson, AZ. (Sept. 1997, p. 1031)

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

December 1998

14-18 **First International Conference on Semigroups of Operators, Theory and Applications**, Marriot Hotel, Newport Beach, California. (Feb. 1998, p. 296)

January 1999

January-June **The Fields Institute for Research in Mathematical Sciences Program in Probability and Its Applications**, The Fields Institute, Toronto, Ontario, Canada.

13-16 **Joint Mathematics Meeting**, San Antonio Convention Center, San Antonio, Texas.

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.

July 1999

*7-17 **Emerging Applications of Dynamical Systems**, University of Minnesota, Minneapolis, Minnesota.

Information: R. N. Shekoury, e-mail: `shekoury@go.com.jo`.

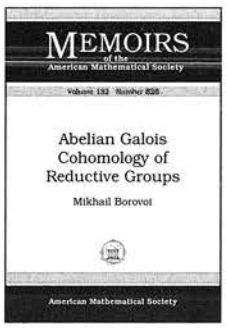
August 1999

*19-21 **20th Anniversary of Boundary Elements Conference (BEM 20)**, University of Central Florida, Orlando, Florida.

Information: R. N. Shekoury, e-mail: `shekoury@go.com.jo`.

New Publications Offered by the AMS

Algebra and Algebraic Geometry



Abelian Galois Cohomology of Reductive Groups

Mikhail Borovoi, *Tel Aviv University, Israel*

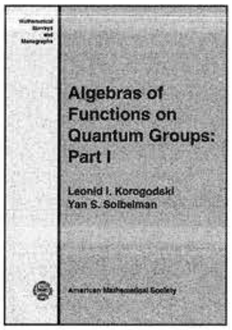
In this volume, a new functor $H^2_{ab}(K, G)$ of abelian Galois cohomology is introduced from the category of connected reductive groups G over a field K of characteristic 0 to the category of abelian groups. The abelian Galois cohomology and the abelianization map $ab^1 : H^1(K, G) \to H^2_{ab}(K, G)$ are used to give a functorial, almost explicit description of the usual Galois cohomology set $H^1(K, G)$ when K is a number field.

Contents: Introduction; The algebraic fundamental group of a reductive group; Abelian Galois cohomology; The abelianization maps; Computation of abelian Galois cohomology; Galois cohomology over local fields and number fields; References.

Memoirs of the American Mathematical Society, Volume 132, Number 626

February 1998, 50 pages, Softcover, ISBN 0-8218-0650-5, LC 97-47116, 1991 *Mathematics Subject Classification*: 20G10; 14E20, 18G50, **Individual member $21**, List $35, Institutional member $28, Order code MEMO/132/626N

Independent Study



Algebras of Functions on Quantum Groups: Part I

Leonid I. Korogodski and **Yan S. Soibelman**, *Institute for Advanced Study, Princeton, NJ*

The book is devoted to the study of algebras of functions on quantum groups. The authors' approach to the subject is based on the parallels with symplectic geometry, allowing the reader to use geometric intuition in the theory of quantum groups. The book includes the theory of Poisson-Lie algebras (quasi-classical version of algebras of functions on quantum groups), a description of representations of algebras of functions and the theory of quantum Weyl groups. This book can serve as a text for an introduction to the theory of quantum groups.

Contents: Introduction; Poisson Lie groups; Quantized universal enveloping algebras; Quantized algebras of functions; Quantum Weyl group and the universal quantum R-matrix; Bibliography.

Mathematical Surveys and Monographs

April 1998, approximately 167 pages, Hardcover, ISBN 0-8218-0336-0, 1991 *Mathematics Subject Classification*: 17B37; 16W30, 81R50, **All AMS members $39**, List $49, Order code SURV-SOIBELMANN

Algèbre Non Commutative, Groupes Quantiques et Invariants

J. Alev and **G. Cauchon**, Editors

The seventh meeting of the Contact Franco-Belge was held in Reims in June 1995. The goal of the meeting was the presentation of recent advances in several related areas where a non-commutative algebraic approach is necessary.

The first part of the book contains five articles on new progress in classical problems; the second part, five papers on Hopf algebras, quantum groups and their representations; and the third part, six papers on invariant theory and representation theory. Two chapters are in French, remaining chapters are in English.

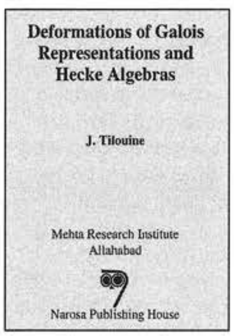
Titles in this series are published by the Société Mathématique de France and distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: S. S. Abhyankar, Hilbert's Thirteenth Problem; **B. Keller**, Basculement et homologie cyclique; **A. A. Kirillov**

and **A. Melnikov**, On a remarkable sequence of polynomials; **M. Van den Bergh**, Division algebras on $\mathbb{P}^2$ of odd index, ramified along a smooth elliptic curve are cyclic; **A. van den Essen**, Polynomial automorphisms and the Jacobian conjecture; **S. Caenepeel**, Harrison cocycles and the group of Galois coobjects; **J. Donin**, **D. Gurevich**, and **V. Rubtsov**, Quantum hyberboloid and braided modules; **S. M. Khoroshkin**, Central extension of the Yangian double; **C. M. Ringel**, Quantum Serre relations; **L. Willaert**, Schematic algebras and the Auslander-Gorenstein property; **M. Brion**, Sur certains modules gradués associés aux produits symétriques; **A. Joseph**, Coxeter structure and finite group action; **H. Derksen** and **H. Kraft**, Constructive invariant theory; **L. Le Bruyn**, Orbits of matrix tuples; **O. Mathieu**, Some conjectures about invariant theory and their applications; **A. Melnikov**, Dense orbits in orbital varieties in $\mathfrak{sl}_n$.

Séminares et Congrès, Number 2

December 1997, 294 pages, Softcover, ISBN 2-85629-052-3, 1991 *Mathematics Subject Classification*: 05A15, 12F10, 13A20, 13A50, 13B05, 13P99, 14A15, 14A22, 14E07, 14E09, 14H30, 14L30, 14M99, 15A57, 16E40, 16G20, 16K20, 16R30, 16W30, 16W50, 17B20, 17B35, 17B37, 18E30, 18R50, 20C30, 20D06, 20E22, 20G05, 20E25, **Individual member $59**, List $66, Order code SECO/2N



Deformations of Galois Representations and Hecke Algebras

J. Tilouine, *Université de Paris Nord, Villetaneuse, France*

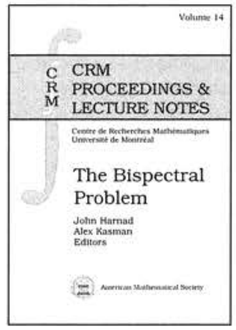
This book presents an expanded version of a course delivered at Hokkaïdo University (Sapporo, Japan) and at the Mehta Research Institute (Allahabad, India). Its aim is to examine aspects of the relationship connecting the local moduli space of deformations of a mod p "modular" Galois representation $\bar{\rho}$ to the corresponding local component of a p-adic Heck algebra.

Published by Narosa Publishing House and distributed by the AMS exclusively in North America and Europe and non-exclusively elsewhere.

Contents: In guise of introduction: GL_1 and class-field theory; Deformation theory; Deformations of Galois representations; The universal ring, functorialities; Obstructions, estimates on dimension; Nearly ordinary Galois representations and their deformations; The Krull dimension of $R^{n.o}$; The Hida-Iwasawa algebra; Classical groups; Universal nearly ordinary Hecke algebra; References.

October 1996, 108 pages, Softcover, ISBN 81-7319-106-9, 1991 Mathematics Subject Classification: 11FXX, **All AMS members $19**, List $24, Order code DGRN

Analysis



The Bispectral Problem

John Harnad and **Alex Kasman**, *Centre de Recherches Mathématiques, Université de Montréal, PQ, Canada*, Editors

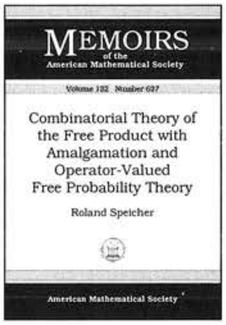
Although originally posed in the context of mathematical problems related to medical imaging, the bispectral problem is now closely related to other topics and has connections to many areas of pure and applied mathematics. The central theme of this book is the search for solutions to eigenvalue problems that satisfy additional equations in the spectral parameter, for example, pairs of eigenvalue equations. This problem, which looks very simple at first, has turned out to be both deep and difficult. Moreover, this concept of bispectrality has been shown to be useful in many active areas of current research in mathematics and physics.

Following several years of exciting new results on the subject, in March 1997 the Centre de Recherces Mathématiques held the first scientific meeting devoted exclusively to the bispectral problem. Collected in this volume are contributions from the speakers at this meeting. The participants at this workshop included a majority of those researchers who have made significant contributions to the subject and many others working on related problems.

Contents: *Part 1:* **B. Bakalov**, **E. Horozov**, and **M. Yakimov**, Automorphisms of the Weyl algebra and bispectral operators; **Y. Berest**, Huygens' principle and the bispectral problem; **F. A. Grünbaum**, Some bispectral musings; **L. Haine**, Beyond the classical orthogonal polynomials; **J. Harnad**, Bispectral operators, dual isomonodromic deformations, and the Riemann-Hilbert dressing method; **A. Kasman**, Darboux transformations and the bispectral problem; **F. Levstein** and **L. F. Matusevich**, The discrete version of the bispectral problem; **M. Rothstein**, Explicit formulas for the Airy and Bessel bispectral involutions in terms of Calogero-Moser pairs; **V. Spiridonov**, **L. Vinet**, and **A. Zhedanov**, Bispectrality and Darboux transformations in the theory of orthogonal polynomials; **A. P. Veselov**, Baker-Akhiezer functions and the bispectral problem in many dimensions; **G. Wilson**, Bispectral algebras of ordinary differential operators; **J. P. Zubelli**, The bispectral problem, rational solutions of the master symmetry flows, and bihamiltonian systems; *Part 2:* **V. Kac** and **J. van de Leur**, The geometry of spinors and the multicomponent BKP and DKP hierarchies; **F. Magri**, The Hamiltonian route to Sato Grassmannian; **V. B. Matveev**, Darboux transformations in associative rings and functional-difference equations; **A. Yu. Orlov**, Remarks about the Calogero-Moser system and the KP equation; Subject index.

CRM Proceedings & Lecture Notes, Volume 14

March 1998, 235 pages, Softcover, ISBN 0-8218-0949-0, LC 97-44028, 1991 *Mathematics Subject Classification*: 34L95, 33C45; 58F07, 13N10, 34L99, 35Q53, 70H05, **Individual member $39**, List $65, Institutional member $52, Order code CRMP/14N



Combinatorial Theory of the Free Product with Amalgamation and Operator-Valued Free Probability Theory

Roland Speicher, *University of Heidelberg, Germany*

Free probability theory, introduced by Voiculescu, has developed very actively in the last few years and has had an increasing impact on quite different fields in mathematics and physics. Whereas the subject arose out of the field of von Neumann algebras, presented here is a quite different view of Voiculescu's amalgamated free product. This combinatorial description not only allows re-proving of most of Voiculescu's results in a concise and elegant way, but also opens the way for many new results.

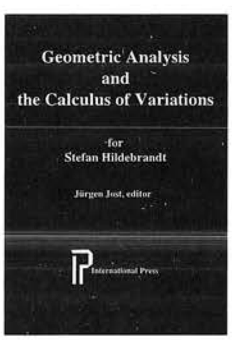
Unlike other approaches, this book emphasizes the combinatorial structure of the concept of "freeness". This gives an elegant and easily accessible description of freeness and leads to new results in unexpected directions. Specifically, a mathematical framework for otherwise quite ad hoc approximations in physics emerges.

This text will also be of interest to those working in discrete mathematics and combinatorics.

Contents: Preliminaries on non-crossing partitions; Operator-valued multiplicative functions on the lattice of non-crossing partitions; Amalgamated free products; Operator-valued free probability theory; Operator-valued stochastic processes and stochastic differential equations; Bibliography.

Memoirs of the American Mathematical Society, Volume 132, Number 627

February 1998, 88 pages, Softcover, ISBN 0-8218-0693-9, LC 97-46539, 1991 *Mathematics Subject Classification*: 46L50; 60-XX, 06-XX, **Individual member $23**, List $39, Institutional member $31, Order code MEMO/132/627N



Geometric Analysis and the Calculus of Variations

for Stefan Hildebrandt

Jürgen Jost, Editor

This text is dedicated to S. Hildebrandt on his 60th birthday and includes current works by his students, colleagues, and friends.

After fleeing East Germany in 1958, Hildebrandt met again his former academic teacher Ernst Hölder in Mainz. This reunion allowed Hildebrandt to continue his mathematics education, which was based on the Liepzig tradition of mathematical analysis of L. Lichenstein, O. Hölder (father of Ernst), E. Hopf and others.

A frequent visitor at the Courant Institute in New York during the time at which the regularity theory for elliptic systems and minimal surfaces were prominent research topics, Hildebrandt formed lasting friendships with other brilliant analysts of his generation: Rabinowitz, Trudinger, Wente, and Widman.

At Courant, he also met the grand masters of the time: Courant, Lewy, Moser and, Nirenberg. In the 30s, when Douglas, Radó, and Courant founded the modern theory of minimal surfaces, the question of boundary regularity for minimal surfaces remained unsettled. Hildebrant achieved a complete solution of the problem. His result not only completed the classical theory, but also was a basis for subsequent new developments. The result brought Hildebrandt immediate fame. He was made a full professor in Mainz in 1967 and in Bonn in 1970. This theorem was only the first in an impressive series of fundamental results by Hildebrandt on various geometrically defined variational problems.

His contributions continued to be fundamental for later research. He achieved a lasting and formative influence on the geometric calculus of variations through his scientific contributions, and also through his direction of several research projects at the German Research Foundation (DFG) and his systematic education and support of a younger generation of German analysts. This book is a compilation of contributed works by those who wish to express their gratitude for the generous support Hildebrandt provided.

International Press publications are distributed worldwide, except in Japan, by the American Mathematical Society.

Contents: **U. Dierkes** and **G. Huisken**, The N-dimensional analogue of the catenary; **F. Duzaar** and **K. Steffen**, The plateau problem for parametric surfaces; **C. Gerhardt**, Closed Weingarten hypersurfaces in space forms; **M.-C. Hong**, **J. Jost**, and **M. Struwe**, Asymptotic limits of a Ginzburg-Landau type functional; **N. M. Ivochkina**, **M. Lin**, and **N. S. Trudinger**, The Dirichlet problem for the prescribed curvature quotient equations; **J. Jost**, Generalized harmonic maps between metric spaces; **N. Korevaar** and **L. Simon**, Equations of mean curvature type; **E. Kuwert**, Weak limits in the freee boundary problem; **F. H. Lin**, Asymptotically conic elliptic operators and Liouville type theorems; **S. Müller** and **V. Šverák**, Attainment results for the two-well problem by convex integration; **B. Nelli** and **J. Spruck**, Constant mean curvature hypersurfaces; **P. H. Rabinowitz**, Homoclinics for a singular Hamiltonian system; **F. Sauvigny**, Uniqueness of Plateau's problem for certain contours; **A. J. Tromba**, Dirichlet's energy on Teichmüller's space is strictly pluri-subharmonic; **H. C. Wente**, The Plateau problem for boundary curves with connectors; **B. White**, Half of Enneper's surface minimizes area; **R. Ye**, Foliation by constant mean curvature spheres.

International Press

December 1997, 383 pages, Hardcover, ISBN 1-57146-037-3, 1991 *Mathematics Subject Classification*: 35-06, 53-06, **All AMS members** $34, List $42, Order code INPR/26N

Supplementary Reading

An Introduction to Measure and Integration

Inder K. Rana, *Indian Institute of Technology, Pawai, India*

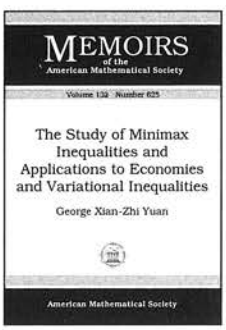
This volume presents a motivated introduction to a subject that goes under various headings such as real analysis, Lebesgue measure and integration, measure theory, modern analysis, advanced analysis, etc.

Prerequisite for the text is a first course in mathematical analysis. The text can be used for a one-year course in the topic as indicated by the title. Due to the lecture-notes style of the text, it would also be appropriate to use for individual self-study. Included is a chart depicting the logical interdependence of the chapters.

Published by Narosa Publishing House and distributed by the AMS exclusively in North America and Europe and non-exclusively elsewhere.

Contents: Prologue: The length function; Riemann integration; Recipes for extending the Riemann integral; Extending the length function; general extension theory; The Lebesgue measure on ℝ and its properties; Integration; Fundamental theorem of the integral calculus for Lebesgue integrals; Measure and integration on product spaces; Modes of convergence and L_p-spaces; The Radon-Nikodym theorem and its applications; Signed measures and complex measures; Appendix; References; Symbol index; Subject index.

March 1997, 380 pages, Hardcover, ISBN 81-7319-120-4, 1991 *Mathematics Subject Classification*: 28-01, **All AMS members $39**, List $49, Order code IMIN



The Study of Minimax Inequalities and Applications to Economies and Variational Inequalities

George Xian-Zhi Yuan, *University of Queensland, Brisbane, Australia*

This book provides a unified treatment for the study of the existence of equilibria of abstract economics in topological vector spaces from the viewpoint of Ky Fan minimax inequalities, which strongly depend on his infinite dimensional version of the classical Knaster, Kuratowski and Mazurkiewicz Lemma (KKM Lemma) in 1961. Studied are applications of general system versions of minimax inequalities and generalized quasi-variational inequalities, and random abstract economies and its applications to the system of random quasi-variational inequalities are given.

Features:

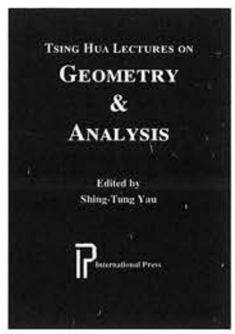
- Presents new results and recent development of KKM theory.
- Offers an overview of modern and up-to-date treatment of the KKM theory, including related articles covering theory and applications.
- Uses an interdisciplinary approach with specific applications in mathematics and economics.
- Includes a comprehensive bibliography.

This text will also be of interest to those working in applications.

Contents: The KKM principle related to Ky Fan minimax inequalities and fixed point theorems; Equilibria of abstract economics in Hausdorff topological vector spaces; Equilibria of abstract economics in locally convex topological vector spaces; Equilibria in Frechet spaces; Equilibria in topological spaces and some applications; Maximal elements and coincidence theorems in product topological spaces; Random abstract economics and applications.

Memoirs of the American Mathematical Society, Volume 132, Number 625

February 1998, 140 pages, Softcover, ISBN 0-8218-0747-1, LC 97-47117, 1991 *Mathematics Subject Classification*: 46H03, 47H04, 47H10, 47N10, 49J35, 49J40, 90A14, 90D06, 90D13, **Individual member $26**, List $43, Institutional member $34, Order code MEMO/132/625N



Tsing Hua Lectures on Geometry & Analysis

Shing-Tung Yau, *Harvard University, Cambridge, MA*, Editor

This book presents lectures given during a seminar organized by S.-T. Yau at Tsing Hua University (Taiwan). Included are lectures by experts in the field and students who studied under Yau. Contributions by guest lecturers and students made this a lively and successful seminar.

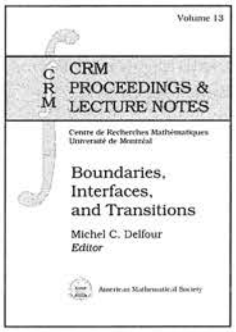
International Press publications are distributed worldwide, except in Japan, by the American Mathematical Society.

Contents: **R. Bartnik**, Energy in general relativity; **S.-C. Chang**, The Calabi flow $\frac{\partial\lambda}{\partial t} = \Delta R$ on Einstein manifolds; **S.-C. Chang**, Existence and convergence of solutions; **C.-C. Chen** and **J.-F. Hwang**, Closed geodesics; **S. Y. Cheng**, On the Chern conjecture for minimal hypersurface; **F. R. K. Chung**, **A. Grigor'yan**, and **S.-T. Yau**, Eigenvalues and diameters for manifolds and graphs; **F. R. K. Chung** and **S.-T. Yau**, A combinatorial trace formula; **G. Huisken**, Lecture one: Mean curvature evolution; **G. Huisken**, Lecture two: Singularities of the mean curvature flow; **G. Huisken**, Lecture three: an evolution equation for isoperimetric problem; **G. Huisken**, Lecture four: an evolution of metrics by the Ricci curvature; **Y.-J. Hong**, On the estimate of the gap between the first two eigenvalues; **J. Jost**, Minimal surfaces and Teichmueller theory; **J. Jost** and **S.-T. Yau**, Harmonic maps and superrigidity; **N. C. Lee**, Estimates for heat kernel and Green's function; **P. Li**, Harmonic maps of complete manifolds; **P. Li**, Harmonic functions on complete Riemannian manifolds; **C.-H. Lin** and **M.-T. Wang**, A note on the exhaustion function for complete manifolds; **L. Simon**, Lectures on singularities of variational problems; **S.-T. Yau**, Sobolev inequality for measure spaces; **S. T. Yau**, A note on the distribution of critical points of eigenfunctions; **M. Dafermos**, Exhaustions of complete manifolds of bounded curvature.

International Press

December 1997, 322 pages, Hardcover, ISBN 1-57146-042-X, 1991 *Mathematics Subject Classification*: 35-06, 53-06, 83-06, **All AMS members $34**, List $42, Order code INPR/25N

Applications



Boundaries, Interfaces, and Transitions

Michel C. Delfour, *Centre de Recherches Mathématiques, Montréal, PQ, Canada*, Editor

There is currently considerable mathematical interest and very real potential for applications in using geometry in the design, identification and control of technological processes. Geometry plays the role of a design variable in the shape optimization of mechanical parts. It also appears as a control variable in optimal swimming, shape control of aircraft wings or stabilization of membranes and plates by periodic variations of the boundary. As it is used as a design or control variable, it often undergoes "mutations" as in the microstructures of materials, crystal growth, image processing or the texture of objects which involve relaxations of classical geometry and geometrical entities. In other areas, such as free and moving boundary problems, the understanding of the underlying phenomena is very much related to the geometric properties of the fronts and the nature of the nonlinearities involved.

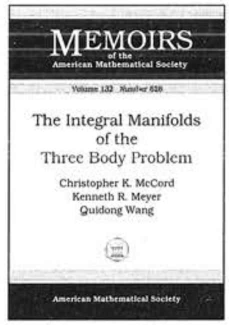
This book brings together tools that have been developed in a priori distant areas of mathematics, mechanics and physics. It provides coverage of selected contemporary problems in the areas of optimal design, mathematical models in material sciences, hysteresis, superconductivity, phase transition, crystal growth, moving boundary problems, thin shells and some of the associated numerical issues.

Contents: K. Coughlin, The transition to turbulence via turbulent bursts; **M. C. Delfour**, Intrinsic differential geometric methods in the asymptotic analysis of linear thin shells; **M. C. Delfour** and **J.-P. Zolésio**, Shape analysis via distance functions: Local theory; **I. Müller**, Six lectures on shape memory; **J. Rubinstein**, Six lectures on superconductivity; **H. M. Soner**, Front propagation; **A. Visintin**, Six talks on hysteresis; **M. J. Ward**, Dynamic metastability and singular perturbations; **J.-J. Xu**, Dendrites, fingers, interfaces and free boundaries.

CRM Proceedings & Lecture Notes, Volume 13

April 1998, approximately 352 pages, Softcover, ISBN 0-8218-0505-3, LC 97-52240, 1991 *Mathematics Subject Classification*: 35Kxx, 73Kxx, 73Bxx, 82Dxx, 49Qxx, 76Fxx; 76Exx, 35Qxx, 73Exx, 35Dxx, 47Hxx, **Individual member $57**, List $95, Institutional member $76, Order code CRMP/13N

Mathematical Physics



The Integral Manifolds of the Three Body Problem

Christopher K. McCord and **Kenneth R. Meyer**, *University of Cincinnati, OH*, and **Quidong Wang**, *University of California, Los Angeles*

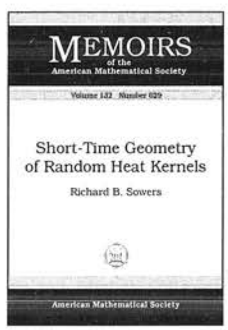
The phase space of the spatial three-body problem is an open subset in $\mathbb{R}^{18}$. Holding the ten classical integrals of energy, center of mass, linear and angular momentum fixed defines an eight dimensional submanifold. For fixed nonzero angular momentum, the topology of this manifold depends only on the energy. This volume computes the homology of this manifold for all energy values. This table of homology shows that for negative energy, the integral manifolds undergo seven bifurcations. Four of these are the well-known bifurcations due to central configurations, and three are due to "critical points at infinity". This disproves Birkhoffs conjecture that the bifurcations occur only at central configurations.

Contents: Introduction; The decomposition of the spaces; The cohomology; The analysis of $\mathfrak{K}(c, h)$for equal masses; The analysis of $\mathfrak{K}(c, h)$ for general masses; Bibliography.

Memoirs of the American Mathematical Society, Volume 132, Number 628

February 1998, 92 pages, Softcover, ISBN 0-8218-0692-0, LC 97-47115, 1991 *Mathematics Subject Classification*: 70F07, 58F05, 57R57; 58F14, **Individual member $24**, List $40, Institutional member $32, Order code MEMO/132/628N

Probability



Short-Time Geometry of Random Heat Kernels

Richard B. Sowers, *University of Illinois, Urbana*

This volume studies the behavior of the random heat kernel associated with the stochastic partial differential equation $du = \frac{1}{2}\Delta u dt = (\sigma, \nabla u) \circ dW_t$, on some Riemannian manifold M. Here Δ is the Laplace-Beltrami operator, σ is some vector field on M, and ∇ is the gradient operator. Also, W is a standard Wiener process and $\circ$ denotes Stratonovich integration. The author gives short-time expansion of this heat kernel. He finds that the dominant exponential term is classical and depends only on the Riemannian distance function. The second exponential term is a work term and also has classical meaning. There is also a third non-negligible exponential term which blows up. The author finds an expression for this third exponential term which involves a random translation of the index form and the equations of Jacobi fields. In the process, he develops a method to approximate the heat kernel to any arbitrary degree of precision.

Contents: Introduction; Guessing the dominant asymptotics; Initial condition and evolution of the approximate kernel; The Minakshisundaram-Pleijel coefficients; Error estimates, proof of the main theorem, and extensions; Appendices; Bibliography.

Memoirs of the American Mathematical Society, Volume 132, Number 629

February 1998, 130 pages, Softcover, ISBN 0-8218-0649-1, LC 97-47114, 1991 *Mathematics Subject Classification*: 35A08, 35K05, 60H15, 93E11; 35A30, 35R60, 58G11, 58G18, 58G32, 60G35, **Individual member $25**, List $41, Institutional member $33, Order code MEMO/132/629N

AMERICAN MATHEMATICAL SOCIETY

PUBLICATIONS *of* CONTINUING INTEREST

Graduate Studies in Mathematics Series

The *Graduate Studies in Mathematics* series appeals to students and to professors. Specifically designed as graduate studies texts, they are also suitable for recommended course reading and/or supplemental course reading. In addition, they make ideal independent study resources. Subject range and in-depth topic coverage also make the *Graduate Studies in Mathematics* series an excellent acquisition for all academic libraries that support mathematics programs.

Partial Differential Equations
Lawrence C. Evans, *University of California, Berkeley*
1998; ISBN 0-8218-0772-2; approximately 712 pages; Hardcover;
All AMS members $60, List $75, Order Code GSM-EVANSCI83

Discovering Modern Set Theory. II: Set-Theoretic Tools for Every Mathematician
Winfried Just, *Ohio University, Athens*, and **Martin Weese**, *University of Potsdam, Germany*
Volume 18; 1997; ISBN 0-8218-0528-2; 224 pages; Hardcover;
All AMS members $29, List $36, Order Code GSM/18CI83

Topics in Classical Automorphic Forms
Henryk Iwaniec, *Rutgers University, New Brunswick, NJ*
Volume 17; 1997; ISBN 0-8218-0777-3; 259 pages; Hardcover;
All AMS members $31, List $39, Order Code GSM/17CI83

Fundamentals of the Theory of Operator Algebras. Volume II
Advanced Theory
Richard V. Kadison, *University of Pennsylvania, Philadelphia*, and **John R. Ringrose**, *University of Newcastle, Newcastle upon Tyne, England*
Volume 16; 1997; ISBN 0-8218-0820-6; 676 pages; Hardcover;
All AMS members $55, List $69, Order Code GSM/16CI83

Fundamentals of the Theory of Operator Algebras. Volume I
Elementary Theory
Richard V. Kadison, *University of Pennsylvania, Philadelphia*, and **John R. Ringrose**, *University of Newcastle, Newcastle upon Tyne, England*
Volume 15; 1997; ISBN 0-8218-0819-2; 398 pages; Hardcover;
All AMS members $47, List $59, Order Code GSM/15CI83

Analysis
Elliott H. Lieb, *Princeton University, NJ*, and **Michael Loss**, *Georgia Institute of Technology, Atlanta, GA*
Volume 14; 1996; ISBN 0-8218-0632-7; 278 pages; Hardcover;
All AMS members $28, List $35, Order Code GSM/14CI83

The Ergodic Theory of Discrete Sample Paths
Paul C. Shields, *University of Toledo, OH*
Volume 13; 1996; ISBN 0-8218-0477-4; 249 pages; Hardcover;
All AMS members $31, List $39, Order Code GSM/13CI83

Lectures on Elliptic and Parabolic Equations in Hölder Spaces
N. V. Krylov, *University of Minnesota, Minneapolis*
Volume 12; 1996; ISBN 0-8218-0569-X; 164 pages; Hardcover;
All AMS members $23, List $29, Order Code GSM/12CI83

Enveloping Algebras
Jacques Dixmier, *Paris, France*
Volume 11; 1996; ISBN 0-8218-0560-6; 379 pages; Hardcover;
All AMS members $47, List $59, Order Code GSM/11CI83

Representations of Finite and Compact Groups
Barry Simon, *California Institute of Technology, Pasadena*
Volume 10; 1995; ISBN 0-8218-0453-7; 266 pages; Hardcover;
All AMS members $27, List $34, Order Code GSM/10CI83

An Invitation to Arithmetic Geometry
Dino Lorenzini, *University of Georgia, Athens*
Volume 9; 1996; ISBN 0-8218-0267-4; 397 pages; Hardcover;
All AMS members $47, List $59, Order Code GSM/9CI83

Discovering Modern Set Theory. I: The Basics
Winfried Just, *Ohio University, Athens*, and **Martin Weese**, *Humboldt University, Berlin, Germany*
Volume 8; 1995; ISBN 0-8218-0266-6; 210 pages; Hardcover;
All AMS members $29, List $36, Order Code GSM/8CI83

Algebraic Number Fields, Second Edition
Gerald J. Janusz, *University of Illinois, Urbana*
Volume 7; 1995; ISBN 0-8218-0429-4; 276 pages; Hardcover;
All AMS members $35, List $44, Order Code GSM/7CI83

Lectures on Quantum Groups
Jens Carsten Jantzen, *Aarhus Universitet, Denmark*
Volume 6; 1995; ISBN 0-8218-0478-2; 266 pages; Hardcover;
All AMS members $35, List $44, Order Code GSM/6CI83

Algebraic Curves and Riemann Surfaces
Rick Miranda, *Colorado State University, Ft. Collins*
Volume 5; 1995; ISBN 0-8218-0268-2; 390 pages; Hardcover;
All AMS members $35, List $44, Order Code GSM/5CI83

The Integrals of Lebesgue, Denjoy, Perron, and Henstock
Russell A. Gordon, *Whitman College, Walla Walla, WA*
Volume 4; 1994; ISBN 0-8218-3805-9; 395 pages; Hardcover;
All AMS members $35, List $44, Order Code GSM/4CI83

An Introduction to Gröbner Bases
William W. Adams, *University of Maryland, College Park*, and **Philippe Loustaunau**, *George Mason University, Fairfax, VA*
Volume 3; 1994; ISBN 0-8218-3804-0; 289 pages; Hardcover;
All AMS members $29, List $36, Order Code GSM/3CI83

Combinatorial Rigidity
Jack Graver, *Syracuse University, NY*, and **Brigitte Servatius** and **Herman Servatius**, *Worcester Polytechnic Institute, MA*
Volume 2; 1993; ISBN 0-8218-3801-6; 172 pages; Hardcover;
All AMS members $25, List $32, Order Code GSM/2CI83

The General Topology of Dynamical Systems
Ethan Akin, *City College (CUNY), New York*
Volume 1; 1993; ISBN 0-8218-3800-8; 261 pages; Hardcover;
All AMS members $29, List $36, Order Code GSM/1CI83

AMS
AMERICAN MATHEMATICAL SOCIETY

All prices subject to change. Charges for delivery are $3.00 per order. For optional air delivery outside of the continental U. S., please include $6.50 per item. *Prepayment required.* Order from: **American Mathematical Society**, P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax (401) 455-4046 or call toll free 800-321-4AMS (4267) in the U. S. and Canada, (401) 455-4000 worldwide. Or place your order through the AMS bookstore at http://www.ams.org/bookstore/. Residents of Canada, please include 7% GST.

For more publications in your subject area visit the AMS Bookstore: www.ams.org/bookstore/

Classified Advertisements

Positions available, items for sale, services available, and more

CONNECTICUT

CENTRAL CONNECTICUT STATE UNIVERSITY
Mathematics

Assistant Professor-Fall 1998. Tenure-track appointment, pending funding of position. Teach a wide variety of courses, ranging from introductory service courses to advanced courses for majors. Teaching load 12 credits per semester. Continued scholarly activity expected. Ph.D. in mathematics required by date of appointment. Experience teaching at a public university and using technology in the classroom a plus. Research background in analysis, dynamical systems, or differential geometry preferred, but any specialty will be considered, including applied mathematics. Please send a letter of application detailing teaching philosophy and research plans, a current curriculum vitae, and three letters of reference (one of which must focus on teaching) to Dr. Jeffery McGowan, Chair, Mathematics Search Committee, Central Connecticut State University, New Britain, CT 06050-4010. Review of applications will begin on March 31, 1998. CCSU aggressively pursues a program of equal employment and educational opportunity and affirmative action. Members of all underrepresented groups, women, veterans, and persons with disabilities are invited and encouraged to apply.

GEORGIA

GEORGIA INSTITUTE OF TECHNOLOGY
The Southeast Applied Analysis Center

The Southeast Applied Analysis Center, in the School of Mathematics, invites applications for postdoctoral/visiting positions in applied mathematics. Fields of interest include combinatorics and algorithms, scientific computing, stochastic analysis, differential equations and modelling. Applicants should arrange for a curriculum vitae, at least three letters of recommendation, and a summary of research plans to be sent to Professor Leonid A. Bunimovich, Director, SAAC, School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332-0160. Georgia Tech, a member of the University System of Georgia, is an Equal Opportunity/Affirmative Action Employer.

INDIANA

UNIVERSITY OF NOTRE DAME
Department of Mathematics
Notre Dame, IN 46556

The Department of Mathematics of the University of Notre Dame invites applications for several visiting and postdoctoral positions to begin in the fall of 1998. These are one-year positions with the possibility for renewal for an additional year. They carry a teaching load of two courses per semester. The department is particularly interested in applicants in fields compatible with its interests: algebra, algebraic geometry, complex analysis, partial differential equations, differential geometry, logic, algebraic topology, and several areas of applied mathematics. Salaries are competitive. The evaluation of candidates will begin on March 1, but late and/or incomplete applications will be considered. To apply, send a curriculum vitae along with a letter of application and a completed AMS Standard Cover Sheet to: Alexander J. Hahn, Chair, at the above address. Please arrange for three letters of recommendation to be sent to the same location. These letters should address the applicant's research accomplishments and at the same time supply evidence that the applicant has the ability to communicate effectively in the classroom. Notre Dame is an Equal Opportunity Employer. Women and minorities are urged to apply.

LOUISIANA

LOUISIANA TECH UNIVERSITY
Mathematics and Statistics

The College of Engineering and Science invites applications for possible non-tenure-track positions at the rank of instructor and tenure-track positions at the rank of assistant professor commencing fall 1998. Rank and salary will be commensurate with qualifications. Excellent credentials are required. Teaching duties will be primarily at the freshman and sophomore

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 1997 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: April issue–January 21, 1998; May issue–February 23, 1998; June/July issue–April 24, 1998; August issue–May 15, 1998; September issue–June 15, 1998; October issue–July 21, 1998.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 1373 (vol. 44).

Situations wanted advertisements from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the U.S. and Canada, or 401-455-4084 worldwide, for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940, or via fax, 401-331-3842, or send e-mail to classads@ams.org. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Advertisers will be billed upon publication.

levels. The Mathematics and Statistics Program offers a B.S., an M.S., and is a major participant in the interdisciplinary Applied Computational Analysis and Modeling Ph.D. program. Please send a letter of application, curriculum vitae, and a list of three professional references to: Dr. James Nelson, Associate Dean for Undergraduate Studies, College of Engineering and Science, Louisiana Tech University, Ruston, LA 71272-0046. Applications will be accepted until April 1, 1998. Louisiana Tech University is an Equal Opportunity/ Affirmative Action Employer. Women and minorities are encouraged to apply.

NEW JERSEY

WILLIAM PATERSON UNIVERSITY
Department of Mathematics

The faculty of William Paterson University seek to create a welcoming and nurturing campus climate for a diverse faculty, staff, and student body. In this spirit, the Department of Mathematics invites applications for two (possibly three) tenure-track positions starting September 1, 1998. The requirements are a Ph.D. in mathematics, strong evidence of commitment to quality teaching, and an ongoing research program.

The department is committed to improving retention and recruitment of students via advisement, precollege programs, and curriculum development. The department is also involved in teacher-training programs. For one position (at the assistant/associate professor level) preference will be given to candidates with demonstrated interest or experience in these activities (position AA).

For the other position(s) (at the assistant professor level) preference will be given to candidates whose field of interest is either in areas of applied mathematics such as mathematical physics, applied analysis, and PDE, or in areas of discrete mathematics such as combinatorics, optimization, graph theory, and computational mathematics (position BB).

Send a letter of interest clearly indicating the position, current vita, graduate transcript (unofficial), and three letters of reference (at least one letter or other evidence should specifically address the applicant's ability to teach effectively) to Dr. S. Maheshwari, Chairperson, Math. Dept., WPUNJ, Wayne, NJ 07470. Review of applications will begin immediately and will continue till the positions are filled. Salary is commensurate with experience. Evidence of U.S. citizenship or permanent residency is required. WPUNJ is an Equal Opportunity/AA Employer and actively seeks applications from women, minorities, and underrepresented groups.

NORTH CAROLINA

UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Mathematics Department
Charlotte, NC 28223

1) Applications are invited for a tenure-track assistant/associate/full professor position in statistics, effective 8/98. Duties include developing research programs, teaching undergraduate and graduate courses, supervising master's and Ph.D. theses, and consulting. Junior candidates must demonstrate strong potential, and senior candidates must have proven outstanding records in teaching, research, consulting, and external funding. 2) Several visiting positions are also available in statistics, probability, numerical analysis, analysis, topology, ODE/PDE, and algebra. Please send vita, three letters of recommendation, and a short abstract of current research to Professor Zhiyi Zhang, Department of Mathematics, University of North Carolina at Charlotte, Charlotte, NC 28223. AA/EOE.

NORTH CAROLINA STATE UNIVERSITY
Department of Mathematics

The Department of Mathematics expects to make an appointment in the general area of applied probablity, subject to budgetary approval. The appointment is expected to be at the tenure-track assistant professor level (although a higher-level appointment might be possible for an exceptionally well-qualified applicant). Applicants should have a Ph.D. as well as a tangible record of significant research contributions and an outstanding teaching record. The department has an active group of applied mathematicians with interests including stochastic processes, control, filtering, optimization, and probability. The most serious consideration will be given to candidates who have demonstrated experience in both applications and theory and whose interests complement those listed above. The successful candidate will have the opportunity to become a member of the Center for Research in Scientific Computation, which facilitates interdisciplinary graduate education and research collaboration among applied mathematicians, scientists, and engineers from academia, industry, and government labs. Qualified applicants should send a detailed curriculum vitae, a one-page statement of their teaching and research objectives, and three letters of recommendation to Prof. K. Ito, Dept. of Mathematics, NC State University, Raleigh, NC 27695-8205; kito@eos.ncsu.edu. Full consideration will be given to completed applications received by March 15, 1998. NCSU is an AA/EOE. In its commitment to diversity and equity, NCSU seeks applications from women, minorities, and the disabled.

OKLAHOMA

THE UNIVERSITY OF OKLAHOMA
Department of Mathematics

Applications are invited for two full-time, tenure-track positions beginning August 16, 1998. The positions are initially budgeted at the assistant professor level, but an appointment at the associate professor level may be possible for an exceptional candidate with qualifications and experience appropriate to that rank. Normal duties consist of teaching two courses per semester, conducting research, and rendering service to the department, university, and profession at a level appropriate to the faculty member's experience. Both positions require an earned doctorate and research interests that are compatible with those of the existing faculty; preference will be given to applicants with potential or demonstrated excellence in research and prior successful undergraduate teaching experience. For one of the positions, additional preference will be given to applicants with research interests in applied or computational mathematics. Salary and benefits are competitive. For full consideration, applicants should send a completed AMS cover sheet, curriculum vitae, a description of current and planned research, and three letters of recommendation (at least one of which must address the applicant's teaching experience and proficiency) to:

Search Committee
Department of Mathematics
University of Oklahoma
Norman, OK 73019-0315
Phone: 405-325-6711
Fax: 405-325-7484
e-mail: search@math.ou.edu

Screening of applications will begin on February 15, 1998, and will continue until the position is filled.

The University of Oklahoma is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply. UO has a policy of being responsive to the needs of dual-career couples.

PENNSYLVANIA

PENNSYLVANIA STATE UNIVERSITY

The Commonwealth College invites applications for an assistant professor, tenure-track, 36-week mathematics position at Penn State Fayette. Starting date: August 1998 or as negotiated. Appointment is in the Commonwealth College. Tenure-track faculty are evaluated in the areas of teaching, research, and service, with a typical course load of three courses in the areas of introductory calculus, linear algebra, differential equations, and vector calculus. A Ph.D. in mathematics is required, and at least several years of postdoctoral teaching experience is a plus. Evidence of research productivity will be essential. A commitment to alternative learning techniques and environments will also be considered an asset. A full description of the position and its location is available at: http://www.cwc.psu.edu/. Applicants should submit a letter of application, résumé, academic transcript, and the names, addresses (including e-mail if possible), and phone numbers of three references to: Dr. John Madden, Acting Associate Dean, The Pennsylvania State University, 111 Old Main, Box 005, University Park, PA 16802. Applications will be reviewed beginning immediately and will continue until a suitable candidate is found. The Pennsylvania State University is an Affirmative Action/Equal Opportunity Employer. Women and minorities are encouraged to apply.

PENNSYLVANIA STATE UNIVERSITY

The Commonwealth College invites applications for an assistant professor, tenure-track, 36-week mathematics position at Penn State McKeesport. Starting date: August 1998 or as negotiated. Appointment is in the Commonwealth College to teach 12 contact hours per week of courses in mathematics. Ph.D. in mathematics required. A full description of the position and its location is available at: http://www.cwc.psu.edu/. Applicants should submit a letter of application, résumé, academic transcript, and the names, addresses (including e-mail if possible), and phone numbers of three references to: Dr. John Madden, Acting Associate Dean, The Pennsylvania State University, 111 Old Main, Box 005, University Park, PA 16802. Applications will be reviewed beginning immediately and will continue until a suitable candidate is found. The Pennsylvania State University is an Affirmative Action/Equal Opportunity Employer. Women and minorities are encouraged to apply.

PENNSYLVANIA STATE UNIVERSITY

The Commonwealth College invites applications for an assistant professor, tenure-track, 36-week mathematics position at Penn State Beaver. Starting date: August 1998 or as negotiated. Appointment is in the Commonwealth College to teach standard freshman and sophomore college-level mathematics courses. Candidates in all areas of mathematics will be considered. Candidate must also be committed to scholarly endeavors, including research and publications, and participate actively in campus life. Ph.D. in mathematics and some teaching experience, possibly as a graduate student. A full description of the position and its location is available at: http://www.cwc.psu.edu/. Applicants should submit a letter of application, résumé, academic transcript, and the names, addresses (including e-mail if possible), and phone numbers of three references to: Dr. John Madden, Acting Associate Dean, The Pennsylvania State University, 111 Old Main, Box 005, University Park, PA 16802. Applications will be reviewed beginning immediately and will continue until a suitable candidate is found. The Pennsylvania State University is an Affirmative Action/Equal Opportunity Employer. Women and minorities are encouraged to apply.

WYOMING

UNIVERSITY OF WYOMING
Visiting Positions in Mathematics

The Department of Mathematics anticipates hiring one or more visiting (non-tenure-track) faculty for the 1998-99 academic year. Salary will be appropriate for an assistant professor or for a senior professor seeking a sabbatical supplement. Responsibilities include (1) teaching two courses per semester and (2) contributing to one or more of our active research groups in algebra and combinatorics, analysis, applied mathematics, and math education.

Candidates should have an earned doctorate, proven teaching ability, and strong research promise. Please send vita, three letters of reference, and a statement of teaching qualifications to Myron B. Allen, Head, Department of Mathematics, University of Wyoming, Laramie, WY 82071-3036. (Applicants for tenure-track positions need not submit duplicate applications for visiting positions.) Applications received by March 16, 1998, will receive first consideration.

For more information visit our Web site, http://math.uwyo.edu/. Persons seeking admission, employment, or access to programs of the University of Wyoming shall be considered without regard to race, color, national origin, political belief, handicap, or veteran status.

CYPRUS

UNIVERSITY OF CYPRUS
Department of Mathematics and Statistics
P.O. Box 537
1678 Nicosia, Cyprus

Applications are invited for one tenure-track position in the area of algebra or algebraic geometry at the rank of lecturer or assistant professor. Applications, including a curriculum vitae with a list of publications, a brief statement of research interests, and three letters of reference should be sent to the above address by March 6, 1998.

HONG KONG

THE CHINESE UNIVERSITY OF HONG KONG

Applications are invited for:

Department of Mathematics: (1) Lecturer (carrying the academic title of assistant professor or associate professor, as appropriate) (Ref 97/102(047)/2)

Applicants should specialize in applied analysis/scientific computing and have excellent research and teaching record. Those specializing in other fields with outstanding research profiles will also be considered. The appointee is expected to have effective interaction with other faculty members. Appointment will initially be made on a one-year or two-year contract commencing September 1998.

(2) Instructor (Ref 97/103(047)/2)

Applicants should be excellent teachers and be able to teach a broad range of applied mathematics courses and have experience in computer laboratory. Applicants with strong research profile are preferred. Appointment will initially be made on a one-year contract commencing September 1998.

Annual Salary and Fringe Benefits, Lecturer: HK$522,780-873,360 by 10 increments; Instructor: HK$333,480-527,280 by 10 increments or HK$250,380-318,480 by 5 increments (approx. exchange rate in November 1997: £1=HK$13.22; US$1 = HK$7.8). Starting salary and grade will be commensurate with qualifications and experience.

For post (1): Benefits include leave with full pay, medical and dental care, children's education allowance, housing benefit for eligible appointee subject to the rules for prevention of double housing benefits (with appointee contributing 7.5% of salary toward the provision of housing), and where applicable a contract-end gratuity (15% of basic salary).

For post (2): Benefits include annual leave, medical and dental care.

Further information about the University and the general terms of service for appointees is available on our World Wide Web home page: http://www.cuhk.edu.hk.

Application Procedure:

Please send full résumé, copies of academic credentials, a publication list and/or abstracts of selected published papers, together with names and addresses (fax numbers/e-mail addresses as well, if available) of three referees, to the Personnel Office, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong (Fax: 852-2603-6852) before March 31, 1998. Please quote the appropriate reference number and mark "Recruitment" on cover.

WEST INDIES

UNIVERSITY OF THE WEST INDIES
Cave Hill Campus

Applications are invited from suitably qualified persons for the post of professor or professor/senior lecturer in computer science in the Department of Computer Science, Mathematics and Physics, University of the West Indies, Cave Hill Campus, Barbados. The successful applicant must have sound academic credentials in computer science, with a proven record of publication and distinction in any area of specialization in the discipline. Candidates with experience in providing pedagogical and administrative leadership, particularly at the postgraduate level, and an ability to become involved in outreach and collaborative work in industry and commerce and with organizations/institutions would be highly favored. Duties to be assumed by August 1, 1998, or as soon as possible thereafter. Salary Scale: Professor (in the range): BDS$84,120–103,488 per annum. Senior Lecturer: BDS$60,216 x 1956 - 71,952 x 2112 - 78,288 (Bar) x 2112 - 82,512 per annum. Up to five (5) full economy class passages plus baggage allowance of US$1,800 on appointment and normal termination. Special allowance up to US$600 for shipment of academic books and teaching/research equipment on appointment. Unfurnished accommodations at 10% of basic salary, or optional housing allowance of 20% of basic salary to staff making own housing arrangements. UWI contribution of equivalent of 10% of basic salary to Superannuation Scheme. Annual Study and Travel Grant for self, spouse, and up to three (3) children. Book Grant up to BDS$935 per annum. Detailed application (three copies) giving full particulars of qualifications and experience, and the names and addresses of three (3) referees should be sent as soon as possible to the Campus Registrar, University of the West Indies, P.O. Box 64, Bridgetown, Barbados. In order to expedite the appointment procedure, applicants are advised to ask their referees to send confidential reports directly to the Campus Registrar without waiting to be contacted. The University will send further particulars for this post to all applicants.

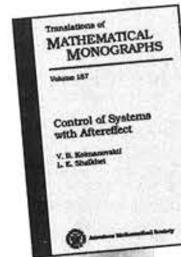
PUBLICATIONS WANTED

MATHEMATICS BOOKS PURCHASED

Pure & appl. adv. & research level, any age, usable cond. Reprints OK. One box to whole libraries sought. Contact: Collier Brown or Kirsten Berg @ **Powell's Technical Bks.**, Portland, OR. Call 800-225-6911, fax 503-228-0505, or e-mail: `kirsten@technical.powells.com`.

American Mathematical Society

Probability



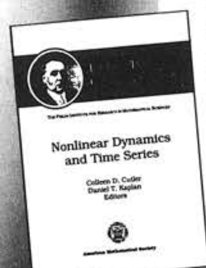
Control of Systems with Aftereffect

V. B. Kolmanovskiĭ, *Moscow University of Electronics and Mathematics, Russia,* and **L. E. Shaĭkhet,** *Donetsk State Academy of Management, Russia*

The study of natural and social phemomena indicates that the future development of many processes depends not only on their present state, but also on their history. Such processes can be described mathematically by using the machinery of equations with aftereffect.

This book is a comprehensive, up-to-date presentation of control theory for hereditary systems of various types. Topics covered include background of the theory of hereditary equations, their applications in modeling real phenomena, optimal control of deterministic and stochastic systems, optimal estimation of systems with delay, and optimal control with uncertainties. The exposition is illustrated by examples, figures, and tables.

Translations of Mathematical Monographs, Volume 157; 1997; 336 pages; Hardcover; ISBN 0-8218-0374-3; List $99; Individual member $59; Order code MMONO/157NA



Nonlinear Dynamics and Time Series

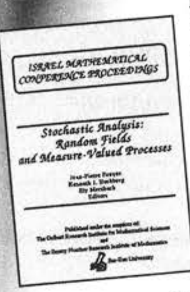
Colleen D. Cutler, *University of Waterloo, ON, Canada,*
Daniel T. Kaplan, *McGill University, Montreal, PQ, Canada,*
Editors

This book is a collection of research and expository papers reflecting the interfacing of two fields: nonlinear dynamics (in the physiological and biological sciences) and statistics. It presents the proceedings of a four-day workshop entitled "Nonlinear Dynamics and Time Series: Building a Bridge Between the Natural and Statistical Sciences" held at the Centre de Recherches Mathématiques (CRM) in Montréal in July 1995. The goal of the workshop was to provide an exchange forum and to create a link between two diverse groups with a common interest in the analysis of nonlinear time series data.

Features:

- A survey of state-of-the-art developments in nonlinear dynamics time series analysis with open statistical problems and areas for further research.
- Contributions by statisticians to understanding and improving modern techniques commonly associated with nonlinear time series analysis, such as surrogate data methods and estimation of local Lyapunov exponents.
- Starting point for both scientists and statisticians who want to explore the field.
- Expositions that are readable to scientists outside the featured fields of specialization.

Fields Institute Communications, Volume 11; 1997; 252 pages; Hardcover; ISBN 0-8218-0521-5; List $79; Individual member $47; Order code FIC/11NA



Stochastic Analysis: Random Fields and Measure-Valued Processes

Jean-Pierre Fouque, *Ecole Polytechnic, CMAP, Palaiseau, France,*
Kenneth J. Hochberg and **Ely Merzbach,** *Bar-Ilan University, Ramat-Gan, Israel*

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

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

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

All prices subject to change. Charges for delivery are $3.00 per order. For optional air delivery outside of the continental U. S., please include $6.50 per item. *Prepayment required.* Order from: **American Mathematical Society,** P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax (401) 455-4046 or call toll free 800-321-4AMS (4267) in the U. S. and Canada, (401) 455-4000 worldwide. Or place your order through the AMS bookstore at http://www.ams.org/bookstore/. Residents of Canada, please include 7% GST.

Centre de recherches mathématiques
Theme Year 1998-1999: Number Theory and Arithmetic Geometry

The theme year in number theory and arithmetic geometry will emphasize several current directions: Algebraic cycles and Shimura varieties, Elliptic curves and modular forms, Representations of p-adic groups, Analytic theory of automorphic L-functions. Following is a schedule of events:

Workshops

NATO ASI - 1998 CRM Summer School
The arithmetic and geometry of algebraic cycles
(Banff, Alberta)
June 7-19, 1998
Organizers: J.D. Lewis (Alberta), N. Yui (Queen's), B. Gordon (Oklahoma), S. Müller-Stach (Essen), S. Saito (Tokyo Institute of Technology)

The list of invited speakers includes: A. Beilinson, S. Bloch, J.-L. Colliot-Thélène, H. Esnault, P. Gajer, B. van Geemen, H. Gillet, B. Gordon, M. Green, U. Jannsen, A. Langer, B. Lawson, J. Lewis, S. Müller-Stach, K. Murty, J. Nekovár, D. Ramakrishnan, W. Raskind, Masahiko Saito, Shuji Saito, Takeshi Saito, C. Schoen, A. Scholl, C. Soulé, V. Voevodsky, N. Yui, D. Zagier, Y. Zarhin

Workshop on Algebraic modular forms and modular forms mod p
October 2-8, 1998
Organizers: H. Darmon (McGill and CICMA) and G. Savin (Utah)

There will be two five-hour lecture series:
B. Gross (Harvard), *Algebraic modular forms*
K. Ribet (UC Berkeley), *Modular forms and two-dimensional Galois representations*
The list of invited participants includes: B. Birch, K. Buzzard, G. Frey, W.-T. Gan, K. Khuri-Makdisi, S. Kudla, J. Lantsky, S. Padowitz, D. Pollack, G. Savin

Workshop on Analytic number theory
October 23-28, 1998
Organizer: R. Murty (Queen's)
The list of invited speakers includes: D. Boyd, K. Dilcher, W. Duke, J. Friedlander, S. Gonek, R. Gupta, J. Hoffstein, H. Iwaniec, K. Murty, R. Murty, M. Nair, A. Perelli, R. Raghunathan, C.S. Rajan, M. Rosen, P. Sarnak, C. Stewart

CMS Winter Meeting Special Session in Number Theory
December 13-15, 1998
Organizer: R. Murty (Queen's) and N. Yui (Queen's)

Workshop on Representations of reductive p-adic groups
(Queen's University, Kingston, Ontario)
May 9-13, 1999
Organizer: F. Murnaghan (Toronto)
The list of invited speakers includes: J. Adler, D. Goldberg, A. Helminck, P. Kutzko, D. Manderscheid, L. Morris, A. Moy, M. Reeder, B. Roberts, A. Roche, P. Sally Jr., G. Savin

Workshop on Arithmetical algebraic geometry
May 14-18, 1999
Organizers: M. Goresky (IAS) and K. Murty (Toronto)
The list of invited speakers includes: A. Baragar, W. Casselman, H. Darmon, B. Gordon, M. Goresky, E. Kani, M. Kolster, J. Kramer, J. Lewis, K. Murty, M. Nori, J. Scherk, N. Yui, S.-W. Zhang

Moonshine Workshop
May 29-June 4, 1999
Organizer: J. McKay (Concordia)

Sixth Conference of the Canadian Number Theory Association
(Winnipeg, Manitoba)
Co-sponsored by The Fields Institute
June 20-24, 1999
Organizers: J. Borwein (Simon Fraser), D. Boyd (UBC), C. David (CICMA and Concordia), R. Murty (Queen's), C. Stewart (Waterloo) and H. Williams (Manitoba)

Seminar courses

Seminar courses will last from one to three months.

Modular forms and congruences
September - December, 1998
Lecturer: H. Darmon (McGill and CICMA)

The Chebotarev density theorem and some applications
October, 1998
Lecturer: K. Murty (Toronto)

An introduction to sieve methods
November, 1998
Lecturer: R. Murty (Queen's)

Mini-courses

There will be several mini-courses of two weeks each spread throughout the year.

Iwasawa theory of modular forms
September, 1998
Lecturer: M. Bertolini (Universita di Pavia)

Ordinary representations and modular forms
October, 1998
Lecturer: C. Skinner (Institute for Advanced Study)

Rankin-Selberg L-functions
November, 1998
Lecturer: C.S. Rajan (Tata Institute)

Modular forms and modular curves
January, 1999
Lecturer: I. Chen (CICMA, Concordia, and McGill)

Automorphic forms over function fields
January, 1999
Lecturer: A. Schweizer (CICMA, Concordia, and McGill)

Hilbert modular varieties
February, 1999
Lecturer: E. Goren (CICMA, Concordia, and McGill)

Topics in p-adic Galois representations
February, 1999
Lecturer: A. Iovita (CICMA, Concordia, and McGill)

Polynomial constructions, Galois theory and elliptic curves
March, 1999
Lecturer: J.-F. Mestre (Paris VII, Jussieu)

The spectrum of multiplicative values
The distribution, and extreme values, of L-functions
March, 1999
Lecturer: A. Granville (Georgia)

Representations of reductive p-adic groups
April, 1999
Lecturer: F. Murnaghan (Toronto)

Chaire Aisenstadt Lectures

September 1998
Lecturer: Andrew Wiles (Princeton)
May 1999
Lecturer: Frans Oort (Utrecht)

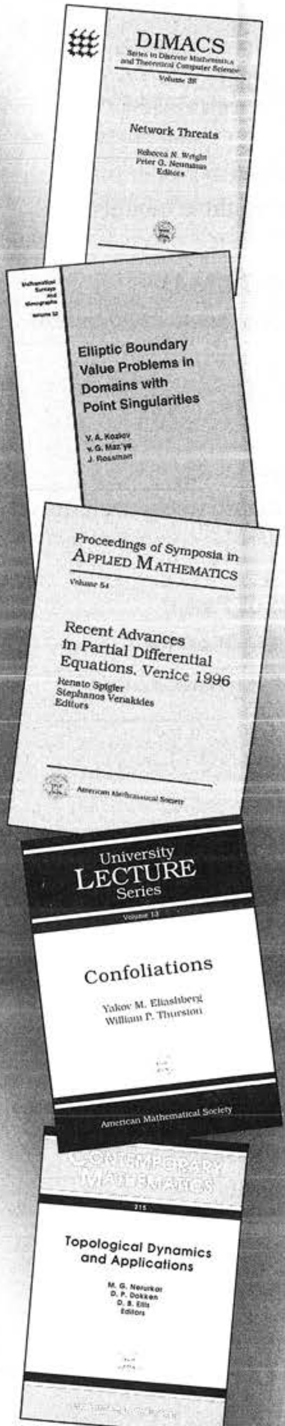
Organizing Committee

Henri Darmon (McGill and CICMA), Mark Goresky (IAS), Hershy Kisilevsky (Concordia and CICMA), Fiona Murnaghan (Toronto), Kumar Murty (Toronto), Ram Murty (Queen's), Chair

Those wishing to participate in the above activities are invited to write to: Louis Pelletier, CRM, Université de Montréal, C.P. 6128, succ. Centre-ville, Montréal (Québec) CANADA H3C 3J7
or e-mail to ACTIVITES@CRM.UMontreal.CA
World Wide Web: http://www.CRM.UMontreal.CA

American Mathematical Society

Recently Published Titles from the AMS



Confoliations

Yakov M. Eliashberg, *Stanford University, CA*, and **William P. Thurston**, *University of California, Davis*

This book presents the first steps of a theory of confoliations designed to link geometry and topology of three-dimensional contact structures with the geometry and topology of codimension-one foliations on three-dimensional manifolds. Developing almost independently, these theories at first glance belonged to two different worlds: The theory of foliations is part of topology and dynamical systems, while contact geometry is the odd-dimensional "brother" of symplectic geometry.

However, both theories have developed striking similarities. Confoliations—which interpolate between contact structures and codimension-one foliations—should help us to understand better links between the two theories. These links provide tools for transporting results from one field to the other.

University Lecture Series, Volume 13; 1997; 66 pages; Softcover; ISBN 0-8218-0776-5; List $16; All AMS members $13; Order code ULECT/13NA

Elliptic Boundary Value Problems in Domains with Point Singularities

V. A. Kozlov and **V. G. Maz'ya**, *Linköping University, Sweden*, and **J. Rossmann**, *Rostock University, Germany*

This monograph systematically treats a theory of elliptic boundary value problems in domains without singularities and in domains with conical or cuspidal points. This exposition is self-contained and a priori requires only basic knowledge of functional analysis. Restricting to boundary value problems formed by differential operators and avoiding the use of pseudo-differential operators makes the book accessible for a wider readership.

The authors concentrate on fundamental results of the theory: estimates for solutions in different function spaces, the Fredholm property of the operator of the boundary value problem, regularity assertions and asymptotic formulas for the solutions near singular points. A special feature of the book is that the solutions of the boundary value problems are considered in Sobolev spaces of both positive and negative orders. Results of the general theory are illustrated by concrete examples. The book may be used for courses in partial differential equations.

Mathematical Surveys and Monographs, Volume 52; 1997; 414 pages; Hardcover; ISBN 0-8218-0754-4; List $99; Individual member $59; Order code SURV/52NA

Network Threats

Rebecca N. Wright, *AT&T Labs Research, Florham Park, NJ*, and **Peter G. Neumann**, *SRI International, Menlo Park, CA*, Editors

The volume offers a timely assessment of avoiding or minimizing network threats. Presented here is an interdisciplinary, system-oriented approach that encompasses security requirements, specifications, protocols, and algorithms. The text includes implementation and development strategies using real-world applications that are reliable, fault-tolerant, and performance oriented. The book would be suitable for a graduate seminar on computer security.

DIMACS: Series in Discrete Mathematics and Theoretical Computer Science, Volume 38; 1997; 110 pages; Hardcover; ISBN 0-8218-0832-X; List $29; All AMS members $23; Order code DIMACS/38NA

Perspectives on Quantization

Lewis A. Coburn, *State University of New York at Buffalo*, and **Marc A. Rieffel**, *University of California, Berkeley*, Editors

This book presents the proceedings of a 1996 Joint Summer Research Conference sponsored by AMS-IMS-SIAM on "Quantization" held at Mount Holyoke College (Northampton, MA). The purpose of the conference was to bring together researchers on various mathematical aspects of quantization.

In the early work of Weyl and von Neumann at the beginning of the quantum era, the setting for this enterprise was operators on Hilbert space. This setting has been expanded, especially over the past decade, to involve C^*-algebras—noncommutative differential geometry and noncommutative harmonic analysis—as well as more general algebras and infinite-dimensional manifolds. The applications now include quantum field theory, notable conformal and topological field theories related to quantization of moduli spaces, and constructive quantum field theory of supersymmetric models and condensed matter physics (the fractional quantum Hall effect in particular).

The spectrum of research interests which significantly intersects the topic of quantization is unusually broad, including, for example, pseudodifferential analysis, the representation theory of Lie groups and algebras (including infinite-dimensional ones), operator algebras and algebraic deformation theory. The papers in this collection originated with talks by the authors at the conference and represent a strong cross-section of the interests described above.

Contemporary Mathematics, Volume 214; 1998; 195 pages; Softcover; ISBN 0-8218-0684-X; List $39; Individual member $23; Order code CONM/214NA

Recent Advances in Partial Differential Equations, Venice 1996

Renato Spigler, *University of Padova, Italy*, and **Stephanos Venakides**, *Duke University, Durham, NC*, Editors

The work of Lax and Nirenberg on partial differential equations (PDEs) over the last half-century has dramatically advanced the subject and has profoundly influenced the course of mathematics.

A large number of mathematicians honored these two exceptional scientists in a week-long conference in Venice (June, 1996) on the occasion of their 70th birthdays.

This volume contains the proceedings of the conference, which focused on the modern theory of nonlinear PDEs and their applications. Among the topics treated are turbulence, kinetic models of a rarefied gas, vortex filaments, dispersive waves, singular limits and blow-up of solutions, conservation laws, Hamiltonian systems and others. The conference served as a forum for the dissemination of new scientific ideas and discoveries and enhanced scientific communication by bringing together such a large number of scientists working in related fields. The event allowed the international mathematics community to honor two of its outstanding members.

Proceedings of Symposia in Applied Mathematics, Volume 54; 1997; 393 pages; Hardcover; ISBN 0-8218-0657-2; List $59; Individual member $35; Order code PSAPM/54NA

Topological Dynamics and Applications

M. G. Nerurkar, *Rutgers University, Camden, NJ*, **D. P. Dokken**, *St. Paul, MN*, and **D. B. Ellis**, *Beloit College, WI*, Editors

This book is a very readable exposition of the modern theory of topological dynamics and presents diverse applications to such areas as ergodic theory, combinatorial number theory and differential equations. There are three parts: 1) The abstract theory of topological dynamics is discussed, including a comprehensive survey by Furstenberg and Glasner on the work and influence of R. Ellis. Presented in book form for the first time are new topics in the theory of dynamical systems, such as weak almost-periodicity, hidden eigenvalues, a natural family of factors and topological analogues of ergodic decomposition. 2) The power of abstract techniques is demonstrated by giving a wide range of applications to areas of ergodic theory, combinatorial number theory, random walks on groups and others. 3) Applications to non-autonomous linear differential equations are shown. Exposition on recent results about Floquet theory, bifurcation theory and Lyapanov exponents is given.

Contemporary Mathematics, Volume 215; 1998; 334 pages; Softcover; ISBN 0-8218-0608-4; List $69; Individual member $41; Order code CONM/215NA

All prices subject to change. Charges for delivery are $3.00 per order. For optional air delivery outside of the continental U. S., please include $6.50 per item. *Prepayment required.* Order from: **American Mathematical Society**, P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax (401) 455-4046 or call toll free 800-321-4AMS (4267) in the U. S. and Canada, (401) 455-4000 worldwide. Or place your order through the AMS bookstore at http://www.ams.org/bookstore/. Residents of Canada, please include 7% GST.

AMERICAN MATHEMATICAL SOCIETY

Application for Membership 1998

(January–December)

Date . . . . 19 . . . .

Please read the "Membership Categories" section of this form to determine the membership category for which you are eligible. Then fill out this application and return it as soon as possible.

. . . .
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)

. . . .

. . . .

Address for all mail

. . . .

. . . .

. . . .

Telephone number(s) . . . .

Electronic address . . . .

. . . .
Signature

Prepayment Methods and Mailing Addresses

All prices quoted in U.S. dollars.
Payment by check must be drawn on U.S. bank if paid in U.S. dollars.

Send checks, money orders, UNESCO coupons to American Mathematical Society, P.O. Box 5904, Boston, MA 02206-5904

To use credit cards, fill in information requested and mail to American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248 or call (401) 455-4000 or 1-800-321-4AMS.

For Foreign Bank Transfers: American Mathematical Society, State Street Bank and Trust Company, 225 Franklin St., ABA #011000028, Account #0128-262-3, Boston, MA 02110.

American Express ☐ *Discover* ☐ *VISA* ☐ *MasterCard* ☐

. . . .
Account number ***Expiration date***

M8NO

Fields of Interest

If you wish to be on the mailing lists to receive information about publications in fields of mathematics in which you have an interest, please consult the list of major headings below. These categories will be added to your computer record so that you will be informed of new publications or special sales in the fields you have indicated.

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

Membership Categories

Please read the following to determine what membership category you are eligible for, and then indicate below the category for which you are applying.

*For **ordinary members** whose annual professional income is below $45,000, the dues are $96; for those whose annual professional income is $45,000 or more, the dues are $128.*

*The **CMS cooperative rate** applies to ordinary members of the AMS who are also members of the Canadian Mathematical Society and reside outside of the U.S. For members whose annual professional income is $45,000 or less, the dues are $82; for those whose annual professional income is above $45,000, the dues are $109.*

*For a **joint family membership,** one member pays ordinary dues, based on his or her income; the other pays ordinary dues based on his or her income, less $20. (Only the member paying full dues will receive the* Notices *and the* Bulletin *as a privilege of membership, but both members will be accorded all other privileges of membership.)*

*Minimum dues for **contributing members** are $192. The amount paid which exceeds the higher ordinary dues level and is purely voluntary may be treated as a charitable contribution.*

*For either **students** or **unemployed individuals,** dues are $32, and annual verification is required.*

*The annual dues for **reciprocity members** who reside outside the U.S. and Canada are $64. To be eligible for this classification, members must belong to one of those foreign societies with which the AMS has established a reciprocity agreement, and annual verification is required. Reciprocity members who reside in the U.S. or Canada must pay ordinary member dues ($96 or $128).*

*The annual dues for **category-S members,** those who reside in developing countries, are $16. Members can chose only one privilege journal. Please indicate your choice below.*

*Members can purchase a **multi-year membership** by prepaying their current dues rate for either two, three, four or five years. This option is not available to category-S, unemployed, or student members.*

1998 Dues Schedule (January through December)

Ordinary member . . . . ☐ $96 ☐ $128

CMS cooperative rate . . . . ☐ $82 ☐ $109

Joint family member (full rate) . . . . ☐ $96 ☐ $128

Joint family member (reduced rate) . . . . ☐ $76 ☐ $108

Contributing member (minimum $192) . . . . ☐

Student member (please verify)[1] . . . . ☐ $32

Unemployed member (please verify)[2] . . . . ☐ $32

Reciprocity member (please verify)[3] . . . . ☐ $64 ☐ $96 ☐ $128

Category-S member[4] . . . . ☐ $16

Multi-year membership . . . . $ . . . . for . . . . years

[1] ***Student Verification*** (sign below)

I am a full-time student at . . . .

. . . . *currently working toward a degree.*

[2] ***Unemployed Verification*** (sign below) *I am currently unemployed and actively seeking employment.*

[3] ***Reciprocity Membership Verification*** (sign below) *I am currently a member of the society indicated on the right and am therefore eligible for reciprocity membership.*

. . . .

Signature

[4] ☐ *send* **NOTICES** ☐ *send* **BULLETIN**

Reciprocating Societies

- ☐ Allahabad Mathematical Society
- ☐ Australian Mathematical Society
- ☐ Azerbaijan Mathematical Society
- ☐ Berliner Mathematische Gesellschaft e.V.
- ☐ Calcutta Mathematical Society
- ☐ Croatian Mathematical Society
- ☐ Cyprus Mathematical Society
- ☐ Dansk Matematisk Forening
- ☐ Deutsche Mathematiker-Vereinigung e.V.
- ☐ Edinburgh Mathematical Society
- ☐ Egyptian Mathematical Society
- ☐ Gesellschaft für Angewandte Mathematik und Mechanik
- ☐ Glasgow Mathematical Association
- ☐ Hellenic Mathematical Society
- ☐ Icelandic Mathematical Society
- ☐ Indian Mathematical Society
- ☐ Iranian Mathematical Society
- ☐ Irish Mathematical Society
- ☐ Israel Mathematical Union
- ☐ János Bolyai Mathematical Society
- ☐ The Korean Mathematical Society
- ☐ London Mathematical Society
- ☐ Malaysian Mathematical Society
- ☐ Mathematical Society of Japan
- ☐ Mathematical Society of the Philippines
- ☐ Mathematical Society of the Republic of China
- ☐ Mongolian Mathematical Society
- ☐ Nepal Mathematical Society
- ☐ New Zealand Mathematical Society
- ☐ Nigerian Mathematical Society
- ☐ Norsk Matematisk Forening
- ☐ Österreichische Mathematische Gesellschaft
- ☐ Palestine Society for Mathematical Sciences
- ☐ Polskie Towarzystwo Matematyczne
- ☐ Punjab Mathematical Society
- ☐ Ramanujan Mathematical Society
- ☐ Real Sociedad Matemática Española
- ☐ Saudi Association for Mathematical Sciences
- ☐ Sociedad Colombiana de Matemáticas
- ☐ Sociedad Española de Matemática Aplicada
- ☐ Sociedad de Matemática de Chile
- ☐ Sociedad Matemática de la Republica Dominicana
- ☐ Sociedad Matemática Mexicana
- ☐ Sociedad Uruguaya de Matemática y Estadística
- ☐ Sociedade Brasileira Matemática
- ☐ Sociedade Brasileira de Matemática Aplicada e Computacional
- ☐ Sociedade Paranaense de Matemática
- ☐ Sociedade Portuguesa de Matemática
- ☐ Societat Catalana de Matemàtiques
- ☐ Societatea de Ştiinţe Matematice din România
- ☐ Societatea Matematicienilor din Romania
- ☐ Société de Mathématiques Appliquées et Industrielles
- ☐ Société Mathématique de Belgique
- ☐ Société Mathématique de France
- ☐ Société Mathématique Suisse
- ☐ Society of Associations of Mathematicians & Computer Science of Macedonia
- ☐ Society of Mathematicians, Physicists, and Astronomers of Slovenia
- ☐ South African Mathematical Society
- ☐ Southeast Asian Mathematical Society
- ☐ Suomen Matemaattinen Yhdistys
- ☐ Svenska Matematikersamfundet
- ☐ 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

Order Form

ORDERED BY

Name __________

Address __________

City __________

State __________

Zip __________

Country __________

Code __________

e-mail __________

MAIL TO (IF DIFFERENT)

Name __________

Address __________

City __________

State __________

Zip __________

Country __________

Code __________

e-mail __________

Qty.	Code	Title	Price	Total
		Shipping and Handling ($3.00 per order).		$3.00
		Or for optional delivery by air outside the continental U.S, pay $6.50 per item.		
		Residents of Canada, please include 7% GST.		
			Total	

For orders with remittances:
(Payment must be made in U.S. currency drawn on a U.S. bank)
American Mathematical Society
P.O. Box 5904
Boston, MA 02206-5904

For credit card orders:
American Mathematical Society
P.O. Box 6248
Providence, RI 02940-6248
800-321-4AMS (4267)
(401) 455-4000, worldwide
cust-serv@ams.org

PAYMENT METHOD

☐ Check or Money Order ☐ American Express ☐ Discover
☐ MasterCard ☐ Visa

Card Number __________ Expiration Date __________

Signature __________

Please send me information about AMS membership

☐ individual
☐ institutional
☐ corporate
☐ institutional associate

CHARGE BY PHONE IN US AND CANADA 800.321.4AMS

Publications, videotapes, and miscellaneous items are sent via UPS to U.S. addresses and as printed matter elsewhere unless another delivery method is requested. Charges for delivery are $3.00 per order, or for air delivery outside the continental U.S., please include an additional $6.50 per item. **Journal back numbers**, *Mathematical Reviews* indexes, and review volumes are sent via surface mail to any destination unless air delivery is requested. Postage for surface mail is paid by the AMS. Air delivery rates, which will be quoted upon request, must be paid by the purchaser.

Customers in these areas should request price information and order directly from the indicated distributors: **AUSTRALIA, NEW ZEALAND, PAPUA NEW GUINEA:** D. A. Information Services Pty. Ltd., 648 Whitehorse Road, Mitcham, Vic 3132, Australia. Tel. (+613 or 03) 9210 7777, Fax (+613 or 03) 9210 7788; exclusive distributor of AMS books. **EUROPE, MIDDLE EAST, AFRICA:** Oxford University Press, Walton Street, Oxford OX2 6DP England. Tel: (0) 1865-556767, Telefax (0) 1865-267782; exclusive distributor of AMS books. Individual members can order either through OUP or direct from the AMS to receive member discount. **INDIA:** International Book Agency, Flat No. 2, Nirala Market, Nirala Nagar, Lucknow, 226-020, India. Tel: 91-522-370506, Fax Nos.: 91-522-222062, 210376; exclusive distributor of AMS books. **INDIA, SRI LANKA, NEPAL, BANGLADESH, PAKISTAN:** Globe Publication Pvt. Ltd., B-13, 3rd Floor, A Block, Shopping Complex, Naraina Vihar, Ring Road, New Delhi, India. Tel.:5460211, 5460212, Fax: 5752535; exclusive distributor of AMS paper journals only. **KOREA:** Sejong Books, Inc., 81-4 Neung-Dong, Kwangjin-Ku, Seoul 143-180, Korea. Tel: 011-822-498-0300, Fax Nos. 011-822-3409-0321 or 0302, e-mail: sjbk@inet.co.kr; recommended distributor of AMS books. **JAPAN:** Maruzen Co. Ltd., P. O. Box 5050, Tokyo International 100-31, Japan. Tel. Tokyo: 03-3272-7211, Telex J26516; exclusive distributor of AMS books and journals.

VISIT THE AMS BOOKSTORE AT http://www.ams.org/bookstore/

Fold here

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL

FIRST-CLASS MAIL PERMIT NO. 554B PROVIDENCE, RI

POSTAGE WILL BE PAID BY ADDRESSEE

Membership and Customer Services
AMERICAN MATHEMATICAL SOCIETY
P. O. Box 6248
Providence, RI 02940-9943

Fold here

Staple here

Meetings & Conferences of the AMS

On behalf of the Society, it is with deep regret that I announce the unexpected death of Professor William A. Harris Jr., Associate Secretary for the Western Section, on January 8, 1998, in Los Angeles, California.

—Robert M. Fossum, Secretary

Louisville, Kentucky

University of Louisville

March 20–21, 1998

Meeting #931

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: January 1998
Program issue of *Notices*: May 1998
Issue of *Abstracts*: Volume 19, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Program

The complete program for this meeting is available at `http://www.ams.org/meetings`. Follow the links to Sectional Meetings to get the most up-to-date information on all speakers and the titles of the talks. The May issue of the *Notices* will carry the full program of record for this meeting.

Registration and Meeting Information

The registration desk will be located in the lobby of Burhans Hall. The hours of operation will be 7:30 a.m. to 5:00 p.m. on Friday and 7:30 a.m. to noon on Saturday. Lectures will take place in Burhans Hall and the Founders Union Building.

Registration fees: (payable on-site only) $30/AMS members; $45/nonmembers; $10/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Manhattan, Kansas

Kansas State University

March 27–28, 1998

Meeting #932

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: January 1998
Program issue of *Notices*: June 1998
Issue of *Abstracts*: Volume 19, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Program

The complete program for this meeting is available at `http://www.ams.org/meetings`. Follow the links to Sectional Meetings to get the most up-to-date information on all speakers and the titles of the talks. The June issue of the *Notices* will carry the full program of record for this meeting.

Registration and Meeting Information

The registration desk will be located inside the main entrance to Cardwell Hall, and will be open 8:00 a.m. to 5:00 p.m. on Friday, and 8:00 a.m. to noon on Saturday. Invited Addresses will take place in Cardwell Hall Room 101, and all Special Sessions will take place in Cardwell Hall or Ackert Hall.

Registration fees: (payable on-site only) $30/AMS members; $45/nonmembers; $10/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Philadelphia, Pennsylvania

Temple University

April 4–6, 1998

Meeting #933

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: January 1998
Program issue of *Notices*: June 1998
Issue of *Abstracts*: Volume 19, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: February 11, 1998

Invited Addresses

Tobias H. Colding, Courant Institute - New York University, *Title to be announced.*

Martin Davis, University of California, Berkeley, *Title to be announced.*

Ezra Getzler, Max-Planck-Institute and Northwestern University, *Title to be announced.*

Yanyan Li, Rutgers University, *Title to be announced.*

Elias M. Stein, Princeton University, *Title to be announced.*

Special Sessions

Differential Geometric Methods in Hydrodynamics (Code: AMS SS J1), **Gerard K. Misiolek**, University of Notre Dame and California Institute of Technology.

Harmonic Analysis and Its Applications to PDEs (Code: AMS SS G1), **Cristian E. Gutierrez**, Temple University, and **Guozhen Lu**, Wright State University.

Heat Kernel Analysis on Lie Groups (Code: AMS SS H1), **Leonard Gross**, Cornell University, and **Omar Hijab**, Temple University.

Mathematical Pedagogy (Code: AMS SS I1), **Orin N. Chein**, Temple University.

Modular Identities and Q-Series in Number Theory (Code: AMS SS A1), **Marvin I. Knopp** and **Boris Datskovsky**, Temple University.

Nonlinear Partial Differential Equations (Code: AMS SS K1), **Yanyan Li**, Rutgers University.

PDEs in Several Complex Variables (Code: AMS SS B1), **Shiferaw Berhanu** and **Gerardo Mendoza**, Temple University.

Radon Transforms and Tomography (Code: AMS SS C1), **Eric L. Grinberg**, Temple University, and **Eric Todd Quinto**, Tufts University.

Rings and Representations (Code: AMS SS E1), **Maria E. Lorenz**, Ursinus College, and **Martin Lorenz**, Temple University.

Sparse Elimination Methods in Polynomial System Solving (Code: AMS SS L1), **Ioannis Z. Emiris**, INRIA, Sophia-Antipolis, France, and **J. Maurice Rojas**, Massachusetts Institute of Technology.

Sparse Matrix Computations (Code: AMS SS M1), **Jesse Barlow**, Pennsylvania State University, and **Daniel B. Szyld**, Temple University.

The History of American Mathematics (Code: AMS SS D1), **David E. Zitarelli**, Temple University, and **Karen H. Parshall**, University of Virginia.

Topology of Manifolds and Varieties (Code: AMS SS F1), **Georgia Triantafillou**, Temple University, and **Sylvain E. Cappell**, New York University-Courant Institute.

There also will be a session for 10-minute contributed papers (code: AMS CP 1).

Davis, California

University of California

April 25–26, 1998

Meeting #934

Western Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: February 1998
Program issue of *Notices*: June 1998
Issue of *Abstracts*: Volume 19, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: March 4, 1998

Invited Addresses

Edward Frenkel, UC Berkeley, *Recent progress in geometric Langlands correspondence.*

Ian Putnam, University of Victoria, *Interactions between C*-algebras and dynamics.*

Boris Rozovsky, University of Southern California, *Wiener chaos and stochastic PDEs.*

William Thurston, University of California, Davis, *Three-manifolds, foliations and circles.*

Special Sessions

C-algebras and Dynamics* (Code: AMS SS A1), **Jerry Kaminker**, Indiana University-Purdue University at Indianapolis, **Ian Fraser Putnam**, University of Victoria, and **Jack Spielberg**, Arizona State University.

Differential Equations with Applications (Code: AMS SS B1), **Sally Sailai Shao**, Cleveland State University, and **Tatsuhiko J. Tabara**, Golden Gate University.

Dualities in Mathematics and Physics (Code: AMS SS C1), **Edward Frenkel** and **Nicolai Reshetikhin**, University of California, Berkeley.

Dynamical Systems and Mathematical Physics (Code: AMS SS D1), **Motohico Mulase** and **Bruno L Nachtergaele**, University of California, Davis.

Finite Groups and Representations (Code: AMS SS E1), **Kenechukwu Kenneth Nwabueze**, University of Brunei Darussalam.

Geometric Analysis (Code: AMS SS F1), **Chikako Mese**, University of Southern California, and **Richard M. Schoen**, Stanford University.

Graph Theory (Code: AMS SS H1), **David Barnette**, University of California, Davis.

Mathematical Biology (Code: AMS SS I1), **Alexander Isaak Mogilner**, University of California, Davis.

Mathematical Physics and Topology (Code: AMS SS J1), **Gregory J. Kuperberg** and **Albert Schwarz**, University of California, Davis.

Nonlinear Analysis (Code: AMS SS K1), **John K. Hunter** and **Blake Temple**, University of California, Davis.

Random Fields and Stochastic Partial Differential Equations (Code: AMS SS L1), **Arthur J. Krener**, University of California, Davis, and **Boris Rozovsky**, University of Southern California.

The Geometry and Topology of 3-Manifolds (Code: AMS SS G1), **Dmitry Fuchs**, **Joel Hass**, **Ramin Naimi**, and **William Thurston**, University of California, Davis.

There also will be a session for 10-minute contributed papers (code: AMS CP 1).

Chicago, Illinois

DePaul University-Chicago

September 12–13, 1998

Meeting #935

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: June 1998
Program issue of *Notices*: November 1998
Issue of *Abstracts*: Volume 19, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: May 26, 1998
For abstracts: July 21, 1998

Invited Addresses

Vitaly Bergelson, Ohio State University, *Title to be announced.*

Sheldon Katz, Oklahoma State University, *Title to be announced.*

Ralf Spatzier, University of Michigan, *Title to be announced.*

Vladimir Voevodsky, Northwestern University, *Title to be announced.*

Special Sessions

Algebraic Coding (Code: AMS SS C1), **William C. Huffman**, Loyola University of Chicago, and **Vera S. Pless**, University of Illinois at Chicago.

Algebraic Combinatorics: Association Schemes and Related Topics (Code: AMS SS L1), **Sung Yell Song**, Iowa State University.

Algebraic Geometry and Mirror Symmetry (Code: AMS SS N1), **Ezra Getzler** and **Mikhail Kapranov**, Northwestern University, and **Sheldon Katz**, Oklahoma State University.

Commutative Algebra (Code: AMS SS J1), **Irena V. Peeva**, Massachusetts Institute of Technology, and **Michael Stillman**, Cornell University.

Complex Dynamics (Code: AMS SS H1), **Shmuel Friedland**, University of Illinois at Chicago.

Complexity of Geometric Structures on Manifolds (Code: AMS SS F1), **Melvin G. Rothenberg** and **Shmuel A. Weinberger**, University of Chicago.

Ergodic Theory and Topological Dynamics (Code: AMS SS G1), **Roger L. Jones**, DePaul University, and **Randall McCutcheon**, Wesleyan College.

Fourier Analysis (Code: AMS SS E1), **Marshall Ash**, DePaul University, and **Mark A. Pinsky**, Northwestern University.

K-Theory and Motivic Cohomology (Code: AMS SS D1), **Kevin Knudson**, Northwestern University, and **Mark Walker**, University of Nebraska-Lincoln.

Number Theory (Code: AMS SS I1), **Jeremy T. Teitelbaum** and **Yuri Tschinkel**, University of Illinois at Chicago.

Orthogonal Polynomial Series, Summability and Conjugates (Code: AMS SS M1), **Calixto P. Calderon**, University of Illinois at Chicago, and **Luis A. Caffarelli**, University of Texas at Austin.

Rigidity in Geometry and Dynamics (Code: AMS SS K1), **Steven E Hurder**, University of Illinois at Chicago, and **Ralf J. Spatzier**, University of Michigan.

Stochastic Analysis (Code: AMS SS A1), **Richard B. Sowers**, University of Illinois-Urbana, and **Elton P. Hsu**, Northwestern University.

Topics in Mathematics and Curriculum Reform (Code: AMS SS B1), **Richard J. Maher**, Loyola University Chicago.

There also will be a session for 10-minute contributed papers (code: AMS CP 1).

Winston-Salem, North Carolina

Wake Forest University

October 9–10, 1998

Meeting #936

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: August 1998
Program issue of *Notices*: December 1998
Issue of *Abstracts*: Volume 19, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 23, 1998
For abstracts: August 18, 1998

Invited Addresses

David F. Anderson, University of Tennessee, *Title to be announced.*

Idris Assani, University of Carolina, Chapel Hill, *Title to be announced.*

Marcy Barge, Montana State University, *Title to be announced.*

Roger Temam, University of Paris XI and Indiana University, *Title to be announced.*

Special Sessions

Abelian Groups and Modules (Code: AMS SS B1), **Ulrich Albrecht**, Auburn University.

Combinatorics and Graph Theory (Code: AMS SS A1), **Bruce Landman**, University of North Carolina.

Commutative Ring Theory (Code: AMS SS E1), **David F. Anderson**, University of Tennessee, Knoxville, and **Evan Houston**, University of North Carolina, Charlotte.

Ergodic Theory (Code: AMS SS F1), **Idris Assani**, University of North Carolina, Chapel Hill.

Modern Methods in Set Theory and General Topology (Code: AMS SS H1), **Winfried Just** and **Paul Szeptycki**, Ohio University.

Noncommutatuve Algebra (Code: AMS SS C1), **Ellen Kirkman** and **James Kuzmanovich**, Wake Forest University.

Recent Results on the Topology of Three-Manifolds (Code: AMS SS D1), **Hugh Nelson Howards**, Wake Forest University.

Spectral Theory of Differential Equations and Applications (Code: AMS SS G1), **Dominic Clemence** and **Alexandra Kurepa**, North Carolina A&T University.

There also will be a session for 10-minute contributed papers (code: AMS CP 1).

State College, Pennsylvania

Pennsylvania State University

October 24–25, 1998

Meeting #937

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 1998
Program issue of *Notices*: January 1999
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: July 7, 1998
For abstracts: September 1, 1998

Invited Addresses

Jeffrey Adams, University of Maryland, College Park, *Title to be announced.*

Nigel D. Higson, Pennsylvania State University, *Title to be announced.*

Tasso J. Kaper, Boston University, *Title to be announced.*

Kate Okikiolu, University of California, San Diego, and MIT, *Title to be announced.*

Special Sessions

C-Algebraic Methods in Geometry and Topology* (Code: AMS SS B1), **Nigel D. Higson**, Pennsylvania State University, and **Erik Guentner** and **John D. Trout Jr.**, Dartmouth College.

Mathematical Modeling of Inhomogeneous Materials: Homogenizaton and Related Topics (Code: AMS SS D1), **Leonid Berlyand**, Pennsylvania State University, and **Karl Voss**, Yale University.

Modeling of Phase Transitions of Partially Ordered Physical Systems (Code: AMS SS C1), **Maria-Carme T. Calderer**.

Partitions and q-Series (Code: AMS SS A1), **George E. Andrews** and **Ken Ono**, Pennsylvania State University.

There also will be a session for 10-minute contributed papers (code: AMS CP 1).

Tucson, Arizona

University of Arizona-Tucson

November 14–15, 1998

Meeting #938

Western Section
Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: September 1998

Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: February 12, 1998
For consideration of contributed papers in Special Sessions: July 29, 1998
For abstracts: September 23, 1998

San Antonio, Texas

San Antonio Convention Center

January 13-16, 1999

Joint Mathematics Meetings, including the 105th Annual Meeting of the AMS, 82nd Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).

Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 1998
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 14, 1998
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

Gainesville, Florida

University of Florida

March 12-13, 1999

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 11, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Urbana, Illinois

University of Illinois, Urbana-Champaign

March 18-21, 1999

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 18, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Galois Representations (Code: AMS SS C1), **Nigel Boston**, University of Illinois-Urbana, and **Michael Larsen**, University of Missouri.

Nonstandard Analysis (Code: AMS SS B1), **C. Ward Henson** and **Peter Loeb**, University of Illinois-Urbana.

Recent Progress in Elementary Geometry (Code: AMS SS A1), **John E. Wetzel**, University of Illinois-Urbana, and **Clark Kimberling**, University of Evansville.

Las Vegas, Nevada

University of Nevada-Las Vegas

April 10-11, 1999

Western Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 10, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Buffalo, New York

State University of New York at Buffalo

April 24-25, 1999

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 24, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Michele M. Audin, University Louis Pasteur, Strasbourg, *Title to be announced.*

Jeff Smith, Purdue University, *Title to be announced.*

Alexander A. Voronov, Massachusetts Institute of Technology, *Title to be announced.*

Gregg J. Zuckerman, Yale University, *Title to be announced.*

Providence, Rhode Island

Providence College

October 2–3, 1999

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Austin, Texas

University of Texas-Austin

October 8–10, 1999

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Washington, District of Columbia

Sheraton Washington Hotel and Omni Shoreham Hotel

January 19–22, 2000

Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM), and the annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).

Associate secretary: Robert M. Fossum, pro tem
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 20, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Lowell, Massachusetts

University of Massachusetts, Lowell

April 1–2, 2000

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 1, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Notre Dame, Indiana

University of Notre Dame

April 7–9, 2000

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 7, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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 As-

sociation of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).

Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 11, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Columbia, South Carolina

University of South Carolina

March 16–18, 2001

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 15, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Williamstown, Massachusetts

Williams College

October 13–14, 2001

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 11, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Western Section: Robert M. Fossum (pro tem), Department of Mathematics, University of Illinois, 1409 W. Green St., Urbana, IL 61801-2975; e-mail: rmf@ams.org; telephone: 217-244-1741.

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: Robert J. Daverman, Department of Mathematics, University of Tennessee, Knoxville, TN 37996-1300; e-mail: daverman@novell.math.utk.edu; telephone: 423-974-6577.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Up-to-date meeting and conference information is available on the World Wide Web at www.ams.org/meetings/.

Meetings:

1998

March 20-21	Louisville, Kentucky	p. 448
March 27-28	Manhattan, Kansas	p. 449
April 4-6	Philadelphia, Pennsylvania	p. 449
April 25-26	Davis, California	p. 450
September 12-13	Chicago, Illinois	p. 451
October 9-10	Winston-Salem, No. Carolina	p. 451
October 24-25	State College, Pennsylvania	p. 452
November 14-15	Tucson, Arizona	p. 452

1999

January 13-16	San Antonio, Texas Annual Meeting	p. 452
March 12-13	Gainesville, Florida	p. 452
March 18-21	Urbana, Illinois	p. 453
April 10-11	Las Vegas, Nevada	p. 453
April 24-25	Buffalo, New York	p. 453
October 2-3	Providence, Rhode Island	p. 453
October 8-10	Austin, Texas	p. 453

2000

January 19-22	Washington, DC Annual Meeting	p. 454
April 1-2	Lowell, Massachusetts	p. 454
April 7-9	Notre Dame, Indiana	p. 454

2001

January 10-13	New Orleans, Louisiana Annual Meeting	p. 454
March 16-18	Columbia, South Carolina	p. 454
October 13-14	Williamstown, MA	p. 455

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 150 in the January issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of TeX is necessary to submit an electronic form, although those who use plain TeX, AMS-TeX, LaTeX, or AMS-LaTeX may submit abstracts with TeX coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html or send mail to abs-submit@ams.org, typing help as the subject line, and descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

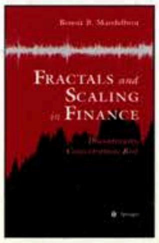
Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

1998:

June 21-July 23: Joint Summer Research Conferences in the Mathematical Sciences, South Hadley, MA. See pp. 1412-1416 (November 1997) and pp. 146-148 (January 1998) for details.

SPRINGER FOR MATHEMATICS



BENOIT MANDELBROT, IBM Research Division, Yorktown Heights, NY

FRACTALS AND SCALING IN FINANCE

Discontinuity, Concentration, Risk

This is the first book in the Selecta, the collected works of Benoit Mandelbrot. This volume incorporates his original contributions to finance. The chapters consist of much new material prepared for this volume, as well as reprints of his classic papers which are devoted to the roles that discontinuity and related forms of concentration play in finance and economics. Much of this work helps to lay a foundation for evaluating risks in trading strategies.

Contents: Introduction: Major Themes • New Methods in Statistical Economics • Historical Background • States of Randomness • Self-similarity and Self-affinity • Rank Sized Plots • Proportional Growth and Other Explanations of Scaling • A Case Against the Log Distribution • Personal Incomes and Firm Sizes • Random Flight on Wall Street • Nonlinear Forecasts

1997/551 PP./HARDCOVER/$39.95/ISBN 0-387-98363-5

GABOR TOTH, Rutgers University, Camden, NJ

GLIMPSES OF ALGEBRA AND GEOMETRY

Glimpses of Algebra and Geometry fills a gap between undergraduate and graduate mathematics studies by exploring the subtle and sometimes puzzling connections between number theory, classical geometry and modern algebra in a clear and easily understandable style. *Glimpses* will appeal to students who wish to learn modern mathematics, but have few prerequisite courses, and to high-school teachers who always had a keen interest in mathematics, but seldom the time to pursue background technicalities. Even postgraduate mathematicians will enjoy being able to browse through a number of mathematical disciplines in one sitting. Highlights in *Glimpses* include discussions of: Rationality, Elliptic Curves and Fermat's Last Theorem, Fundamental Theorem of Algebra, Möbius Geometry, Hyperbolic Geometry and Riemann Surfaces, Platonic Solids, Topology of Surfaces, The Four Color Theorem and The Fourth Dimension. Over 160 computer generated images, accessible to readers via the World Wide Web, facilitate further understanding of mathematical concepts and proofs. Additionally, the author includes recommended Web sites at the end of each section.

1998/336 PP., 170 ILLUS./HARDCOVER/$39.95
ISBN 0-387-98213-2
UNDERGRADUATE TEXTS IN MATHEMATICS

Springer

http://www.springer-ny.com

LENORE BLUM, International Computer Science Institute, Berkeley, CA and City University of Hong Kong; **FELIPE CUCKER,** City University of Hong Kong and Universität Pompeu Fabra, Barcelona, Spain; **MICHAEL SHUB,** IBM T.J. Watson Research Center, Yorktown Heights, NY and **STEVE SMALE,** City University of Hong Kong

COMPLEXITY AND REAL COMPUTATION

The classical theory of computation has its origins in the work of Gödel, Turing, Church, and Kleene, and has been an extraordinarily successful framework for theoretical computer science. The thesis of this book, however, is that it provides an inadequate foundation for modern scientific computation where most of the algorithms are real number algorithms. The authors develop a formal theory of computation which integrates major themes of the classical theory and which is more directly applicable to problems in mathematics, numerical analysis, and scientific computing. The book opens with a foreword by Richard M. Karp.

1997/453 PP./HARDCOVER/$39.95/ISBN 0-387-98281-7

ROBERT D. FRIEDMAN, Columbia University, New York

ALGEBRAIC SURFACES AND HOLOMORPHIC VECTOR BUNDLES

This book covers the theory of algebraic surfaces and holomorphic vector bundles in an integrated manner. A novel feature of the book is its integrated approach to algebraic surface theory and the study of vector bundle theory on both curves and surfaces. The book also has a strong emphasis on examples, both of surfaces and vector bundles. Over 100 exercises form an integral part of the text.

Contents: Curves on a Surface • Coherent Sheaves • Birational Geometry • Stability • Some Examples of Surfaces • Vector Bundles Over Ruled Surfaces • An Introduction to Elliptic Surfaces • Vector Bundles Over Elliptic Surfaces • Bogomolov's Inequality and Applications • Classification of Algebraic Surfaces and of Stable Bundles

1998/APP. 264 PP./SOFTCOVER/$44.95
ISBN 0-387-98361-9
UNIVERSITEXT

PETER L. DUREN, JUHA M. HEINONEN, both of University Of Michigan, Ann Arbor; **BRAD G. OSGOOD,** Stanford University, CA and **BRUCE P. PALKA,** University Of Texas, Austin (Eds.)

QUASICONFORMAL MAPPINGS AND ANALYSIS

A Collection of Papers Honoring F.W. Gehring

This book comprises a broad selection of expository articles that were written in conjunction with an international conference held to honor F.W. Gehring on the occasion of his 70th birthday. The objective of both the symposium and the present volume was to survey a wide array of topics related to Gehring's fundamental research in the field of quasiconformal mappings, emphasizing the relation of these mappings to other areas of analysis. The 9 principal speakers of the symposium (Astala, Baernstein Earle, Jones, Kra, Lehto, Martin, Sullivan, and Väisälä) provide broad expository articles on various aspects of quasiconformal mappings and their applications to other fields of mathematical analysis. 12 other distinguished mathematicians contribute articles to this volume.

1998/412 PP./HARDCOVER/$59.95/ISBN 0-387-98299-X

JOURNAL

FINANCE AND STOCHASTICS

Editor: **D. SONDERMANN,** Bonn, Germany

Co-Editors: **A.N. SHIRYAEV,** Moscow and **S.E. SHREVE,** Pittsburgh, PA

Advisory Board: **Y. AÏT-SAHALIA,** Chicago, IL; **F. DELBAEN,** Zürich, Switzerland; **P. EMBRECHTS,** Zürich, Switzerland; **H. FÖLLMER,** Berlin, Germany; **Y. KABANOV,** Moscow; **S. KUSUOKA,** Tokyo, Japan

The purpose of *Finance and Stochastics* is to provide a high standard publication forum for research in all areas of finance based on stochastic methods, and on specific topics in mathematics (in particular probability theory, statistics and stochastic analysis) motivated by the analysis of problems in finance.

Finance and Stochastics encompasses—but is not limited to—the following fields: Theory and analysis of financial markets, continuous time finance, derivatives research, insurance in relation to finance, portfolio selection, credit and market risks, term structure models, statistical and empirical financial studies, numerical and stochastic solution techniques for problems in finance, intertemporal economics, uncertainty and information in relation to finance. *Finance and Stochastics* will also publish surveys on financial topics of general interest if they clearly picture and illuminate the basic ideas and techniques at work, the interrelationship of different approaches and the central questions which remain open. Special issues may be devoted to specific topics in rapidly growing research areas.

Visit the Editor's homepage:
http://addi.or.uni-bonn.de:1048/finasto.html

ISSN 0949-2984 TITLE NO. 780 • 1998, VOLUME 2, 4 ISSUES
SUBSCRIPTION RATE: $243.00

Second Edition

N. U., PRABHU, Cornell University, Ithaca, NY

STOCHASTIC STORAGE PROCESSES

Queues, Insurance Risk, Dams, and Data Communication

1997/224 PP./HARDCOVER/$59.95
ISBN 0-387-98248-5
APPLICATIONS OF MATHEMATICS, VOLUME 15

ORDER TODAY!

CALL: 1-800-SPRINGER or Fax: (201)-348-4505

WRITE: Springer-Verlag New York, Inc., Dept. S231, PO Box 2485, Secaucus, NJ 07096-2485

VISIT: Your local technical bookstore

E-MAIL: orders@springer-ny.com

INSTRUCTORS: Call or write for info on textbook exam copies

Your 30-Day return privilege is always guaranteed!

3/98 *Reference: S231*

0002-9920(199803)45:2;1-0