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of the American Mathematical Society

May 1997

Volume 44, Number 5

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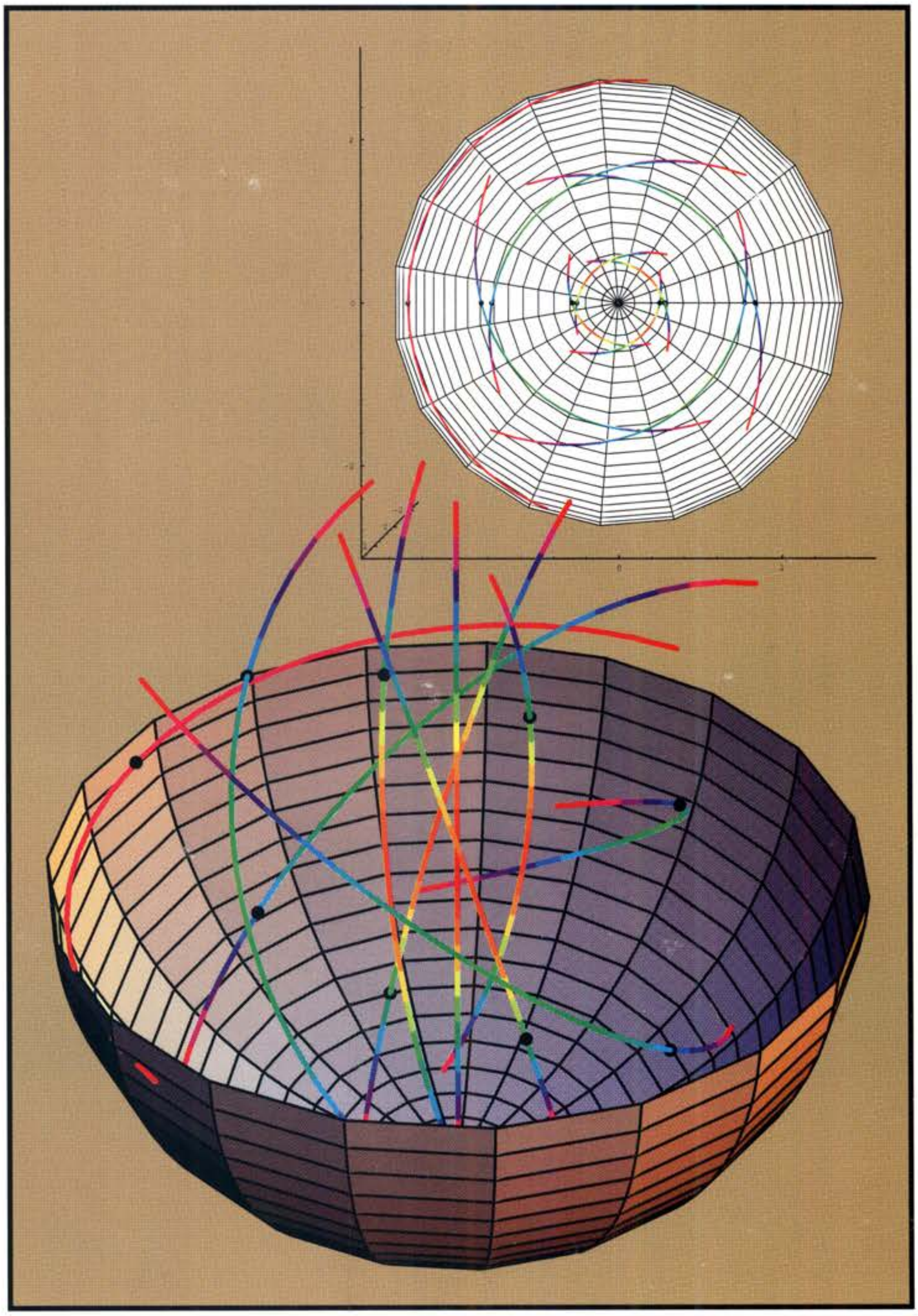

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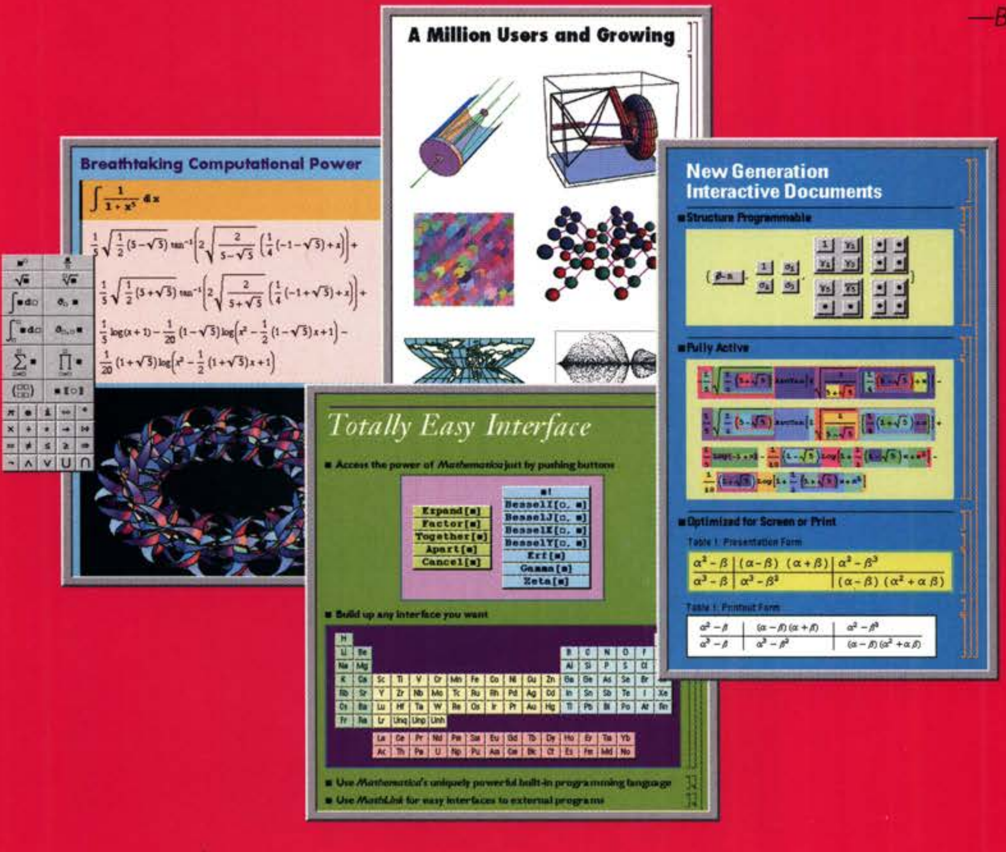
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MATHEMATICA

Dear Andy:

You are about to graduate from the University of Michigan with a major in mathematics and are about to enter graduate school, which is yet another step towards becoming a professional mathematician.

I take this occasion to wish you as much fun and satisfaction in your life as I have had in mine. I cannot think of any other profession giving as much fulfillment as the one I pursued my whole life, and it makes me immensely proud and happy that you chose to follow the same path. Mazel Tov.

Your loving dad,

Paul

Paul Nevai

(pali+@osu.edu)

MATHEMATICS from Birkhäuser

Selected Works of Norman Levinson

J.A. Nohel, *ETH Zurich, Switzerland* **& D.H. Sattinger,** *University of Minnesota, Minneapolis (Eds.)*

Norman Levinson (1912-1975) was one of the most respected mathematicians throughout the world and one of the most beloved in the Cambridge, MA community. His undergraduate and graduate education was at MIT, and thereafter, except for brief periods of leave, his remarkable 38-year mathematical career was spent at MIT — from Instructor to Professor and finally Institute Professor.

These Selected Papers reaffirm why Levinson gained recognition as one of the outstanding analysts in the world for his original ideas and fundamental contributions to research in complex, harmonic and stochastic analysis, linear and nonlinear ordinary and partial differential and integral equations, and analytic number theory, a field to which he returned towards the end of his life to make significant advances through his work on the Riemann hypothesis.

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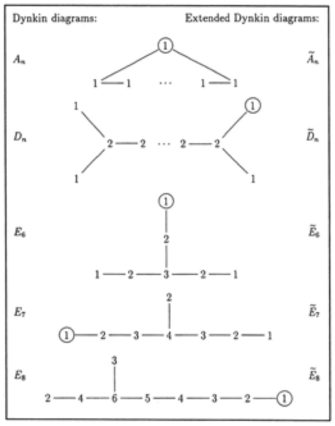

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Mathematical Vitality versus Constraint of Foreigners

At the 1997 meeting in San Diego, the AMS Council passed a resolution deploring the intent of "The Illegal Immigration Reform and Immigrant Responsibility Act of 1996" to restrict visits by foreign nationals. In particular, the Council is concerned about the potentially adverse effects of Section 641 of this act on international mathematical contacts. This section instructs universities to set up surveillance operations on foreign students and visitors with F, J, and M visas. While the Act (and particularly Section 641) is of considerable concern to all academic disciplines, it is especially disturbing to the American mathematical community, which since its inception has benefited enormously from foreign contacts.

In her recent illuminating article "Historical contours of the American mathematical research community", Karen Parshall details the crucial contribution of foreigners to U.S. mathematics. The emergence of the American mathematical community in the second half of the nineteenth century might be said to date from the founding of Johns Hopkins University and the hiring of the British algebraist J. J. Sylvester in 1876. In subsequent decades, students from the dominant mathematical centers in Europe (e.g., Klein in Göttingen) spread over the U.S. and formed a foundation on which mathematical research in the U.S. was built. In the 1930s American mathematics received a tremendous boost from the migration of mathematicians fleeing tyranny in Europe: for example, Artin, Brauer, Noether, Siegel, Courant, von Karman, von Mises, Neyman, von Neumann, Friedrichs, and Weyl came at this time. More recently, waves of research mathematicians from the former Soviet Union, Eastern Europe, and China continue to stimulate and enrich U.S. mathematics. Nowadays visits by foreign mathematicians inform the American mathematical community of much new mathematics and create many opportunities for collaborative research. Moreover, in many mathematics departments, my own included, a substantial percentage of the faculty is foreign-born. It should be noted that this influx of foreigners, although beneficial in many ways, has also contributed to an undesirably tight job market.

Short-term visits and long-term stays of foreign mathematicians are undeniably of enormous importance to the continued vitality of American mathematics. For this reason the AMS should do all within its power to change and challenge the adverse provisions of the recent immigration act as they affect mathematicians.

A Note to Subscribers:
The next issue of the *Notices* will be a combined June/July issue and will not be mailed to subscribers until around June 13.

Letters to the Editor

Just What You Wanted for Christmas

One of the ways by which the National Academy of Science (NAS), the National Academy of Engineering (NAE), and the Institute of Medicine (IM) help set public policy is through reports by the Committee on Science, Engineering and Public Policy (COSEPUP). COSEPUP is a joint committee of NAS, NAE, and IM and includes members of their councils. The COSEPUP report *Science, Technology and the Federal Government*[1] was produced under the auspices of the National Research Council and sets out national goals for science as well as a new framework for funding[2] based upon these goals.

As summarized on page 29 of the report, the goals are:

- The United States should be among the world leaders in all major areas of science.
- The United States should maintain clear leadership in some major areas of science.
- The comparative performance of U.S. research in a major field would be assessed by independent panels of experts from within and outside the field.
- The implementation of these goals for science requires more coherent federal budgetary procedures.

The first two goals distinguish between major areas of science where the United States should be *among the world leaders* and some major areas where the United States should *maintain clear leadership*. The report recommends that federal funding be guided by this distinction and sets forth criteria which call for clear leadership in a field.[3] Two of the criteria are:

- The field is demonstrably and tightly coupled to national objectives that can be met only if U.S. research performers are clear leaders.
- The field affects other areas of science disproportionately and therefore has a multiplicative effect on other scientific advances, especially those where clear leadership is the objective.

There is a case that mathematical research is not a major area of science in which the United States should maintain clear leadership. The argument is plainly stated by John Hopcroft,[4] a member of the National Science Board, which sets NSF policy.

> Pick the field of mathematics and say, "How would we decide what funding level is appropriate?" Well, the first thing you have to do is decide which of the two categories math falls into. Are we just going to be world-class in that area, or does it meet a condition so that we have to strive to be number one? Your first response might be: "Well, mathematics surely is an enabling science. All sciences depend on mathematics, and therefore we ought to be number one." But if you think a little bit more about it, if you look

---

[1] Science, Technology and the Federal Government: National Goals for a New Era, *by the Committee on Science, Engineering and Public Policy, chaired by Phillip Griffiths, National Academy Press, Washington, DC, 1993.*

[2] *Ibid, p. 24.*

[3] *Ibid, p. 20.*

[4] *John Hopcroft is dean of engineering at Cornell University. He spoke at the Fifth Academic Leadership Series at Robert Purcell Community Center, December 11, 1995. The quoted remarks are from his speech. A videotape of the Fifth Academic Leadership Series is available from Cornell University.*

> at Ph.D.-level mathematics today, you might say, "How many other fields of science really depend on that? Maybe in this area we only have to allocate enough funds to be world-class, not to be number one." And I believe that is what is indeed happening today.
>
> However, if you look at K–12 mathematics, you would discover that that meets two of the conditions on the list. It's certainly enabling. If we don't have our students coming out of high school with a strong background in mathematics, we're not going to have scientists of the future. And second, there's probably a clear economic need, because we need a trained work force, and so forth. That is the reason why the federal government gave NSF, a few years ago, 500 million dollars it didn't ask for for K–12 math and science education.

I feel that the mathematics research community has not adequately addressed *Science, Technology and the Federal Government* in the public arena.

Moss Sweedler
Cornell University

(Received December 26, 1996)

Computer Technology, the *Standards*, and Reform

I agree with Professor Wu's thoughtful "Forum" article criticizing aspects of the reform movement and in particular the NCTM *Standards (Curriculum and Evaluation Standards for School Mathematics*, NCTM, Reston, VA, 1989). The nation was ill served by the publication of these "Standards". While the *Standards* talk about problem solving (*Standards*, p. 4, no. 2), the *Standards* recommend that "decreased attention" be paid to "word problems by type", explicitly mentioning work (*Standards*, p. 127), but presumably targeting problems of motion, mixture, and investment as well.

The *Standards* speak of "removing the 'computational gate' to the study of high school mathematics" (*Standards*, p. 130). On the elementary level, skills in basic arithmetic are ridiculed as "'shopkeeper' arithmetic skills" (*Standards*, p. 3). In keeping with this view, the *Standards* would downplay (*Standards*, p. 21) or abolish (*Standards*, p. 8) the teaching of long division. Along with long division, "Long division without remainders" is also to be deemphasized (*Standards*, p. 21).

The *Standards* correctly observe that computer technology has great potential for classroom use. But at the same time, the *Standards* show a propensity for applications utilizing computer technology, while dispensing with important algebraic underpinnings (*Standards*, p. 148 and p. 150). The approach throughout the *Standards* is towards superficial exposure to mathematical topics, new instructional methods (which have their place), exploration (certainly welcome), increased emphasis on formulation and verification of conjectures (also welcome), together with minimal demands for mastery.

The approach is in keeping with the "call for liberating mathematics from the clutches of skill" made by Professor Gerald Rising in his article "Which Way Mathematics Education?" [*New York State Mathematics Teachers' Journal*, vol. 28, no. 1, Winter 1977–78, p. 16]. Professor Rising was a member of one of the "working groups" which assembled the *Standards* (*Standards*, p. iii and p. v). If anyone has any doubt that mathematics educators ran the show, I would encourage that person to read the comment on page 248 (near the *end* of the *Standards*) where we are told: "A mathematics-educator will bring a knowledge of mathematics and instruction" to the evaluation process.

While mathematics educators should have some role in the development of a curriculum for school mathematics, it is essential that mathematically well-trained high school teachers and several seasoned professors of pure and applied mathematics take an active role in the development of such a curriculum. There should be adequate testing and widespread consultation before any such curriculum receives endorsement from the MAA or AMS.

As a college teacher I dislike the lax preparation for serious college-level mathematics that the NCTM *Standards* promote, and as a parent I am aghast that some of this nonsense has even infected the parochial school our youngest daughter attends.

I certainly do not oppose the intelligent use of technology in the mathematics classroom. But when the use of technology supplants the acquisition of the basic skills necessary to intelligently use that technology or to master serious mathematics, especially calculus, one runs the risk of creating a new learning disability: Computer-Assisted Mathematical Incompetence.

I believe the NCTM *Standards* have already significantly harmed our national scientific, engineering, and business infrastructure. And the well-financed assault of the reform movement would likely continue unabated were it not for outspoken math-

About the Cover

The figures depict side and top views of a foliation of $\mathbb{RP}^3$ by circles. More precisely, several left cosets in $SO(3)$ of the isotropy group H of $(0,0,1)^T$ are displayed. The fibers lie in the ball with center $(0,0,0)$ and radius π, with antipodal points on the boundary identified. (The colors on the fibers indicate distance from the origin; the dots indicate intersection with the plane $y = 0$.) Note that the fibration $\mathbf{S}^1 \to \mathbb{RP}^3 \to \mathbf{S}^2$ depicted is double covered by the Hopf fibration $\mathbf{S}^1 \to \mathbf{S}^3 \to \mathbf{S}^2$. The detailed structure present in the figure (such as the overall z-axis symmetry, the fibers lying in planes, and the double cosets $H \backslash SO(3)/H$ comprising nested tori) is explored in detail in the article by Rick Kreminski in *Mathematica in Education and Research*, vol. 6, no. 1, TELOS/Springer-Verlag (WWW: `http://www.telospub.com`).

ematicians like Professors Wu and George Andrews. As with any movement, not everything in it is bad. There is perhaps a new enthusiasm for teaching in the reform movement and, when properly directed, enthusiasm is certainly good. But on balance the *Standards* are bad news for mathematics and disciplines which require serious mathematics.

Richard H. Escobales Jr.
Canisius College

(The author wishes to thank his student, Brian Lombardo, for making some useful suggestions at the galley stage.)

(Received December 31, 1996)

Researchers and Precollege Education

Susan Landau's otherwise excellent editorial (*Notices* **44** [February, 1997], p. 188) omitted one of the most important ways that mathematicians can be socially responsible—by working to improve precollege math education. More research mathematicians than ever before have become interested in contributing to society in this way. For example, K–12 education was a major theme at the recent "Symposium on the Future of Math Education at Research Universities", held in Berkeley at M.S.R.I. on December 5–6, 1996.

In order to contribute to improving math education in the broad sense, one needs to understand what goes on in a typical classroom. This means visiting and observing average public school classes. Work in elite schools and in special programs for selected youngsters may be helpful in producing the next generation of research mathematicians, but it has nothing at all to do with math education for the masses.

As always when embarking on something new, it is wise to approach work in the schools with a certain amount of caution and humility. One should avoid messianic delusions. The reasons for the poor state of math education in the U.S. are complex, multifaceted, and deep-rooted. There is no quick fix, and the view that any of us can singlehandedly turn things around is naive and unproductive.

My own work with the schools has been on a very small scale. I teach a course for math education majors that includes weekly visits to an inner-city middle school, where my students and I present nontraditional enrichment topics in geometry, statistics, and discrete math to four sixth-grade classes. I do not know whether or not we are having a measurable impact. But what I do know is that my university students and I find these visits to be tremendously stimulating and enlightening.

Neal Koblitz
University of Washington, Seattle

(Received January 27, 1997)

Mathematical Research and Education

While generally agreeing with Sherman Stein's letter in the March 1997 issue about the need for mathematics departments to involve themselves seriously in the preparation of teachers, I would like to make a few comments.

Too many of us believe that, as Stein writes, "Someone who wants to do a good job in mathematics education will not have the time or energy to continue mathematics research." This is demonstrably false, and it is not in the interest of our community to continue believing it. While some institutional accommodations may have to be made—a lighter service load or an occasional course reduction—this is no big deal. The real problem is not to sustain both education and research, but to either find money for projects or to invent reasonable projects that do not need extra funding.

It is not true that *Mathematics Teacher* has had no articles on teacher development. The "Projects" section has had frequent articles on teacher development as well as on curriculum and materials development projects.[1] And while many of us might devoutly wish that better professional development had preceded curriculum reform, the way in which professional development is funded (see above paragraph) is the real problem here: simply put, there isn't nearly enough money to do what needs to be done, with or without curriculum reform.

Finally, the NCTM *Standards* are being revised, possibly extensively. This is a three-year process, just begun this academic year, in which all of the professional societies, including the AMS, have considerable input through advisory committees.

Judy Roitman
University of Kansas

(Received February 13, 1997)

Science Wars or Wars of Derision?

The October issue of the *Notices* having recently made it to France, along with news of the "Sokal affair", I was surprised to learn that the AMS has decided to open its pages to what some call the "Science Wars". Evans Harrell's enthusiastic "report" in the October issue on the book *Higher Superstition* (*HS*, in what follows), concludes by assuring us that the book's authors, Paul R. Gross and Norman Levitt, "have done us all a great favor." But Harrell is short on actual quotations from *HS*. *Notices* readers who assume Harrell's civility and amused tolerance reflects the tone of the Gross-Levitt book may be surprised to find in the latter such lines as

> ...sexist discrimination, while certainly not vanished into history, is largely vestigial in the universities; that the only widespread, *obvious* discrimination today is against white males. (*HS*, p. 110).
>
> Among all the pressing possibilities for a searching-out of error in important and problematic sci-

---

[1] *In particular, there have been articles on projects involving research mathematicians.*

> ence ... the most examined case of distorting male contextual values is that perennial feminist whipping boy, biological and behavioral differences between the sexes. (*HS*, p. 145)

> If...the humanities department of MIT ... were to walk out in a huff, the scientific faculty could, at need and with enough released time, patch together a humanities curriculum, to be taught by the scientists themselves ... on the whole it would be, we imagine, no worse than operative. (*HS*, p. 243)

I, for one, find such talk offensive, but some might object that the lines quoted above are incidental to the main argument of the book and should not be taken out of context. The easy retort is that the Gross-Levitt attack on "Science Studies" also operates largely by collecting outrageous quotations, often accompanied by comments that distort their authors' intentions. Several examples are discussed in Roger Hart's review of *HS* in the volume *Science Wars*, an expanded version of the issue of *Social Text* examined by Michael Sullivan in the October issue. Sullivan's otherwise thoughtful article makes the same mistake by reducing Sarah Franklin's contribution to *Social Text* to her (admittedly ill-considered) comparison of Gross and Levitt to Operation Rescue. Scientists willing to make the effort to read past the conventions of an alien discipline might find Franklin's article illuminating, and even convincing, as an expression of what Science Studies might mean to its practitioners.

It might also be pointed out that the "feminist whipping boy" of biological determination of behavioral differences between the sexes, apart from its historical importance in the contemporary critique of science, is immediately relevant to *HS*, given the citation of sociobiologist E. O. Wilson in the acknowledgments and his endorsement on the dust jacket. It is also a prime example of what goes wrong when biologists pretend "to isolate facts from values" in research bearing on human behavior. Two recent articles by mathematician Catherine Goldstein[1] persuasively dissect the ideological presuppositions, not to mention the ignorance of mathematics, that lie behind the endlessly quoted studies purportedly demonstrating male superiority in mathematics.

Goldstein, being French, is presumably vulnerable to Camille Paglia's critique, quoted with approval by Gross and Levitt as "exquisitely formulated": "French rot! Gibberish" (quoted in *HS*, p. 286). This charge cannot be leveled against Mary Beth Ruskai, who has used AMS data to show that claims of "discrimination...against white males" are simply false. Ruskai—who, by the way, has publicly expressed concern about many aspects of Science Studies—has also documented the pervasiveness of the attitude underlying the Gross-Levitt "white males" quote, though in academic circles it is rarely expressed in so crude a form.

Despite its bluster and bad manners, some might claim that the Gross-Levitt book has "done us all a great favor" by asking cultural constructivist critics of science the following question: what criteria do they propose to distinguish "reliable knowledge from superstition" (*HS*, p. 45) (or prejudice, or nonsense)? This is a really important question for Gross and Levitt (and for over a hundred generations of western philosophers, but never mind), and they argue that contemporary science, if it has no foolproof criterion, at least has a reliable methodology. But in their hands this methodology turns out not to be the refined instrument they imagine. For example, I have no doubt that they would pounce on the following quotations, if they were to find them in a book by a literary critic:

> In a way, mathematics is a novel about Nature and Humankind. One cannot tell precisely what mathematics teaches us, in much the same way as one cannot tell what exactly we are taught by *War and Peace*. The teaching itself is submerged in the act of rethinking this teaching.

> Having no external object of study, being based on a consensus of a restricted circle of devotees, ... mathematics could not develop without the permanent control of rigid rules of [the] game.

However, these thoughts were expressed by one of us, and a particularly distinguished one at that, Yu. I. Manin, in his 1990 ICM address, entitled "Mathematics as Metaphor". Having made contributions of undeniable importance to mathematics, Manin is surely entitled to speculate as to their meaning. But even "with enough released time" I can't see how Gross and Levitt would distinguish Manin's metaphors from post-modern prattle on the basis of "no-nonsense logical positivism ... with Popperian addenda" (*HS*, p. 86) alone.

I choose Manin's "Mathematics as Metaphor" as an example because, in one of their more insufferable passages, Gross and Levitt "testify to the *uselessness* of metaphor in mathematical invention..." (*HS*, p. 116) with an air of smug authority. So much for Manin; so much for linguist George Lakoff; so much for "knots", "flows", "surgery", and even "maps". No more "killing homotopy groups". There would be no reason to insist on such a petty point except that it illustrates the combination of arrogance and careless thinking that is a hallmark of *HS* and is precisely analogous to what Gross and Levitt reject in their targets.

I don't want to leave the impression that I am particularly impressed by work in the currently fashionable field of Science Studies, much of which deserves criticism and some of which seems to court ridicule. Like Michael

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[1] Une creativité specifique des femmes en mathematiques? *in Sextant (Revue du Groupe Interdisciplinaire d'Études sur les Femmes), vol. 2, 1994.*

On ne nait pas mathematicien, *in Le Sexe des Sciences, Editions Autrement, Serie Sciences en Societé, no. 6 (date not indicated).*

Sullivan, I see an urgent need to "open lines of communication and narrow the cultural gaps in the academe." When I first heard about the Gross-Levitt book, I was hoping it could serve that purpose. But all Gross and Levitt proved is that misreading the work of other disciplines is as much a problem for scientists as for nonscientists. *HS* is in many ways the mirror image of the caricatures of science created by the more outlandish of contemporary science critics (who account for only a small minority of the contributors to the notorious issue of *Social Text*, by the way, though you wouldn't know that from the media coverage). No doubt the book would have been more serious and constructive had it been written by Michael Sullivan and Evans Harrell, to judge by their articles in the *Notices*. But a serious and constructive book would not have found a publisher in the current intellectual climate, where, as a critic wrote recently in *The Nation*, "Derision, more often than not, is the currency of exchange in culture-war literature; neither side listens to the other." *Higher Superstition* is no exception.

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Mathematicians and Social Responsibility

Susan Landau's editorial (*Notices* **44** [February, 1997], p. 188) outlines four obligations (not claimed to be exhaustive) that mathematicians have in order to meet their social responsibilities. I object to three of them: (1) "responding to *The Bell Curve* as mathematicians, and unraveling the arguments behind the statistical claims in the book." The book is described (in a footnote) as arguing that "racial differences in IQ measurement are determined largely by genetics." On the contrary, the authors (Charles Murray and Richard Herrnstein) take great pains to avoid giving that impression. For example, on p. 270 they write: "The debate about whether and how much genes and environment have to do with ethnic differences remains unresolved." And again, on p. 311:

> If the reader is now convinced that either the genetic or environmental explanation has won out to the exclusion of the other, we have not done a sufficiently good job of presenting one side or the other. It seems highly likely to us that both genes and environment have something to do with racial differences. What might the mix be? We are resolutely agnostic on that issue; as far as we can determine, the evidence does not yet justify an estimate.

Moreover, the *Wall Street Journal* published a substantial statement ("Mainstream Science on Intelligence", December 13, 1984, p. A18), signed by fifty-two professors characterized as "experts in intelligence and allied fields," consistent with the claims that *The Bell Curve* made. By all means, let us separate the strands of these claims (one meaning of "unravel") for further examination. But when one unravels a braid or a mystery, it ceases to exist; it has been "deconstructed". Under this interpretation, there are postmodernist connotations that mathematicians might not want to be associated with. The claims might be unpleasant, but we should not be obligated to nullify them prior to examining their validity.

(2) "preparing the biology students for the work they will actually do." But that is the obligation primarily of the biology teachers. Teachers of physics, economics, and so forth have similar obligations. I fear that incorporating realistic applications from a wide variety of other disciplines into our mainstream calculus courses will so bog us down in highly specialized modeling tasks and cumbersome algebraic and arithmetic calculations that we will have insufficient time to teach the mathematics properly. Our obligation as mathematicians is not to teach every subject but our own; instead we should give all our students the mathematical tools they will need for their various disciplines, with enough application examples to suggest the power and use of these tools, and try to reveal some of the beauty of our subject along the way.

(3) "providing programs, as Uri Triesman [sic] and others have done, that enable members of underrepresented groups to succeed in mathematics, and in science." My understanding is that these programs have done wonders for selected African-American, Hispanic, and rural white students. But I am concerned about the exclusion that is a central feature of these programs. I prefer to make our most effective pedagogical strategies available to all our students. If limited resources force us to be selective, then I would prefer that the selection be made using individually ascertained characteristics (such as being at risk) rather than group membership. Surely some members of the currently included groups are not at risk, while some members of the currently excluded groups are.

The danger is that social responsibility seems easily to slide into social engineering. If we focus so strongly on groups, then we lose sight of individuals. Murray and Herrnstein take great pains to avoid doing this (see pp. 312–314 of *The Bell Curve*); shouldn't we all?

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Dynkin Diagrams and the Representation Theory of Algebras

Idun Reiten

The Dynkin diagrams A_n, D_n, E_6, E_7, and E_8 and the associated extended Dynkin diagrams $\widetilde{A}_n$, $\widetilde{D}_n$, $\widetilde{E}_6$, $\widetilde{E}_7$, and $\widetilde{E}_8$ (also called Euclidean diagrams) appear in many different parts of mathematics. Often their occurrence can be traced back to fairly elementary considerations, and the first part of this paper is devoted to such a discussion. In the second part we discuss how and why these diagrams have come up in the representation theory of finite-dimensional algebras and related topics. They have occurred in many major results, so this area illustrates well the importance of the diagrams. We stress the connections with the elementary considerations in the first part, as well as the important role the Dynkin and extended Dynkin diagrams have played in establishing new and interesting relationships with other fields of mathematics.

Dynkin Diagrams

We start by stating some simple problems whose solutions are given by a collection of graphs and where the answers turn out to be the same even though the problems look quite different. In this connection we list the graphs known as Dynkin and extended Dynkin diagrams.

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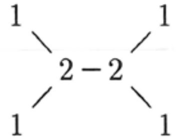
Additive and Subadditive Functions

A graph Σ consists of vertices together with edges between vertices. Assume that Σ is finite and connected and with no loops, that is, no edge $\circlearrowleft$. We denote the set of vertices by $\Sigma_0 = \{1, \dots, n\}$. Denote by $\mathbb{N}$ the positive integers, and let $a \colon \Sigma_0 \to \mathbb{N}$ be a function. Writing $a(i) = a_i$, we say that a is *subadditive* if for each i we have $2a_i \geq \sum_{\underset{i}{\bullet}\!-\!\underset{j}{\bullet}} a_j$, where the sum runs over all edges connected with the vertex i. If we have equality for all i, then a is said to be *additive*. We consider graphs equipped with functions with values in the positive integers. We write the values of the functions at the vertices and use the following examples for illustration.

(1) $a_1 \,\rule{2em}{0.4pt}\, a_2$ (2) $1 = 1$

(3) $a_1 \equiv a_2$ (4)



We ask the following questions.

- Which graphs Σ admit an additive function?
- Which graphs Σ admit a subadditive function?

We now consider our examples from this point of view.

(1) If $a_1 = a_2 = 1$, we get a subadditive function which is not additive. There cannot be an additive function, since $2a_1 = a_2$ and $2a_2 = a_1$ is impossible.

(2) We see that the function listed is additive. Note that the summation is over different edges, so that the relevant equation is $2 \cdot 1 = 1 + 1$.

(3) There is no subadditive function, since $2a_1 \geq 3a_2$ and $2a_2 \geq 3a_1$ is impossible.

(4) It is easy to see that the function listed is additive.

Quadratic Forms

We now define a quadratic form q_Σ associated with a finite connected graph Σ without loops, with vertices $\Sigma_0 = \{1, \ldots, n\}$. Denote by $\mathbb{R}$ the real numbers and by $\underline{x} = (x_1, \ldots, x_n)$ a vector in $\mathbb{R}^n$.

Define the quadratic form $q_\Sigma : \mathbb{R}^n \to \mathbb{R}$ by $q_\Sigma(x_1, \ldots, x_n) = \sum_{i=1}^n x_i^2 - \sum_{\underset{i}{\bullet}\!-\!\underset{j}{\bullet}} x_i x_j$, where the last summation is over all edges. We consider the following basic questions.

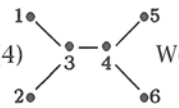
- When is q_Σ positive definite, that is, $q_\Sigma(\underline{x}) > 0$ for $\underline{x} \neq 0$?
- When is q_Σ positive semidefinite, that is, $q_\Sigma(\underline{x}) \geq 0$ for all $\underline{x}$?

Again, we investigate the graphs in the four examples, at the same time illustrating the definition.

(1) $\underset{1}{\bullet}\!\!\frac{\quad\quad}{}\!\!\underset{2}{\bullet}$. We have $q_\Sigma(x_1, x_2) = x_1^2 + x_2^2 - x_1x_2 = (x_1 - \frac{x_2}{2})^2 + 3\frac{x_2^2}{4} > 0$ for $(x_1, x_2) \neq (0, 0)$. Hence q_Σ is positive definite.

(2) $\underset{1}{\bullet}\!=\!=\!=\!\underset{2}{\bullet}$. We have $q_\Sigma(x_1, x_2) = x_1^2 + x_2^2 - 2x_1x_2 = (x_1 - x_2)^2 \geq 0$ for all (x_1, x_2). This shows that q_Σ is positive semidefinite, but it is not positive definite since $q_\Sigma(1, 1) = 0$.

(3) $\underset{1}{\bullet}\!\equiv\!\equiv\!\equiv\!\underset{2}{\bullet}$. We have $q_\Sigma(x_1, x_2) = x_1^2 + x_2^2 - 3x_1x_2$. Since $q_\Sigma(1, 1) = -1$ and $q_\Sigma(1, -1) = 1$, it follows that q_Σ is not positive semidefinite.

(4) 

We have $q_\Sigma(x_1, x_2, x_3, x_4, x_5, x_6)$ $= x_1^2 + x_2^2 + x_3^2 + x_4^2 + x_5^2 + x_6^2 - x_1x_3 - x_2x_3 - x_3x_4 - x_4x_5 - x_4x_6 = \frac{1}{4}(x_3 - 2x_1)^2 + \frac{1}{4}(x_3 - 2x_2)^2 + \frac{1}{4}(x_4 - 2x_5)^2 + \frac{1}{4}(x_4 - 2x_6)^2 + \frac{1}{2}(x_3 - x_4)^2$. Since $q_\Sigma(1, 1, 2, 2, 1, 1) = 0$ and $q_\Sigma(\underline{x}) \geq 0$ for all $\underline{x}$, we have that q_Σ is positive semidefinite but not positive definite.

Dynkin and Extended Dynkin Diagrams

Looking at the answers to the two questions for the four examples in the previous sections, we see that the existence of an additive function corresponds to the associated quadratic form being positive semidefinite but not positive definite and that the existence of a subadditive nonadditive function corresponds to the quadratic form being positive definite. Surprisingly, this connection holds in general, and here the Dynkin and extended Dynkin diagrams, which are listed in Figure 1, appear.

Theorem 1.1 Let Σ be a finite connected graph with no loops.

(a) The following are equivalent.

(i) There is a subadditive nonadditive function for Σ.

(ii) The quadratic form q_Σ is positive definite.

(iii) Σ is a Dynkin diagram.

(b) The following are equivalent.

(i) There is an additive function for Σ.

(ii) The quadratic form q_Σ is positive semidefinite but not positive definite.

(iii) Σ is an extended Dynkin diagram.

There are two families of the Dynkin and extended Dynkin diagrams and three exceptional ones (see Figure 1). The total diagram represents the extended Dynkin diagram including the encircled vertex, and the corresponding Dynkin diagram is obtained by dropping the encircled vertex and associated edges. The index denotes the number of vertices of the Dynkin diagram. We have equipped the graphs with functions, which are additive for the extended Dynkin diagrams and subadditive nonadditive for the Dynkin diagrams. Any vertex with value 1 can be chosen as encircled vertex.

It is often convenient to describe a finite graph Σ with no loops and vertex set $\Sigma_0 = \{1, \ldots, n\}$ in terms of an associated matrix $C = (c_{ij})_{1 \leq i,j \leq n}$, called the *Cartan* matrix. By definition $c_{ii} = 2$ for $1 \leq i \leq n$, and $-c_{ij} = -c_{ji}$ is the number of edges between i and j. So associated with the graph $\underset{1}{\bullet}\!\!\frac{\quad}{}\!\!\underset{2}{\bullet}$ is the matrix $\begin{pmatrix} 2 & -1 \\ -1 & 2 \end{pmatrix}$.

One naturally wonders if there is a direct connection between existence of additive or subadditive functions for a graph Σ and properties of the associated quadratic form. We give an indication of such a connection.

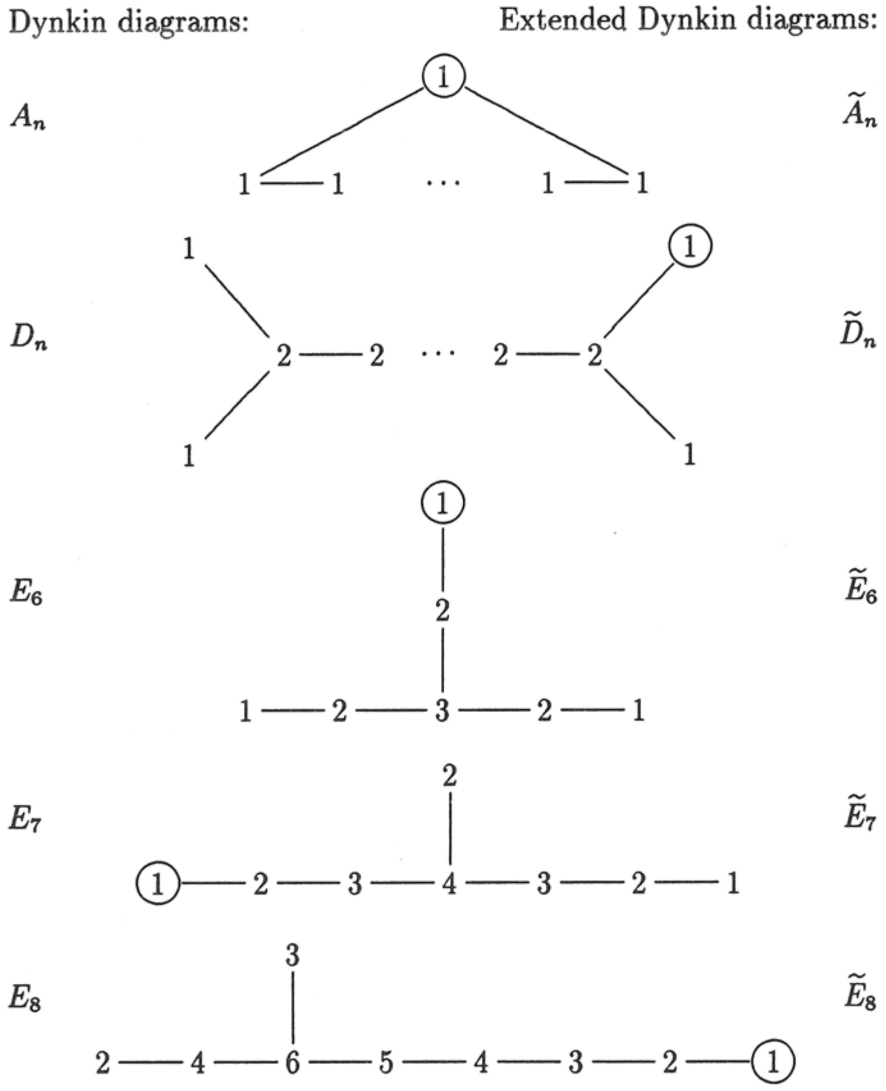


Figure 1. The Dynkin and extended Dynkin diagrams.

Let Σ be a finite connected graph with no loops, vertex set $\Sigma_0 = \{1, \dots, n\}$ and additive function $a: \Sigma_0 \to \mathbb{N}$. For each edge e between i and j and $\underline{x} = (x_1, \dots, x_n)$ in $\mathbb{R}^n$, define $q_e(\underline{x}) = \frac{1}{2a_ia_j}(a_jx_i - a_ix_j)^2$. The coefficient of x_ix_j in q_e is $-\frac{2a_ia_j}{a_ia_j} = -1$, and the coefficient of x_i^2 is $\frac{a_j}{2a_i}$. Since a is additive, the coefficient of x_i^2 in $\Sigma_e q_e$, where the sum is over all edges in Σ, is $\frac{1}{2a_i}(\sum_{\underset{i}{\bullet}\text{---}\underset{j}{\bullet}} a_j) = 1$. The last sum is taken over all edges with i as end vertex. We then see that $q_\Sigma = \Sigma_e q_e$, so that q_Σ is positive semidefinite. Since $q_\Sigma(a_1, \dots, a_n) = 0$, it is not positive definite.

A finite graph Σ with single edges and an integer $p \geq 3$ or $p = \infty$ attached to each edge is called a *Coxeter* diagram. When $p = 3$ is attached to an edge, the convention is to drop the corresponding number in the Coxeter diagram. If p is attached to the edge $\underset{i}{\bullet}\text{---}\underset{j}{\bullet}$, define $t_{ij} = 2\cos\frac{\pi}{p}$ if $p \geq 3$ is an integer and $t_{ij} = 2$ if $p = \infty$. Now define for a Coxeter diagram Σ with vertex set $\Sigma_0 = \{1, \dots, n\}$ the quadratic form $q_\Sigma: \mathbb{R}^n \to \mathbb{R}$ by $q_\Sigma(x_1, \dots, x_n) = \sum_{i=1}^n x_i^2 - \sum_{\underset{i}{\bullet}\text{---}\underset{j}{\bullet}} t_{ij}x_ix_j$ where the sum runs over all edges. For example, if Σ is the Coxeter diagram $\bullet\overset{4}{\text{---}}\bullet$, then $q_\Sigma(x_1, x_2) = x_1^2 + x_2^2 - 2(\cos\frac{\pi}{4})x_1x_2 = x_1^2 + x_2^2 - \sqrt{2}x_1x_2$. Note that when $p = 3$, we have $2\cos\frac{\pi}{3} = 1$, so we have the old definition when all associated numbers are 3. In addition to A_n, D_n, E_6, E_7, and E_8, the Coxeter diagrams

$$B_n: \bullet\text{---}\bullet \cdots \bullet\overset{4}{\text{---}}\bullet,$$

$$F_4: \bullet\text{---}\bullet\overset{4}{\text{---}}\bullet\text{---}\bullet,$$

$$H_3: \bullet\overset{5}{\text{---}}\bullet\text{---}\bullet,$$

$$H_4: \bullet\overset{5}{\text{---}}\bullet\text{---}\bullet\text{---}\bullet,$$

and

$$I_2(m)\colon \bullet\text{——}\bullet$$

also give positive definite quadratic forms [20].

Weyl Groups

As before let Σ be a finite connected graph without loops, with vertices $\Sigma_0 = \{1, \dots, n\}$. Associated with Σ is a group of linear transformations W_Σ from $\mathbb{R}^n$ to $\mathbb{R}^n$ called the Weyl group of Σ. It is generated by reflections $\sigma_1, \dots, \sigma_n$, defined as follows. For $\underline{x} = (x_1, \dots, x_n)$ we have $\sigma_i(x_1, \dots, x_n) = (y_1, \dots, y_n)$ where $y_j = x_j$ for $j \neq i$ and $y_i = -x_i + \sum_{\underset{i}{\bullet}\text{—}\underset{j}{\bullet}} x_j$, where the sum runs over all edges having i as an end vertex.

For example, if Σ is the graph $\underset{1}{\bullet}\text{——}\underset{2}{\bullet}\text{——}\underset{3}{\bullet}$, we have

$$\begin{aligned}
\sigma_1(x_1, x_2, x_3) &= (-x_1 + x_2, x_2, x_3)\\
\sigma_2(x_1, x_2, x_3) &= (x_1, -x_2 + x_1 + x_3, x_3)\\
\sigma_3(x_1, x_2, x_3) &= (x_1, x_2, -x_3 + x_2).
\end{aligned}$$

Note that if q_Σ is the quadratic form associated with Σ and B_Σ is the corresponding symmetric bilinear form, given by

$$B_\Sigma(\underline{x}, \underline{y}) = q_\Sigma(\frac{1}{2}(\underline{x} + \underline{y})) - q_\Sigma(\frac{1}{2}(\underline{x} - \underline{y})),$$

then $\sigma_i(\underline{x}) = \underline{x} - 2B(f_i, \underline{x})f_i$. Here f_i denotes the i^{th} coordinate vector.

There is the following connection with Dynkin diagrams.

Theorem 1.2 Let Σ be a finite connected graph without loops and W_Σ the associated Weyl group. Then Σ is a Dynkin diagram if and only if W_Σ is a finite group.

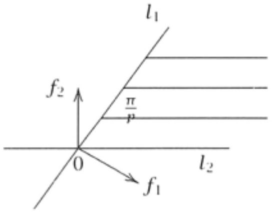
For a Dynkin diagram Σ with n vertices the elements of $\mathbb{R}^n$ of the form $w(f_i)$ for $w \in W_\Sigma$ and $i = 1, \dots, n$ are the *roots*. It is known that for each root $\underline{x}$ either $\underline{x}$ or $-\underline{x}$ is positive, where $\underline{x}$ is said to be positive if $x_i \geq 0$ for all i and $x_i > 0$ for at least one i. So in our example the positive roots are $(1, 0, 0)$, $(0, 1, 0)$, $(0, 0, 1)$, $(1, 1, 0)$, $(0, 1, 1)$, $(1, 1, 1)$, and the negative ones are the opposite ones.

Let Σ be a Dynkin diagram. The linear transformations σ_i have the property that $\sigma_i^2 = 1$ for each vertex i. Also, it is easy to see from the definition that for $i \neq j$ we have $(\sigma_i\sigma_j)^2 = 1$ if and only if there is no edge between i and j and that $(\sigma_i\sigma_j)^3 = 1$ if there is an edge. It turns out that the group W_Σ is determined by the generators σ_i with the above relations. A group generated by a finite number of elements $s_1, \dots, s_n$ with relations $s_i^2 = 1$ for $i = 1, 2, \dots, n$ is called a *Coxeter* group. It is determined by the associated Coxeter graph, which has vertices $\{1, \dots, n\}$. There is an edge between i and $j (i \neq j)$ if $(s_i s_j)^2 \neq 1$. Then this edge is labelled by ∞ if $(s_i s_j)^t \neq 1$ for all t, and by m_{ij} if $(s_i s_j)^{m_{ij}} = 1$ and m_{ij} is minimal with this property. (If $m_{ij} = 3$, the usual convention is to drop the number 3.) In particular, we see that when Σ is Dynkin, the group W_Σ has Σ as associated Coxeter diagram.

Origins

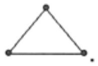
Two different lines of research led to the study of the Weyl groups. On one hand there are the five regular polyhedra (Platonic solids) from ancient times. A study of their rotation groups was started in the last century. Also, finite and, more generally, discrete groups generated by reflections with respect to hyperplanes in $\mathbb{R}^n$ were studied, first for n equal to 2 or 3. The symmetry groups of the regular polyhedra are examples of finite groups generated by reflections. Associated with a discrete reflection group is a so-called fundamental region, bounded by the reflecting hyperplanes. For the classification of such reflection groups Coxeter associated a (Coxeter) graph with the fundamental region (or alternatively with the reflection group as explained in the preceding section). We illustrate the basic ideas with easy examples in $\mathbb{R}^2$.

Consider two lines l_1 and l_2 in the plane intersecting at an angle $\frac{\pi}{p}$, where $p \geq 3$ is an integer. We have marked a fundamental region by stripes, and f_1 and f_2 are unit vectors perpendicular to the lines l_1 and l_2.



The associated Coxeter diagram has two vertices, corresponding to the two lines l_1 and l_2, and there is an edge between the vertices expressing that the lines are not perpendicular. Corresponding to the angle being $\frac{\pi}{p}$, we label the edge by p, to get $\bullet\overset{p}{\text{——}}\bullet$ (where one writes $\bullet\text{——}\bullet$ when $p = 3$). Associated with the two lines l_1 and l_2 is the group generated by the reflections σ_1 and σ_2 in these lines. Note that $\sigma_1\sigma_2$ is rotation by $\frac{2\pi}{p}$ around 0, so that $(\sigma_1\sigma_2)^p = 1$ (and this relation determines the group). When $p = 3$, we have the symmetric group S_3. A positive definite quadratic form is defined directly from the geometry as follows. Let $x_1 f_1 + x_2 f_2$ with x_1 and x_2 in $\mathbb{R}$ be an element in $\mathbb{R}^2$ and $\langle\, ,\,\rangle$ the standard bilinear form. Since $\langle f_1, f_2\rangle = -\cos\frac{\pi}{p} = \langle f_2, f_1\rangle$, we have $\langle x_1 f_1 + x_2 f_2, x_1 f_1 + x_2 f_2\rangle = x_1^2 + x_2^2 - (2\cos\frac{\pi}{p})x_1 x_2$, in particular $x_1^2 + x_2^2 - x_1 x_2$ if $p = 3$. This is the form we associated directly to the Coxeter diagram $\bullet\overset{p}{\text{——}}\bullet$ or $\bullet\text{——}\bullet$ after Theorem 1.1, and the classification of finite reflection groups is in terms of the Coxeter graphs with positive definite quadratic form listed above.

The extended Dynkin diagrams (in addition to some further Coxeter diagrams) occur in the classification of discrete reflection groups which are not finite. As an example, consider three lines in the plane where any two intersect at an angle $\frac{\pi}{3}$, and mark by stripes a fundamental region.

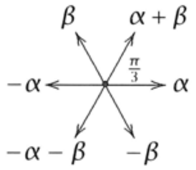
The same principle gives the graph . Since the three unit vectors perpendicular to the lines are not a basis for $\mathbb{R}^2$, we now get a quadratic form $x_1^2+x_2^2+x_3^3-x_1x_2-x_1x_3-x_2x_3$, which is positive semidefinite but not positive definite. The connection with additive functions also occurred in this setting (see [9]).

The classification of complex simple Lie algebras started in the last century. These Lie algebras are classified in terms of a finite set of elements, called *roots*, of the dual vector space H^* of some subalgebra H of the simple Lie algebra L. There is a subset of *simple roots*, which form a basis for H^*. Also, there is a natural symmetric nondegenerate bilinear form on the simple Lie algebra L, equivalently a positive definite quadratic form, which induces a bilinear and a quadratic form on H^*.

As a concrete example we have the Lie algebra $sl(3, \mathbb{C})$ whose elements are the 3×3 matrices over $\mathbb{C}$ where the sum of the diagonal elements is zero. Here H can be chosen to be the subalgebra of L spanned over $\mathbb{C}$ by the elements $h_1 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$ and $h_2 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$. The simple roots are $\alpha: H \to \mathbb{C}$ where $\alpha(rh_1 + sh_2) = -2r + s$ and $\beta: H \to \mathbb{C}$ where $\beta(rh_1 + sh_2) = r - 2s$, for r and s in $\mathbb{C}$. For the induced bilinear form $(\, ,\,)$ on H^* we have $(\alpha, \alpha) = \frac{1}{3} = (\beta, \beta)$ and $(\alpha, \beta) = (\beta, \alpha) = -\frac{1}{6}$. "Normalizing", we get the matrix

$$\begin{pmatrix} \frac{2(\alpha,\alpha)}{(\alpha,\alpha)} & \frac{2(\beta,\alpha)}{(\alpha,\alpha)} \\ \frac{2(\alpha,\beta)}{(\beta,\beta)} & \frac{2(\beta,\beta)}{(\beta,\beta)} \end{pmatrix} = \begin{pmatrix} 2 & -1 \\ -1 & 2 \end{pmatrix},$$

which is the associated Cartan matrix and which corresponds to the Dynkin diagram $\bullet\text{——}\bullet$. In this case there are six roots: α, β, $\alpha - \beta$, $-\alpha$, $-\beta$, $-\alpha - \beta$. We consider the real vector space spanned by α and β and transform to $\mathbb{R}^2$ with the standard bilinear form. We then have $(\alpha, \beta) = ||\alpha||\,||\beta|| \cos\theta$, where θ is the angle between α and β, so that $\cos\theta = -\frac{1}{2}$. Hence we have the following picture



The associated Weyl group W is generated by the reflections σ_α and σ_β in the lines perpendicular to the vectors α and β (given by $\sigma_\alpha(\xi) = \xi - \frac{2(\xi,\alpha)}{(\alpha,\alpha)}\alpha$ and $\sigma_\beta(\xi) = -\frac{2(\xi,\beta)}{(\beta,\beta)}\beta$). The elements of W permute the roots. We have $(\sigma_\alpha\sigma_\beta)^3 = 1$, and W is isomorphic to the symmetric group S_3 in this case.

The Dynkin diagrams A_n, D_n, E_6, E_7, E_8 correspond to the case where all roots have equal length. Further diagrams (B_n, C_n, F_4, G_2) occur in general. (See [6, 9, 19] for more details on the material in this section.)

Representation Theory of Algebras

When the Dynkin or extended Dynkin diagrams appear in a classification theorem in mathematics, there are some immediate interesting questions. Is there a naturally defined quadratic form or some (sub)additive function explaining the occurrence? Is there a direct relationship with other theorems where the same diagrams occur? If so, can new proofs be given, taking advantage of the connection? Can results already developed in another field be applied to get new information?

Within the representation theory of finite-dimensional algebras, and the related area of Cohen-Macaulay modules over certain commutative rings, the Dynkin and extended Dynkin diagrams have appeared in many important theorems. We discuss some of the main occurrences, emphasizing the above point of view.

Background on Representation Theory of Algebras

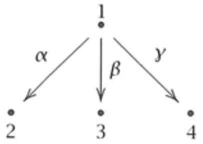
We give some background on the representation theory of finite-dimensional algebras, which we always assume to be associative with unit.

First we give typical examples of the algebras we are talking about. Let k throughout be an algebraically closed field. Some first examples (of finite-dimensional k-algebras) are group algebras kG where G is a finite group, and factor rings of polynomial rings over k, such as $k[X]/(X^4)$ and $k[X,Y]/(X,Y)^2$. Also, there are various subrings of the ring of $n \times n$ matrices over k such as $\left(\begin{smallmatrix} k & 0 \\ k & k \end{smallmatrix}\right)$; other examples come from the representation theory of Lie algebras.

An interesting class of examples is defined in terms of quivers. A *quiver* Γ is an oriented graph, i.e., a set of vertices together with a set of arrows between vertices. We assume here that Γ has only a finite number of vertices and arrows. A *path* in Γ is either the "trivial" path e_i associated with a vertex i or a sequence $\alpha_n \cdots \alpha_1$ of arrows with $n \geq 1$ where if $n > 1$, α_i ends at the vertex where α_{i+1} starts for $i = 1, \dots, n-1$. A nontrivial path $\alpha_n, \dots, \alpha_1$ is an *oriented cycle* if α_n ends at the vertex where α_1 starts. As a vector space over k, the *path algebra* $k\Gamma$ has a basis consisting of the paths in Γ. Then $k\Gamma$ is finite-dimensional over k if and only if Γ has no oriented cycles. Multiplication of basis elements is given by composition of paths when possible and is defined to be 0 otherwise. For example, if Γ is the quiver $\underset{1}{\bullet} \xrightarrow{\alpha} \underset{2}{\bullet} \xrightarrow{\beta} \underset{3}{\bullet}$, then $\{e_1, e_2, e_3, \alpha, \beta, \beta\alpha\}$ is a k-basis for $k\Gamma$. And for the multiplication we have, for example, $\beta \cdot \alpha = \beta\alpha$, $\alpha \cdot \beta = 0$, $e_2 \cdot \alpha = \alpha$, $\alpha \cdot e_2 = 0$, $e_1 \cdot \alpha = 0$, $\alpha \cdot e_1 = \alpha$, $\alpha \cdot \beta\alpha = 0$, and $\beta\alpha \cdot \alpha = 0$.

In the representation theory of algebras we are interested in studying the modules over the algebra, in particular those which are finitely generated. For the group algebras kG this is the same as investigating the representations of G over k. Amongst the modules, we are interested in their building blocks up to direct sums, that is, the *indecomposable* modules. For a finite-dimensional k-algebra Λ a nonzero Λ-module M is indecomposable if whenever $M = L \oplus N$, a direct sum, then L or N is zero. In particular, the simple modules, that is, the modules having no submodules except zero and the whole module, are indecomposable. For any finitely generated Λ-module M we have $M = M_1 \oplus \cdots \oplus M_n$, where the M_i are indecomposable, and such a decomposition is unique up to isomorphism and order of summands. Basic questions are centered around trying to understand the module theory. Much attention has been devoted to questions of when we have finite or tame representation type. Λ is said to have *finite representation type*, or *finite type* for short, if there is only a finite number of indecomposable (finitely generated) Λ-modules up to isomorphism. Amongst the finite-dimensional k-algebras of infinite type there is the important class of *tame* algebras. The definition of *tame* is rather technical, but loosely speaking, this is a class of algebras where an explicit classification of the indecomposable modules is possible. The Kronecker algebra $k(\bullet \rightrightarrows \bullet)$ is a typical example of a tame algebra whose classification of indecomposable modules was carried out by Kronecker around 1890.

When studying representations, each finite-dimensional k-algebra Λ, where k is an algebraically closed field, can be replaced by the factor algebra $k\Gamma/I$ of a path algebra $k\Gamma$ modulo an ideal I contained in J^2, where J is the ideal in $k\Gamma$ generated by the arrows in Γ. It then turns out that the quiver Γ is uniquely determined by the k-algebra Λ. A useful point of view on the module theory of $k\Gamma$ is to associate with a module over $k\Gamma$ a so-called *representation* of the quiver Γ. This means that (for a quiver Γ) there is a (finite-dimensional) vector space $V(i)$ associated with the vertex i, and if α is an arrow from i to j, there is a linear transformation $f_\alpha \colon V(i) \to V(j)$. For example, let Γ be the quiver



Then a representation of Γ over k is given by four vector spaces $V(1)$, $V(2)$, $V(3)$, and $V(4)$, together with linear transformations $f_\alpha \colon V(1) \to V(2)$, $f_\beta \colon V(1) \to V(3)$, and $f_\gamma \colon V(1) \to V(4)$, associated with the arrows α, β, and γ. Writing the vector space $V(i)$ at the vertex i and the linear transformation corresponding to an arrow next to the arrow, we get that

$$\begin{tikzcd} & k \arrow[dl, "\mathrm{id}"'] \arrow[d, "0"] \arrow[dr, "0"] & \\ k & 0 & 0 \end{tikzcd}$$

is such a representation of the quiver Γ. (See [5] for details.)

Path Algebras of Finite Representation Type

One of the first main theorems in the modern phase of representation theory of finite-dimensional algebras, dating back to the early seventies, was Gabriel's classification of the path algebras of finite (representation) type in terms of Dynkin diagrams. As we are going to discuss, this appearance of Dynkin diagrams strongly influenced the development of representation theory.

Theorem 2.1 Let Γ be a finite connected quiver without oriented cycles.

(a) The path algebra $k\Gamma$ over the field k is of finite type if and only if the underlying graph $|\Gamma|$ of Γ is a Dynkin diagram.

(b) Assume that $|\Gamma|$ is a Dynkin diagram with vertices $\{1, \dots, n\}$, and let V be a representation of Γ over k. Then the assignment

$$V \mapsto [V] = (\dim_k V(1), \dots, dim_k V(n)) \in \mathbb{R}^n$$

sending a representation to its *dimension vector* provides a one-one correspondence between indecomposable representations of Γ (or indecomposable $k\Gamma$-modules) and positive roots for $|\Gamma|$.

As an example, consider the quiver Γ: $\bullet \longrightarrow \bullet \longrightarrow \bullet$ with underlying graph $\bullet \!-\!\!-\!\!-\! \bullet \!-\!\!-\!\!-\! \bullet$. The positive roots are listed just before Theorem 1.2. The corresponding indecomposable representations of Γ are $k \to 0 \to 0$, $0 \to k \to 0$, $0 \to 0 \to k$, $k \xrightarrow{\text{id}} k \to 0$, $0 \to k \xrightarrow{\text{id}} k$, and $k \xrightarrow{\text{id}} k \xrightarrow{\text{id}} k$.

Since the answer to the question of finite type was given in terms of Dynkin diagrams and there was hence a connection with the quadratic form $q_{|\Gamma|}$ being positive definite, Tits was inspired to give a direct argument, using geometry, for the fact that if $k\Gamma$ is of finite type, then $q_{|\Gamma|}$ is positive definite (see [8]). This suggested a closer connection with the Weyl group being finite. And indeed shortly thereafter Bernstein-Gelfand-Ponomarev gave a new and elegant proof of Gabriel's theorem based on such connections [8]. They proved finite type in the Dynkin case by establishing a direct one-one correspondence between indecomposable modules and positive roots for the associated Dynkin diagram.

Also, quivers Γ where $|\Gamma|$ is extended Dynkin are important in representation theory, and they correspond to the tame algebras which are not of finite type. The diagrams B_n, C_n, F_4, and G_2 appear for finite type when the field k is not algebraically closed [11].

In addition to the immediate offsprings of Gabriel's theorem, there have been some further long-range influences. Quadratic forms still play an important role in representation theory, and the central theory of tilting which compares the module theory of an algebra with the module theory of certain endomorphism algebras, has its origin in this work. Also, for path algebras $k\Gamma$ of infinite representation type the dimension vectors of the indecomposable representations are the roots (real and imaginary) for certain infinite-dimensional Lie algebras [21]. In recent years there has been work by Ringel, Riedtmann, Schofield, and others on constructing part of the Lie algebra starting with the path algebra. Also, there are, via the Dynkin diagrams, connections with C^*-algebras [17, 13].

Self-injective Algebras of Finite Type

In this section we try to give a rough idea of how and why the Dynkin diagrams appear in the classification of another class of finite-dimensional k-algebras of finite type, called self-injective algebras.

Let Λ be a finite-dimensional k-algebra. Recall that a sequence $0 \to A \xrightarrow{f} B \xrightarrow{g} C \to 0$ of Λ-modules and Λ-homomorphisms is *exact* if f is one-one, g is onto, and the kernel of g is equal to the image of f. This means that the module C is isomorphic to the factor module $B/f(A)$, also as a vector space over k. Hence we have the equality $\dim_k B = \dim_k A + \dim_k C$.

As an example, assume now that there are exactly four indecomposable Λ-modules—V_1, V_2, V_3, V_4—up to isomorphism and that V_4 is isomorphic to Λ. Assume further that we have maps $f_i\colon V_i \to V_{i+1}$ and $g_i\colon V_{i+1} \to V_i$ for $i = 1, 2, 3$ giving rise to the exact sequences

$$\begin{tikzcd}
0 \arrow[r] & V_1 \arrow[r, "f_1"] & V_2 \arrow[r, "g_1"] & V_1 \arrow[r] & 0
\end{tikzcd}$$

$$\begin{tikzcd}
0 \arrow[r] & V_2 \arrow[r, "\left(\begin{smallmatrix} f_2 \\ g_1 \end{smallmatrix}\right)"] & V_3 \oplus V_1 \arrow[r, "(g_2{,}f_1)"] & V_2 \arrow[r] & 0
\end{tikzcd}$$

$$\begin{tikzcd}
0 \arrow[r] & V_3 \arrow[r, "\left(\begin{smallmatrix} f_3 \\ g_2 \end{smallmatrix}\right)"] & V_4 \oplus V_2 \arrow[r, "(g_3{,}f_2)"] & V_3 \arrow[r] & 0 .
\end{tikzcd}$$

We have the following quiver, where the vertex i corresponds to the module V_i and the arrows come from the six maps f_i, g_i for $i = 1, 2, 3$:

$$\begin{tikzcd}
\underset{1}{\bullet} \arrow[r, shift left] & \underset{2}{\bullet} \arrow[l, shift left] \arrow[r, shift left] & \underset{3}{\bullet} \arrow[l, shift left] \arrow[r, shift left] & \underset{4}{\bullet} \arrow[l, shift left]
\end{tikzcd}$$

Replacing each pair of arrows $\bullet \rightleftarrows \bullet$ by an edge $\bullet\!\!-\!\!\!-\!\!\!-\!\!\bullet$, we get the graph $\bullet\!\!-\!\!\!-\!\!\!-\!\!\bullet\!\!-\!\!\!-\!\!\!-\!\!\bullet\!\!-\!\!\!-\!\!\!-\!\!\bullet$. If we write $a_i = \dim_k V_i$, the above three exact sequences imply $2a_1 = a_2$, $2a_2 = a_1 + a_3$, and $2a_3 = a_2 + a_4 > a_2$. Hence we get a subadditive nonadditive function $a_1 \text{ --- } a_2 \text{ --- } a_3$. This way we obtain a Dynkin diagram, here A_3, associated with Λ.

The above situation is realized for $\Lambda = k[X]/(X^4)$. The structure theorem for modules over the principal ideal domain $k[X]$ can be used to show that the indecomposable Λ-modules are $V_1 = k[X]/(X)$, $V_2 = k[X]/(X^2)$, $V_3 = k[X]/(X^3)$, and $V_4 = \Lambda$.

The above sequences are the *almost split sequences* for $k[X]/(X^4)$, as introduced in joint work with Auslander in the early seventies (see [5]). That an exact sequence

$$0 \to A \xrightarrow{f} B \xrightarrow{g} C \to 0$$

of Λ-modules is almost split means by definition the following: (i) The end terms A and C are indecomposable. (ii) The sequence does not split; that is, there is no Λ-homomorphism $h: C \to B$ with $gh = \mathrm{id}_C$. (iii) Given any map $s: X \to C$ with X indecomposable such that s is not an isomorphism, there is some $t: X \to B$ such that $gt = s$.

Let C be an indecomposable module over a finite-dimensional k-algebra Λ such that C is not a direct summand of Λ. Then there is an almost split sequence $0 \to A \to B \to C \to 0$ unique up to isomorphism. Similarly we can start on the left with any indecomposable Λ-module A which is not a direct summand of the Λ-module $\mathrm{Hom}_k(\Lambda, k)$. There is also in general an associated quiver, defined as in the above example, called the *AR*-quiver of Λ.

For the algebra $k[X]/(X^4)$ we see that the set of indecomposable modules occurring on the right of almost split sequences coincides with the set of those occurring on the left. This property characterizes the class of *self-injective* algebras where group algebras kG for a finite group G are also examples. For an almost split sequence $0 \to A \to B \to C \to 0$ write $A = \tau C$. In our example we had $\tau C = C$ for all almost split sequences, but this is normally not the case, even for self-injective algebras of finite type. For this class one has $\tau^t C \simeq C$ for some positive integer t. In this case one obtains in a similar way a Dynkin diagram. Now the vertices correspond to τ-orbits.

Associating Dynkin diagrams with self-injective algebras of finite type goes back to [24] and was the basis for a classification theorem for this class of algebras. The idea of using dimension functions in this investigation appeared in [27,18].

Preprojective Algebras

Again let Σ be a finite connected graph with no loops and vertices $\{1, \dots, n\}$. We associate with Σ a k-algebra $\Pi(\Sigma)$, called the *preprojective* algebra of Σ. Interesting ring theoretic properties of $\Pi(\Sigma)$ depend on Σ, and again the Dynkin and extended Dynkin diagrams appear in a natural way.

Associate with the graph Σ the quiver $\overline{\Sigma}$ having the same vertices as Σ and where each edge $\underset{i}{\bullet}\!\!-\!\!\!-\!\!\!-\!\!\underset{j}{\bullet}$ in Σ is replaced by a pair of arrows $\underset{i}{\bullet} \rightleftarrows \underset{j}{\bullet}$. So for each arrow $\underset{i}{\bullet} \xrightarrow{\alpha} \underset{j}{\bullet}$ in $\overline{\Sigma}$ there is an arrow $\underset{i}{\bullet} \xleftarrow{\alpha^*} \underset{j}{\bullet}$. Let Γ be any quiver, without oriented cycles, with underlying graph Σ. Consider the element $r = \sum_\alpha \alpha^*\alpha - \alpha\alpha^*$ in $k\overline{\Sigma}$, where the sum runs over all arrows α in Γ. Then $\Pi(\Sigma)$ is defined to be the factor algebra $k\overline{\Sigma}/(r)$. For example, if Σ is the graph $\bullet\!\!-\!\!\!-\!\!\!-\!\!\bullet\!\!-\!\!\!-\!\!\!-\!\!\bullet$, then we can choose Γ to be the quiver $\bullet \xrightarrow{\alpha} \bullet \xrightarrow{\beta} \bullet$. Then $\overline{\Sigma}$ is the quiver $\bullet \underset{\alpha^*}{\overset{\alpha}{\rightleftarrows}} \bullet \underset{\beta^*}{\overset{\beta}{\rightleftarrows}} \bullet$ and $r = \alpha^*\alpha - \alpha\alpha^* + \beta^*\beta - \beta\beta^*$. The algebra $\Pi(\Sigma)$ is not necessarily finite dimensional over k. In fact, there is the following result.

Theorem 2.2 Let Σ be a finite connected graph without loops and $\Pi(\Sigma)$ the associated preprojective algebra over k.

(a) $\Pi(\Sigma)$ is a finite-dimensional k-algebra (or an artin ring) if and only if Σ is a Dynkin diagram.

(b) $\Pi(\Sigma)$ is a noetherian ring if and only if Σ is a Dynkin or an extended Dynkin diagram.

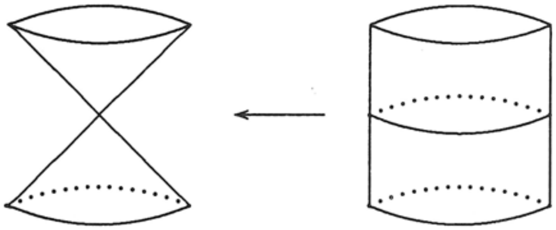
Let Γ be a finite connected quiver without oriented cycles and $\Sigma = |\Gamma|$ the underlying graph. In [7] there is a construction of the preprojective algebra $\Pi(\Sigma)$ in terms of the module theory for $k\Gamma$.

Part (a) of Theorem 2.2 goes back to [16, 24, 12]. In [24] such ideas appeared in connection with self-injective algebras of finite type, and in [12] a more general setting is treated.

Rational Double Points

We shall see how the idea of using length functions on modules in almost split sequences for finite-dimensional algebras to obtain Dynkin diagrams can be extended to some classes of commutative rings.

Associated with the rotation groups of the regular polyhedra (the polyhedral groups) are the *binary* polyhedral groups, from which the polyhedral groups are obtained as factors by normal subgroups of order 2. Together with cyclic and dihedral groups, the binary polyhedral groups are all the finite subgroups of the special linear group $SL(2,\mathbb{C})$ up to conjugation. Via the inclusion $G \subset SL(2,\mathbb{C})$ of a nontrivial finite group G there is an action of G on $\mathbb{C}^2$, inducing the quotient $\mathbb{C}^2/G$ which has a singularity only at the origin. Actually, $\mathbb{C}^2/G$ is isomorphic as a variety to the hypersurface $\{(x,y,z) \in \mathbb{C}^3; f(x,y,z) = 0\}$ in $\mathbb{C}^3$ for some polynomial f. These are isolated singularities, called Kleinian singularities. Associated with each such hypersurface is a *resolution graph* which is known to be Dynkin. In the resolution of the singularity there is a family of curves lying above the singular point. The vertices in the graph correspond to the curves, and there are edges where the corresponding curves intersect. As a simple example (drawing the real part), we can think of



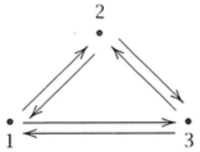
where there is one curve lying above the singular point, corresponding to the graph with only one vertex and no edges (see [26]).

The group $G \subset SL(2,k)$ also acts naturally on the power series ring $k[[X,Y]]$ where k is an algebraically closed field of characteristic zero. We denote the corresponding invariant ring by $R = k[[X,Y]]^G$, where $r \in R$ if $g(r) = r$ for all $g \in G$. The *(maximal) Cohen-Macaulay modules*, denoted by $CM(R)$, are the finitely generated R-modules which are finitely generated free as T-modules for a certain subring T of R. In other words, for each module B in $CM(R)$ there is some n such that as T-module B is isomorphic to T^n, a direct sum of n copies of T. There is a more general existence theorem for almost split sequences which applies to this situation and was the basis for analogous theories for finite-dimensional k-algebras and certain classes of commutative rings [1]. The rings $R = k[[X,Y]]^G$ with $G \subset SL(2,\mathbb{C})$ have only a finite number of indecomposable modules in $CM(R)$, and for the almost split sequences the left and right terms are always isomorphic. R is an indecomposable R-module in $CM(R)$ and is the only one which does not occur on the right, or on the left, of an almost split sequence. But a remarkable fact is that there is an exact sequence $0 \to R \xrightarrow{f} E \xrightarrow{g} R$, called the *fundamental exact sequence*, with properties similar to those of an almost split sequence, except for $g\colon E \to R$ being surjective. Also in the setting of $CM(R)$ there is a function, the rank r over T, which has the property that $r(A)+r(C) = r(B)$ for each exact sequence $0 \to A \to B \to C \to 0$ in $CM(R)$. Here $r(X) = n$ when X is isomorphic to T^n as T-module. In addition, we have $2r(R) = r(E)$, and due to this extra feature we get in this situation an additive function associated with the whole AR-quiver. This way we get an extended Dynkin diagram by using the results in section "Dynkin and Extended Dynkin Diagrams" and first proving that there are no loops.

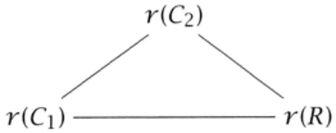
We illustrate with a concrete example. If we let $G = \langle g \rangle \subset SL(2,k)$ where $g = \left(\begin{smallmatrix} \rho & 0 \\ 0 & \rho^2 \end{smallmatrix}\right)$ and $\rho \neq 1$ is a third root of 1, we get $R = k[[X^3, XY, Y^3]]$ and can choose T to be $k[[X^3, Y^3]]$. In this case there are three indecomposable modules: C_1, C_2, and $C_3 = R$ in $CM(R)$. The almost split sequences are

$$(*) \qquad \begin{aligned} &0 \to C_1 \to C_2 \oplus R \to C_1 \to 0 \\ &0 \to C_2 \to C_1 \oplus R \to C_2 \to 0 \\ &0 \to R \to C_1 \oplus C_2 \to R. \end{aligned}$$

They give rise to the AR-quiver



where the vertex i corresponds to the module C_i. We have $2r(C_1) = r(C_2) + r(R)$, $2r(C_2) = r(C_1) + r(R)$, and $2r(R) = r(C_1) + r(C_2)$. Replacing each pair of arrows $\bullet \rightleftarrows \bullet$ by an edge $\bullet\!-\!\!-\!\bullet$, we get an additive function



for the extended Dynkin diagram $\widetilde{A}_2$, and a subadditive function

$$r(C_1) \;\text{——}\; r(C_2)$$

for the Dynkin diagram A_2.

There is yet another way of associating a graph (and a quiver) with a finite group $G \subset SL(2,k)$, due to McKay. The vertices of this McKay quiver are in one-one correspondence with the irreducible representations $V_1, \ldots, V_n$ of G over k. The inclusion $G \subset SL(2, k)$ corresponds to a representation V, and there is an arrow from V_i to V_j if V_j is a summand of $V \otimes_k V_i$. (Actually, the number of arrows is the multiplicity of V_j.) It turns out that the arrows occur in pairs $\bullet \rightleftarrows \bullet$, and we obtain the McKay graph by replacing a pair of arrows $\bullet \rightleftarrows \bullet$ by an edge. McKay observed that this graph is an extended Dynkin diagram [23]. If the vertex corresponding to the trivial representation k is removed, it is a Dynkin diagram which coincides with the resolution graph for $R = k[[X, Y]]^G$.

Actually, the results for the AR-quiver were first proved through establishing an isomorphism with the corresponding McKay quiver [2]. Then a more direct approach along the lines sketched here was given, valid more generally for what is called rational double points, also when no group is involved [3]. These are two-dimensional hypersurfaces over k of finite representation type for any characteristic of k, and they are exactly the Kleinian singularities in characteristic zero.

Finite-Dimensional Algebras and Rational Double Points

We have seen two ways of associating a quiver with a finite-dimensional algebra: the ordinary quiver and the *AR*-quiver. In each case there is a class of algebras where finite type is characterized via an associated Dynkin diagram. For the *AR*-quiver there are similar situations in other settings where almost split sequences exist, and we have seen how Dynkin and extended Dynkin diagrams are associated with rational double points from this point of view. A third type of occurrence was through the construction of a special type of algebra $\Pi(\Sigma)$, the preprojective algebra, from a graph Σ, where Dynkin and extended Dynkin diagrams corresponded to particularly nice classes of algebras, artinian and noetherian.

Turning things around, let us start with a Dynkin diagram Σ, with associated extended Dynkin diagram $\tilde{\Sigma}$, and let k be a field (which is algebraically closed and of characteristic zero). Then associated with Σ and $\tilde{\Sigma}$ are the preprojective algebras $\Pi(\Sigma)$ and $\Pi(\tilde{\Sigma})$ and a rational double point R. Also, we can choose quivers Σ' and $\tilde{\Sigma}'$ with underlying graphs Σ and $\tilde{\Sigma}$ so that we have the path algebras $k\Sigma'$ and $k\tilde{\Sigma}'$. A natural question is whether there is a useful relationship between the various objects associated with the same Dynkin diagram. Actually, in some sense $\Pi(\Sigma)$ and $\Pi(\tilde{\Sigma})$ provide a link between path algebras and rational double points. We have already mentioned that $\Pi(\Sigma)$ and $\Pi(\tilde{\Sigma})$ can be constructed from modules over $k\Sigma'$ and $k\tilde{\Sigma}'$. On the other hand, when R is a rational double point, it turns out that we have the following (see [25]).

Theorem 2.3 Let Σ be a Dynkin diagram, $\tilde{\Sigma}$ the associated extended Dynkin diagram, and R the corresponding rational double point over k, where k is an algebraically closed field of characteristic zero. Let M be the direct sum of one copy of each indecomposable module in $CM(R)$. Then we have the following:

(a) $\Pi(\tilde{\Sigma}) \simeq \mathrm{End}_R(M)$.

(b) $\Pi(\Sigma) \simeq \underline{\mathrm{End}}_R(M)$, the factor ring of $\mathrm{End}_R(M)$ modulo the homomorphisms factoring through a free R-module.

Here the fact that we have a Dynkin diagram for R when removing the module R is reflected in the fact that $\underline{\mathrm{End}}_R(M)$ is finite dimensional over k when R is an isolated singularity.

It is not hard to see that the ring R itself can be constructed from $\Pi(\tilde{\Sigma})$, as $e\Pi(\tilde{\Sigma})e$, where e is the idempotent in $\Pi(\tilde{\Sigma})$ corresponding to the vertex of R in the quiver for $\Pi(\tilde{\Sigma})$.

This connection was used in [4] to study the module theory for $\Pi(\Sigma)$ by taking advantage of known properties of the rational double point R to obtain the following.

Theorem 2.4 Let Σ be a Dynkin diagram and k a field. If C is an indecomposable $\Pi(\Sigma)$-module which is not projective, then $\tau^6 C \simeq C$.

This result was first proved by Ringel and Schofield using different methods. The surprising fact here is that we have periodicity for τ, with low period, even though the module structure for $\Pi(\Sigma)$ may be extremely complicated. It should also be noted that, inspired by our method, we could start with a one-dimensional ring corresponding to R and get algebras related to $\Pi(\Sigma)$ where even $\tau^3 C \simeq C$ for each indecomposable nonprojective module C [4].

The connection between the invariant ring $R = k[[X, Y]]^G$ and the corresponding preprojective algebra $\Pi(\Sigma)$ has recently been further exploited in [10]. Here a family of deformations R^λ of R are studied through investigating related deformations $\Pi(\Sigma)^\lambda$ of $\Pi(\Sigma)$, where R^λ is obtained from $\Pi(\Sigma)^\lambda$ as R is obtained from $\Pi(\Sigma)$. Through this correspondence the role of the roots for the extended Dynkin diagram Σ for the homological properties of R^λ and $\Pi(\Sigma)^\lambda$ is emphasized. There is earlier related work by Kronheimer, Lusztig, and Nakajima.

In conclusion, we hope to have shown how the appearance of Dynkin and extended Dynkin diagrams can be traced back to basic considerations and how it has stimulated exciting developments.

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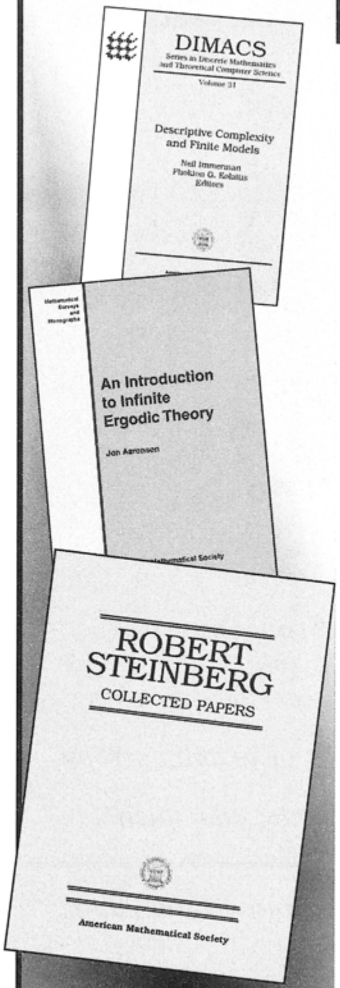

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Calculus Reform—For the Millions

David Mumford

About twenty years ago I was part of a group of professors from many fields who met once a month for dinner and an after-dinner talk given by one of the members. It was entertaining to hear glimpses of legal issues, historical problems, discussions of what freedom meant in different cultures. But then I had to give one of these talks! I was working on algebraic geometry then, and I tried to figure out what I could say that would hold my colleagues' attention while digesting a large meal. In the end I decided to stick to a rather anecdotal level but to inject one bit of real math. I thought I would try to explain to them the first mathematical formula that I had seen in school which totally bewildered me. This was $e^{i\pi} = -1$. It seemed to me that here was a nugget of real math and maybe it could be explained. Here is how I tried.

I got e into the picture by discussing a savings bank which pays 100% interest, and convinced them that in a year they would get more than \$2 for each \$1 invested. It was not hard to convince them they would get between \$2.50 and \$3 per dollar invested, and we could define e to be their balance after a year. Then I needed i. Most people have heard of i, and I just described it as part of a game invented by mathematicians to get enough numbers so every equation has solutions: starting with the one new rule that multiplying i by i you get -1, you get all the numbers $a + ib$ and their arithmetic. Next, imagine you go to the neighborhood savings bank, and it is running a special promotion with a new account which pays *imaginary* interest at the rate of 100%. The audience immediately sees that you get imaginary interest building up and that the interest on the interest is decreasing your total of *real* dollars. You run them through a few more numbers, and they see that their real funds will go to 0, while their imaginary funds build up to about $1.i$; then they go into real debt, next imaginary debt, and finally get their real \$1 back, which they immediately withdraw! A little picture in the complex plane convinces them that this will take 2π years, while after π years they were in debt \$1 : voilà, $e^{i\pi} = -1$!

What is the point of this struggle to communicate some tiny bit of math? For me, the lesson was that I think my audience got a bit of honest math from this and that what they struggled to learn consisted of some numerical fiddling, some geometry (the circle showing the evolution of your balance in the complex plane), and some thinking about the rules which underlie arithmetic and exponentiation. I do not think I said anything mathematically dishonest, yet I certainly gave *no proof of anything.* I think this is the same approach as that taken by many calculus reform texts, and it is exactly the philosophy of the Gleason-Hallett Calculus Consortium.

The problem of communicating comes up in many situations other than after-dinner speeches. For nearly fifteen years I have been doing applied mathematics, and I have to talk especially to biologists, psychologists, and engineers. The same rules seem to apply. If I mention L^p, they have me pegged as "one of them".

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Of course, the tolerance level varies. Some engineers have been rather thoroughly mathematicized: in control theory everything is done in multiple Banach spaces. But I know a psychologist who hates math yet understands absolutely correctly the meaning of robust statistics. For pure mathematicians and statisticians, robust statistics refers to statistics that work when the variables being measured are not normally distributed and still give you good estimates of things like the mean and variance of the variable. In real life I think it is fair to say that nothing is ever normally distributed because there are always "outliers", exceptional cases which are off the scale. My psychologist friend spent much of his time measuring reaction times and would average over his subjects to get a mean. When I did the same and got terrible results, he said, "Maybe you forgot to throw out the slowest 3 percent?" The point is that about 3 percent of the time, his subjects' minds wandered, and he got absurdly slow responses. Is this math? In fact, yes: there is a very substantial body of theory on what "α-trimmed means" do for you with unknown distributions. My friend has an excellent intuitive grasp of this without knowing any of these theorems.

Often a picture is what facilitates communication. When you were in grade school, you might have been puzzled, as I was, when asked to accept the formula $\frac{1}{\frac{1}{a}} = a$. Of course, modern books "prove" this, more or less, manipulating the axioms in the usual way. But does it not become just as clear from a picture which compares:

((••)(••)(••))

How many pairs is 6? **Answer:** 3	*As a formula:* $6/2 = 3$

How many quarter pies in a whole pie? **Answer:** 4	*As a formula:* $1/(1/4) = 4$

An example, a picture, an explanation is presented. Would it be better to present a proof?

I learned calculus during high school when I stumbled across a great classic of the pedagogical literature: Lancelot Hogben's *Mathematics for the Million*. Hogben explains the essence of calculus, including differentiation, integration (both with many examples up through trig functions), the fundamental theorem, and multivariable integration through Archimedes' great achievement, calculating the volume of a sphere. He does this *in fifty pages*! Was he successful? Well, the book went through four editions over more than thirty years, apparently being read by literally millions. How did he do this? Here is how he introduces the derivative:

> If the points p and q in the course (of a cyclist) are very close together, ... the curved line joining them is difficult to distinguish from a straight line, and the pointer of the speedometer will not shift appreciably during the interval representing the difference between the x co-ordinates of q and p. When p and q are very close together, so that we cannot distinguish them, the line passing through them becomes the tangent at the point $p = q$, and the gradient of this line corresponds with the speedometer-reading at the instant represented by the x co-ordinate of p.
>
> ....
>
> The tangent method is equivalent to taking two points with x co-ordinates x_p and $(x_p + \Delta x)$ and y co-ordinates y_p and $(y_p + \Delta y)$ so close together that Δx and Δy are too small to measure. The gradient is $\frac{\Delta y}{\Delta x} = \tan a$. When Δy and Δx are immeasurably small, we write the ratio (pronounced as dee-wy-by-dee-eks) $\frac{dy}{dx}$.
>
> (pp. 521–522, 3rd edition)

Hogben was a genius at putting things in plain English. He used Δ, but no ϵ or δ. He was also very clear about the need to explain calculus in down-to-earth terms. He railed against Newton himself:

> The intellectual leaders in the Newtonian period did not realize that every intellectual advance raises a constructive problem in education. Newton himself devoted much of his energy to devising long-winded demonstrations in Euclidean geometry instead of trying to make his own methods intelligible to his contemporaries. One result of this was that conspicuous progress in Newtonian mechanics did not take place in his own country during the century which followed the publication of the *Principia*.
>
> (op. cit., p. 567)

A striking contrast for me was the curriculum which my oldest son encountered learning Euclidean geometry in a Paris high school in 1976. Unfortunately, I no longer have the textbook, but the following is close to the definition presented there of a "Euclidean line": a *Euclidean line* is an ordered pair $\{X, \Phi\}$. Its first member is a set X whose elements will be called "points". Its second member is a set Φ of bijections between X and the real line $\mathbf{R}$ which satisfies two axioms. First, for all $\phi, \psi \in \Phi$, the composition $f = \phi \circ \psi^{-1}$ is a map from $\mathbf{R}$ to itself of the form $f(x) = \pm x + a$ for some real number a. Second, for any $\phi \in \Phi$ and any map $f(x) = \pm x + a$, there is a unique $\psi \in \Phi$ such that $\psi = f \circ \phi$.

I believe the same concept was circulating at the time in research circles under the name "torseur". It seemed to me at the time a bizarre way to prepare the next generation of educated Frenchmen. But perhaps Hogben is right and Euclidean geometry has this effect on the abstract thinker.

Watching my children move through the mathematical curriculum of elementary and high schools has been very instructive for me. For instance, I believe there is *no universal best way to teach mathematics* which applies to all the basic skills. It is very tempting to adopt some pedagogical theory or intellectual standpoint and convince yourself that this is the yellow brick road leading to understanding. I am not convinced that the experts who study pedagogy in mathematics have a deeper insight into what works than most concerned parents.

To illustrate, at one extreme I suggest there are some essential topics which *must* be memorized. The multiplication tables are the prime example. People with numerical gifts see the patterns in the tables and use these to learn them faster, but by and large a formula like $7 \times 8 = 56$ has to be memorized (one of my kids learned it because *Creature Double Feature* was on from 7 to 8, Channel 56).

There is a large chorus of people who rail against teaching calculus by "cookbook" methods. But my gut feeling is that some topics needed by everyone in a numerical profession are learned fastest by taking them purely as the rules of a game prescribed by the inventor of that game. Solving equations in algebra is a prime example. If these are taught like a board game, with rigid rules about when you can move a piece from one square to another, they are not much harder than checkers, say. For me, $b^2 - 4ac$ still has the flavor of a memorized icon. One hopes the meaning will come with practice and application. But drilling in cookbook methods seems a reasonable method for bootstrapping the skills of high school students to the level where they can begin to deal symbolically with algebraic relationships. We drill students in conjugating French verbs, so why not in algebra?

But everyone agrees that this approach of memorizing and game playing has real limits. Learning to correctly convert among fractions, decimals, and percents was such a case for some of my children. I do not think this can be learned either by memorization or by pretending it is a bizarre game required to pass tests. It is also an essential skill in later life in thinking about budgets, inflation, savings, and using recipes. What it seems to require is an understanding of what it means based on many simple but real examples: converting dollars to cents, converting proportions in a recipe to numbers of ounces, etc.

Focusing on calculus reform, let us distinguish three types of pedagogical methods. One is memorization and drill. Because of the examples just given, I would defend the proposition that these have their place; they have certainly been used to attain high standardized test scores in calculus as well as in arithmetic and algebra. But we all know that, although often effective for short-term results, this approach has its limits if the concept is subtle or will not be practiced regularly. Another is the use of many examples, numerical and visual and based on things already familiar to the student. This aims at the gradual solidification in the student's mind of an intuitive gut feeling of the meaning of the concept. This is what I think is needed for decimals and fractions. It is what Hogben did so successfully in his classic book and what the Gleason-Hallett reform text aims to do. The third is the presentation of the underlying logic of the theory, making an airtight legal case that such and such and nothing else must be true. All professional mathematicians are in love with this, I among them. The "new math" attempted to bring in logical arguments at the very early stage of basic arithmetic—for instance, by *proving* rules like $\frac{1}{\frac{1}{x}} = x$. The French definition of a Euclidean line is an extreme example of how formal definitions are introduced so that complete proofs can be given.

A very interesting point relating to the use of formal definitions has been raised by Saunders Mac Lane and other critics of the Gleason-Hallett text. They object to the definition of a continuous function—"the closer x gets to a, the closer $f(x)$ gets to $f(a)$" in this book—raising the example of $x \sin(1/x)$. The problem here is that English syntax is notoriously ambiguous in common usage, and the intended meaning is often inferred from common sense rather than from any general syntactic or semantic rules. To give an example of ambiguities in normal English usage, an example much discussed by linguists like Montague is "Three lighthouse keepers saw three ships". In this sentence, the problem is that each lighthouse keeper might have seen a single one out of a set of three distinct ships, they might all have seen the same three ships, or maybe they each saw a ship and no one is sure whether they are the same or different ships. For the sentence above which purports to define continuity, I suggest you ask a mathematically naive friend whether they find anything odd about the sentences: "A clock pendulum is slowing down from friction. As it does so, it gets closer and closer to the vertical position." Or ask whether the assertion that "runner x is getting closer and closer to a new world's record in the 100-meter" implies that x never has a bad day? I certainly agree that a footnote clarifying the Gleason-Hallett definition to say that $f(x)$ need not *go straight* to $f(a)$, but may wobble on the way, is appropriate. But whether the Gleason-Hallett definition is correct as it stands is not a well-posed question: virtually the only sentences in English with an unambiguous interpretation (not requiring the use of common sense by the reader) are those written in mathematical jargon.

If one says instead, "For any $\epsilon > 0$, there is a $\delta > 0$ such that whenever $|x - a| < \delta$, then $|f(x) - f(a)| < \epsilon$," what happens to most students? First off, since Greek letters and complex English syntax ("for any ... there is ... such that whenever ... then ...") are used, the student is convinced that something very complicated must be going on. What is worse, even if you give the simple description of the meaning afterwards, the student will be sure that something more complex is going on or else why did you put it in such an opaque way? I think it is impossible to explain to most students that we prefer the complex syntax of the $\epsilon - \delta$ definition because we have crafted it precisely to squeeze out all the ambiguity of normal English. The important question is: do *most* people learn a new concept most efficiently by being exposed to elegant definitions of this sort? For instance, if your neighbor happens to ask you what you are teaching, and this happens to be calculus, how do you explain the derivative over the fence to him/her?

Wu makes the case in the December *Notices* that even if we admit full rigor is inappropriate for nonhonors students, we should at least aim to train them in making logical deductions. Why? Pure mathematics is the only discipline in which proofs are deemed so basic to knowing the truth. Especially since the advent of Ed Witten on the mathematical scene, we have realized all too clearly how physicists (and mathematical physicists) can often get at the deepest sort of truths without paying any heed to rigorous proofs. He is only the most visible example, as all of modern physics is built on "derivations" which are combinations of heuristics, calculations, and occasional precise arguments. In other sciences, such as chemistry and biology, logical deduction has virtually no place, because the systems being studied are too complicated to allow one to prove anything rigorously: what scientists do is to argue that such and such is the most likely explanation, based on data, analogies with other systems, and appeal to a shared Bayesian model of what one expects this kind of system will do. If scientists use logic so rarely, this is even more true for the rest of the educated public. In political discourse we not only fail to see logic used, we do not even see people using numbers coherently to quantify the issues. If we as a community want to take up an educational cause, maybe we would do better to try to get a larger group of people to believe that numbers can help them understand the world around them.

Applied mathematicians vary hugely on this scale, but many are much more interested in testing a model by simulations than by the much harder rigorous proof. Since all models are incomplete on a fundamental level because they isolate only a few of the complexities of nature, this test by simulation is often the really crucial one. How many years have gone by since Lorenz simulated his three-dimensional dynamical system without anyone being able to rigorously analyze his system? This is typical of nonlinear differential equations. Hodgkin and Huxley won the Nobel prize for their family of PDEs which model conduction on nerve axons. The clincher in their work was their computer simulation which correctly predicted the speed of conduction to within 10 percent. But only toy versions of their equations have been proven to actually produce stable traveling waves. In my own experience in computer vision, a nonlinear parabolic equation was proposed to enhance images. The equation was patently ill-posed, but works extremely well in simulations! The message for pure mathematicians is not to throw it out, but to find a well-posed problem which somehow captures the same significant behavior. The moral in all these cases is that the lack of proofs or even of well-posed models does not inhibit good applied mathematical modeling.

In the nineteenth century there was no clear division between pure and applied mathematics, and people like Riemann went back and forth between the two areas. He was quite satisfied with his use of the Dirichlet principle to prove the existence of solutions of various PDEs, although a rigorous justification of this argument took decades.

I believe I am on firm ground in stating that only lawyers[1] love proofs the way we do. The only colleague in the dinner club mentioned at the be-

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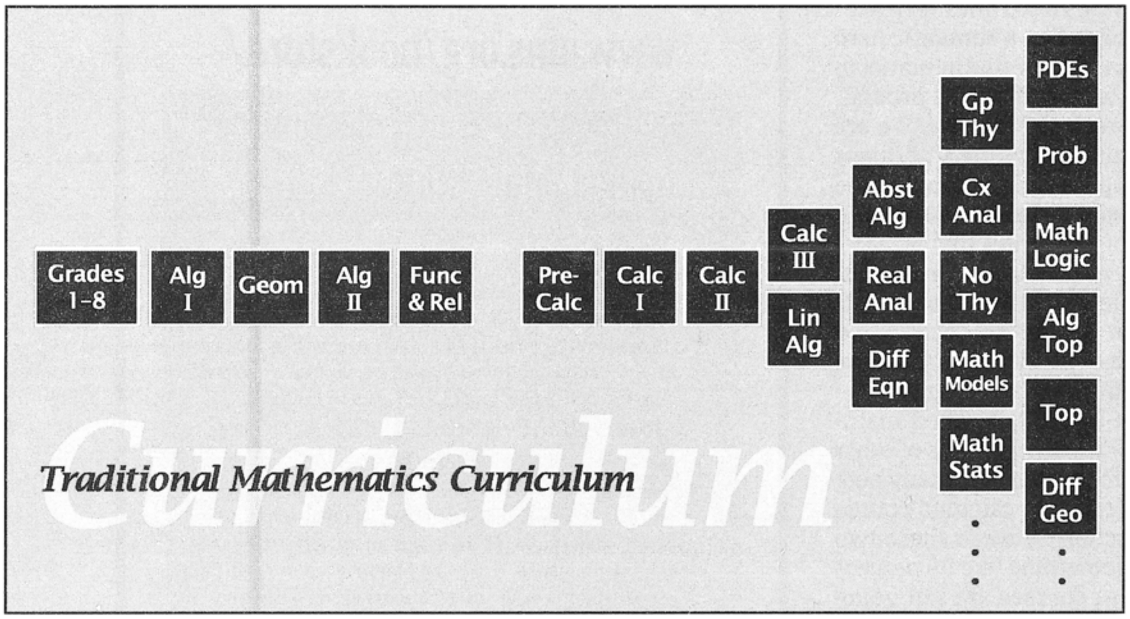
[1] *A referee kindly pointed out that religious scholars form another group which loves proofs too!*

ginning of this article who afterwards wanted to borrow a math book from me was in fact a professor in the law school. But a lawyer's idea of formal argument is so convoluted that it has resisted all attempts by computer scientists working in artificial intelligence to formalize it. A widespread disinterest in proofs is surely one reason why pure mathematics is the most isolated of the sciences. If we could give up our obsession with always being so precise and communicate more loosely what we are doing, we might break into the *New York Times* "Science" section more often. Only when a romantic hero like Erdös, a mathematician's mathematician who maintained a master list of "God's proofs", comes along can we break this barrier. We are intoxicated with the depth and subtlety of things like nonstandard four-space and the proof of the Fermat conjecture. But as a profession we are not very successful in communicating this beauty.

In summary, we have scientists, engineers, economists, and people in the world of affairs in one category—call it P (for "practical"); and we have the twentieth-century community of professional pure mathematicians in another—call it T (for "theorem-loving"). Applied mathematicians, lawyers, and mathematicians of other centuries fall somewhere in between. Many people in group P use calculus. A calculus course is often the last interaction between these two worlds. I would guess something like 99 percent of our students in these courses are not going to join category T. So calculus is our big chance to talk to the other world, P. We have two strategies open to us. One is to use this opportunity to preach the gospel of logic and reveal the beauty of precise definitions. Two examples that are often given are the rigorous definition of limit with ϵ and δ and the mean value theorem. On the other hand, the calculus reform movement (or some of the heads of this many-headed monster) takes the position that neither of these helps the students in group P understand better what calculus is about or what it is good for. Speaking to my mathematical friends and colleagues in group T to find out why they prefer a rigorous approach, I found that for many of them, their first exposure to this sort of rigor was a defining experience in their lives. I seem to be in the minority in having learned calculus from a pedestrian book like Hogben's. But the question is whether there are very many graduates of calculus in group P who found this exposure to rigor to be equally significant. I doubt it. Are we teaching calculus in the hope that a small percentage of our students will catch our love of rigor, or so that most of our students will emerge with the ability to use calculus in their specialties?

Do We Need Prerequisites?

Donal O'Shea and Harriet Pollatsek



Traditional Mathematics Curriculum

Introduction

The schematic above represents the traditional mathematics curriculum from grade school to baccalaureate.

There are, to be sure, differences from region to region and from school to school: geometry may come after algebra, courses may be pushed down one year to allow high school seniors to take calculus. Some colleges offer additional mathematics courses in the first two years, such as Discrete Mathematics or Math for Poets, and many offer several strands of calculus. Moreover, as the implementation of the NCTM Standards proceeds, the dependence of K–12 mathematics courses, one upon the preceding, suggested by the diagram, is lessening. Nonetheless, the structure of the mathematics curriculum is largely that sketched: a sequence of courses, one purportedly building on the other, with little choice until the student's junior year in college.

We pause to list a few of the defects of this curricular structure. Although obvious, they are too seldom acknowledged, and the harm they work is almost always understated.

First, the whole structure creates a climate of fear. A student who does poorly in one course feels incapable of mastering further courses. Parents jockey desperately to keep their children from falling off the narrow track and push them ahead before they are ready. There is good reason for the fear. A student who falls off the track somewhere in high school and enters college requiring one or more precalculus courses has a very long road to negotiate before encountering the useful and appealing ideas in junior- and senior-level mathematics courses. Such students often find themselves effectively closed off from a mathematics major (or even a minor) and any other majors requiring substantial mathematics.

Nor does the curricular structure disenfranchise only those who fall off the track before college. Students who have conceptual difficulties but a high tolerance for work learn to make it

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through high school by concentrating solely on technique. This strategy may serve as a survival mechanism in the first few calculus courses, but ultimately the student is the victim of a cruel joke: all that hard work has left him or her without the conceptual tools needed to benefit from more advanced courses, much less pursue a scientific career.

The curriculum also cheats the very able student who has understood everything but who chooses not to pursue a mathematics major. Such students rarely have time to complete the Calculus I-II-III and Linear Algebra sequence. Those who do almost certainly do not have time to take any other mathematics courses. This is a shame: many of the ideas in the junior–senior-level courses would serve these students well in their chosen professions and stimulate their imaginations. To compound the intellectual shortchanging, the standard Calculus-Linear Algebra sequence was never designed to meet the needs of students who would not continue with mathematics courses.

What, then, of mathematics majors? Here, too, we think the traditional curricular structure is less than optimal. Students who major in mathematics but do not go on to graduate school in mathematics or science do not encounter the range of ideas embraced by modern mathematics until their junior and senior years. They seldom see these ideas used and rarely have sufficient time for real mastery. What remains is only the hazy notion that modern ideas require years and years of calculus and preliminary study. Many of these students become school mathematics teachers and unwittingly propagate the narrow view of mathematics they have experienced.

The mathematics majors who go on to graduate school are the only ones to reap the reward for their years of preparatory study. In the course of doing their doctoral research, they will experience mathematics as a living field: one in which miracles happen, but in which our ignorance dwarfs our knowledge; one where deep problems lurk, but one where even modest insights bring great joy. But even among such students, us included, the curriculum they survived haunts them. The narrow road with course supposedly built upon course becomes an unexamined part of the way we think about teaching mathematics. We internalize it and come to think of it as reflective of the way the discipline really is.

We forget that mathematics is a field in which newcomers can make substantial contributions. We look at the gaps in our own backgrounds and see, not the obvious lesson that one can proceed very far with such gaps, but rather our shortcomings. We have learned to enjoy building towering intellectual structures on narrow, but firm foundations. Our curriculum is an instance of such a structure, and we seldom ask whether we learned mathematics in spite of that structure, not because of it.

In short, we contend that the traditional hierarchical curricular structure brutalizes most who proceed through it. And we count the members of the college and university mathematical community, us included, among the brutalized. How else to explain the perpetuation of such an inhuman gauntlet. How else to explain that when we think of teaching some course—Galois Theory, say—we think first of the prerequisites, Linear Algebra and a semester of Abstract Algebra, that we will use to exclude students rather than how we might explain the material to students without these courses and what opportunities might arise along the way to teach something about vector spaces, groups, and fields. (If this seems impractical, would you tell an interested colleague, a statistician or an electrical engineer, who asked you to explain the elements of Galois theory to first take the prerequisite courses?)

We are not claiming that prerequisites are unnecessary. Rather, we submit that insufficient thought has been given to creating a curriculum which minimizes prerequisites and maximizes a student's options.

This strategy (of concentrating solely on technique) may serve as a survival mechanism in the first few calculus courses, but ultimately the student is the victim of a cruel joke: all that hard work has left him or her without the conceptual tools needed to benefit from more advanced courses, much less pursue a scientific career.

Towards a Broader Curriculum

It is easy to complain about prerequisites and a hierarchical curriculum, and less easy to see what to do about it. We list four challenges that we believe a department will need to confront in reworking offerings to increase access and student choice, and suggest strategies to meet those challenges.

1) Fix the precalculus/calculus sequence. The necessity for some such effort enjoys a growing consensus and needs little further comment. Students entering college have many different needs, and each department needs to ask itself how its calculus offerings meet those needs. At a minimum, no matter where students enter or leave the calculus sequence, the coursework should engage their interest, teach them some substantial mathematics, and enable them to use the ideas of calculus in contexts in which they are likely to need it. This suggests that departments consider replacing the monolithic standard calculus sequence with a variety of offerings. We find Peter Lax's argument that departments assure the highest-quality teaching by giving each instructor maximum flexibility to adopt the calculus book of his or her choice very persuasive. Since the choice of many of the topics and presentation of material in the traditional precalculus course is predicated on students continuing to a traditional calculus course, departments should look very hard at precalculus courses. The wasted resources at the precalculus level are phenomenal. Many schools have found success with a year-long course that covers the traditional precalculus material, together with much of the material in the traditional first- and second-semester calculus courses. Others find that some of the reform courses allow students with weak high school backgrounds to pursue technical and scientific careers.

2) Add entry-level courses that go somewhere. We believe there is a need for serious freshman-level, noncalculus mathematics courses that will expose students to a variety of mathematical ideas and that will prepare them for further study in mathematics. Such courses should increase the mathematical maturity of students and provide them with solid technical and conceptual tools that will stand them in good stead later in life and in subsequent mathematics courses. They can also attract more students to the study of mathematics. Topics from statistics, geometry, algebra, and number theory lend themselves particularly well to developing exploration-based courses that are open to entering freshmen with high school algebra and provide the student with a rich store of examples on which to base further study. Even with a minimum of technique, such courses can build mathematical maturity and whet the appetite for further study.

3) Increase access to advanced mathematics courses. Departments should rework existing junior–senior-level mathematics and statistics courses to eliminate as many prerequisites as possible, thereby making them accessible to students in other majors. We believe that imaginative rethinking of upper-level mathematics courses can go a long way to alleviating some of the narrowness in the mathematics curriculum.

4) Add a program for students planning a Ph.D. in mathematics. The traditional curriculum was designed with the prospective Ph.D. student in mind, and broadening the curriculum is not without cost. In order to make sure that students bound for graduate school are as prepared as those in previous generations, departments will probably find that they need to make some special arrangements for students planning to continue into graduate studies. For example, departments might require such students to do a senior honors thesis or participate in some research experience or seminar. If there are a lot of students who continue on to graduate study, a department might want to consider separate junior- and senior-level honors courses. However it is done, we think that it makes more sense educationally to make special arrangements for the few students who are bound for graduate school than to have the relatively few such students drive the curriculum for the vast majority of other students.

Some Examples

We now discuss some of the tactics we have tried at Mount Holyoke to implement the strategies above and some of the things that we have learned. We do not claim that we have the answers. In fact, we do not even claim that everything we are doing is wise. But we do hope that some of our experiences may prove useful at other institutions and may spur others to their own, perhaps more imaginative and successful efforts.

Regarding the calculus/precalculus sequence, we have done three things. First, we have been heavily involved in the National Science Foundation-funded Five College Calculus in Context program. This program restructures the standard calculus sequence so that the main ideas emerge from real scientific and mathematical questions and so that students who terminate their mathematical studies with any course in the sequence carry away a substantive understanding which will enable them to use the ideas of calculus in contexts in which they are likely to need it. Second, we created a year-long precalculus-calculus sequence, funded by the Dana Foundation, aimed at allowing students with weak high school backgrounds to pursue technical and scientific careers. The course covers the traditional precalculus material, together with most of the material in the traditional first- and second-semester calculus courses. Third, we encourage every instructor to adopt the calculus book of his or her choice.

We undertook two programs aimed at creating introductory courses. The first was funded by a grant from the Sloan Foundation under its New Liberal Arts program. The outcome is a course, Case Studies in Quantitative Reasoning, which provides students with some basic techniques in data analysis, statistical inference, and modeling. The course is now taken by 20 percent of entering first-year students. The second was supported by the NSF and the NECUSE program (New England Consortium for Undergraduate Science Education) of the Pew Charitable Trusts and has put in place three freshman mathematics courses—Geometry, Algebra, and Number Theory—and a sophomore-level course, Laboratory in Mathematical Experimentation. The geometry, algebra, and number theory courses are open to entering freshmen with high school algebra.

Although we did not realize it at the time, the main innovation on which most of our curricular efforts would turn was the introduction of our Laboratory in Mathematical Experimentation course—the Lab, as students call it. On the one hand, the Lab can be taken by any student who has completed our introductory Algebra, Geometry, Number Theory, or Calculus I. On the other, taking the Lab (and sometimes also Linear Algebra) opens the door to several of our reworked advanced courses (see below) for a student who has not taken the calculus sequence.

In the Lab, students carry out five to seven investigations ranging across mathematics and statistics and accessible to beginning college students. The instructor selects topics from a list including stopping times for the Euclidean algorithm for rational integers and for Gaussian integers, graph-coloring and chromatic polynomials, iteration of linear maps in the plane, difference sets, and a randomized response technique for surveys asking sensitive questions.

Each investigation invites students to observe and look for patterns and encourages them to establish language to describe, conjecture, and analyze the phenomena under study. Projects lead to ideas which students will encounter in later courses and supply a repertoire of concrete examples to nourish intuition. In most, the student discovers some things she or he believes to be true and wants to prove but cannot.

Students write a report at the end of each project. We ask them to explain their experimental strategies (what examples they chose and why) and to support their conjectures with arguments based on empirical evidence, on mathematical analysis, and, when possible, with proof. We have found that students who observe a pattern in experimental evidence are strongly motivated to *know* whether the pattern will hold in future examples: they really understand the function of a proof, and they are eager to learn how to construct proofs of their own. In fact, we feel that students can hardly begin to appreciate the meaning of "proof" unless they have had concrete experience with examples which sometimes lead to correct conjectures and sometimes to false ones.

The Lab requires either Calculus I or one of our freshman courses, although most students take it after Calculus II. The reason that the freshman geometry, algebra, and number theory courses work as prerequisites is that these courses also require significant investigation on the part of students. In the geometry course, for example, students investigate what parts of Euclid carry over to the sphere; in the algebra course, students investigate solutions to quadratic equations in finite fields.

Students who take the Lab course develop a good feeling for convergence and for different rates of convergence and different types of asymptotic behavior. This serves them well in calculus, if they have not taken it, and in real analysis.

We have been teaching the Lab each semester since 1989 with good results. The course is very popular and, we believe, does a good job of allowing students to confront major ideas in an active way and make them their own. The substantial writing (and rewriting) they do improves the quality of the proofs they write in this and subsequent courses. We currently require the Lab of all mathematics majors. (*Laboratories in Mathematical Experimentation: A Bridge to Higher Mathematics*, a student laboratory manual for the sixteen investigations developed for the Lab, plus an instructor's manual, are forthcoming from Springer-Verlag.)

Building on our experience with the Lab and with the generous support of the Department of Education's FIPSE (Fund for the Improvement of Post Secondary Education), our department reworked seven of our junior–senior-level courses in order to reduce the prerequisites to at most two semesters of college-level mathematics: Differential Equations with Modeling, Analytic Number Theory, Mathematical Statistics, Lie Groups, Polyhedral Differential Geometry, Theory of Equations, and Symmetry Groups in Geometry and Physics. Our FIPSE grant supported sabbatical visitors whose teaching provided release time for the faculty member developing an advanced course. In addition, a visitor attended and critically commented on each new course under development. (This collegial help proved so valuable that now it is something we try to do for each other.)

By reducing the prerequisites, we hoped to attract students who were not mathematics majors but who would enjoy and be able to use some of the ideas encountered in traditional junior–senior-level courses. (Of course, we also hoped that appealing electives available early in a student's college years might attract more majors.)

We began with our own and others' experience that systematic and thoughtful use of computers often allows the introduction of relatively advanced, but exceedingly useful, ideas at an early stage in an undergraduate's career. As a result, most of our revised courses use computers in an essential way. Happily, the increased computer use also accords well with the way in which mathematics is increasingly practiced outside the classroom.

Normally we offer each course at least once every three years so that students have the option of a more accessible advanced course each semester. Details of the courses are available from the authors or by consulting the department's Web page.

Besides accessibility, other goals guided our development efforts. We sought topics that exhibit some of the range of mathematical ideas currently being investigated and applied. In particular, we wanted students to experience mathematics as a subject created and used by people. We also wanted to give students the opportunity to use the tools, technological and conceptual, that enable them to work with these ideas.

We also considered pedagogical issues in designing these courses. From the Lab and our calculus courses, we learned that working in groups strengthens students' learning of mathematics. Similarly, we found that writing is a useful tool; like group work, it forces a student to express his or her ideas clearly and to organize them coherently. Thus, all the new courses require careful writing. Finally, we wanted our new courses to be exploratory to some degree, and some of the writing we ask of students is a description and analysis of their explorations. Beyond the justifications mentioned in the description of the Lab, we note that successful exploration is not possible without taking risks. We work to create an atmosphere in which students feel free to be adventurous in their thinking. For women especially, encouragement to let go of safe, cautious strategies and try bold ones seems important.

We have also been mindful of the pitfalls in reducing prerequisites. There is a very real danger of ending up with shallow courses that neither stretch students' minds nor prepare them well for further study or for using the ideas in other contexts. We have tried to avoid these pitfalls by building courses around substantial, explicit examples. Learning a few significant examples thoroughly and exploring their implications not only prepares a student well for more general study (and enriches the student who has already had a more general course) but also leaves the student in command of some important ideas. Very often, the computer is the tool that enables us to bring these examples to the desired level.

For instance, the analytic number theory course treats one theorem in theoretical detail (Dirichlet's theorem on primes in progressions) but introduces the statements of others (e.g., the prime number theorem, the prime number theorem for progressions, and Littlewood's theorem) through numerical experimentation. Students are asked to be quite independent as they work with the computers to find their own paths toward the correct statement of a theorem. This is a substantial adjustment for students accustomed to having results given to them in lectures. However, after some initial discomfort (much less for students who have been through the Lab), they rise to the challenge.

For another example, the polyhedral differential geometry course asks students to construct models of polyhedra and to investigate lines, angles, polygons, and areas on them. The students work toward the Gauss-Bonnet theorem for polyhedra and polyhedral analogues of other differential geometric results. In addition, students investigate polygonal knots, equivalence, and Rademacher moves and examine the invariance of knot groups and knot polynomials.

Finally, in order to attend to the needs of students planning to pursue advanced degrees in mathematics, we now do three things. First, we expect such students to do a senior honors thesis. Secondly, we encourage students contemplating further study in mathematics to spend at least one summer at an REU (Research Experiences for Undergraduates) site. We insist that the site students choose be one, like our own, in which they will learn some mainstream mathematics. [Our REU site is supported by the NSF and NECUSE—for more details see the book *Models for Undergraduate Research in Mathematics* (L. Senechal, ed., MAA Notes 18) and the article by O'Shea therein.] In the last few years we have had some truly outstanding senior theses based on work begun in REU programs. Third, we are in the process of instituting a senior seminar in which students will go to the literature and report back on one or two papers of interest to the student and chosen with the help of the instructor. These strategies work well for us because we are a relatively small department: each year we graduate between twenty and twenty-five mathematics and statistics majors, and perhaps two will attend graduate school in mathematics.

How Does It Work?

Here is how our curriculum looks now (See diagram next page).

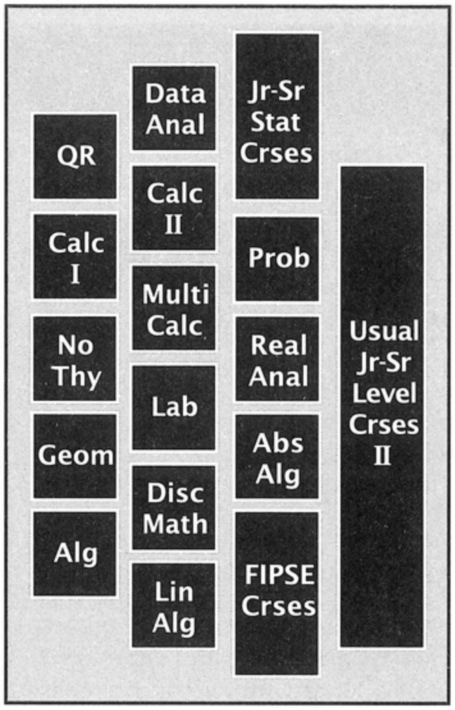
How does all this work? Is the curriculum outlined above an improvement over the standard curriculum? The short answer is that we think so, but we really do not know. We do offer a number of tentative observations and conclusions, organized about the strategies mentioned above.

We will not say too much about calculus, except to remark that some of the reform courses can be taken successfully by students with weak algebra skills. This has allowed us to drop all sections of traditional precalculus. We now advise many students with weak high school algebra backgrounds to take the first semester of Calculus in Context or the quantitative reasoning course because we feel that either is a much better terminal mathematics course than precalculus. Unfortunately, students who go into these courses with weak algebra skills come out with weak algebra skills. Whatever else it did, the traditional course did improve the high school algebra and precalculus skills of successful students. To serve students who do wish to continue to a second semester of mathematics, we offer an intensive high school algebra review during January term (in fact, since skills are easy to teach, we have senior mathematics majors run it).

The geometry, algebra, and number theory first-year courses seem to work well insofar as we have three or four students in each class go on to take further mathematics courses. We have even had a couple of mathematics majors (one now in graduate school), and many more minors, begin their study of mathematics with one of these courses. The downside, of course, is that one often wonders whether something practical like calculus or quantitative reasoning would not be a better choice for students who will take only a single mathematics course. We have no answer for this. The mathematical maturity of students in the alternative first-year courses does seem to increase markedly. However, even if one could actually measure this, it is not clear that the same would not have resulted from a calculus course.

A mixed blessing is that the alternative courses are challenging to teach. Student questions rapidly outrun the ability of the instructor to answer them, and, in order to be comfortable in class, the instructor needs a good knowledge of what is and is not known. This makes for classes that are intellectually engaging for the instructor. On the other hand, a runaway class with problems and conjectures flying left and right and no closure and no results leaves students with no real knowledge. Striking the right balance between exploration and conjecture, theorems and proof is often tricky.

These courses replaced a number of "freshman seminars" we offered many years ago. Those courses were much more in the "math-for-liberal-arts-students" mode. We feel that the new courses are much preferable: They engage students in doing mathematics and permit a student who catches fire and wants to take more mathematics to do so without going back and starting at the beginning of the calculus sequence.



Any two courses in the same column can be taken concurrently or independently. One or two courses in a column serve as prereq for a course in the column to the right. A single course in the first column gives access to the second column, and from anywhere in column i it is always possible to move to some course in column $i + 1$.

We think of the Lab course, on the other hand, as an unqualified (and demonstrable) success. We require it of mathematics majors—it is a prerequisite for Real Analysis—and recommend, but do not require, that it be taken in the sophomore year. The result is that a number of majors take Abstract Algebra without first taking the Lab. Comparing this group with those who take the Lab first shows clearly that, with few exceptions, those who take the Lab first do better than those who do not. This bears out the strong anecdotal evidence that suggests the Lab really does make a substantial difference in students' mathematical maturity. In order to make room for the Lab course, we stopped requiring a fifth semester of calculus (Calculus on Manifolds) of mathematics majors. We have never really had serious doubts that the exchange was in the best interests of our students.

Our experience with the sophomore- and junior-level mathematics courses we reworked has convinced us that it is indeed possible to offer sophisticated topics with fewer prerequisites and neither overwhelm students nor cheat them with superficialities. Students are able to cope with quite advanced topics through their investigation of examples. The key elements here are the provision of opportunities for "pure" exploration not burdened by the instructor's specific agenda, lots of examples, and a variety of fairly routine but difficult computations. Needless to say, the computer is a key tool in most of the explorations. We have found that having students work in groups on such explorations is usually more effective than having them work alone.

Unfortunately, while we have made a number of courses much more accessible, we have so far not succeeded in attracting significant numbers of nonmajors to them. On the other hand, our majors are enthusiastic about these courses, and some of them credit their existence as a factor in their decision to major in mathematics. Whether they take these electives before or after the traditional junior algebra and analysis, they get excited when they see connections between their classes.

Based on the student response, we do feel these courses have strengthened our major. Offering one each semester does mean that we have to offer one less traditional junior–senior-level mathematics course (this means that we offer two, instead of three, more traditional courses each semester), but we feel that the gains outweigh the costs.

Finally, because of the existence of strong REU programs, we do not feel that the preparation of the few students who go on to mathematics graduate school has suffered. On the contrary, we feel that our current students who are bound for graduate schools are actually better prepared than our students a decade ago.

In summary, we have bought into the broader, more accessible curriculum outlined above, and we invite you to consider doing the same. For us, the ideal curriculum would consist of courses which are independent but which nourish one another by increasing the students' repertoire of mathematical examples and experience. Every course should stand alone in the sense that it provides a student with examples and tools which will remain with him or her for life. Progression through the major should provide students with access to ever wider and deeper examples, an enhanced appreciation of what can go right and what can go wrong, a progressively more sophisticated sense of argument, and a growing respect for their own ideas and those of others. It should sharpen students' sense of wonder while providing them with the critical tools to distinguish dross from miracles.

For those who would argue that what we sketch here is a dumbing down of mathematics courses, we issue two challenges. The first is that you make it a principle that *every* mathematics course should increase students' options for further study of mathematics. The second is to thoroughly reexamine the prerequisites for the courses you teach and to consider how the course you want to teach might itself teach the prerequisite topic(s). Even if you retain the prerequisites, the exercise will keep you honest.

Book Review

A Primer of Mathematical Writing

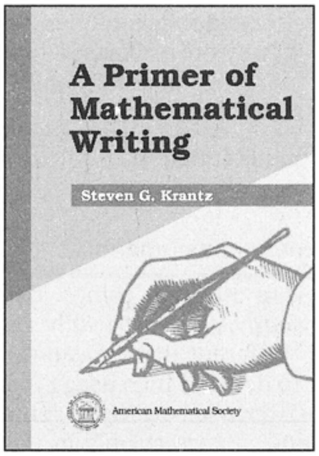
Reviewed by Paul R. Halmos

A Primer of Mathematical Writing
Steven G. Krantz
223 pages
American Mathematical Society
$19.00 Softcover

This is a book that adds new insights to the art of mathematical writing, calls attention to the standard sources, and reiterates and reemphasizes the standard wisdom. It is largely a personal book—it consists of the author's opinions (prejudices?, recommendations?, often virtually orders!) about the subject—but it is at least partly traditional. Its subtitle is *Being a disquisition on having your ideas recorded, typeset, published, read, and appreciated.* His credentials for writing the book are, he says, as follows: "I have written about one hundred articles and have written or edited about fifteen books. I have received a certain amount of praise for my work, and even a few prizes; and I have received plenty of criticism."

The main thesis is that it is worthwhile to write mathematics well, and the author's advice to you (the reader) is "to spend an hour or two with this book, and perhaps to spend another hour or two considering how its precepts apply to your own writing." The book is intended in large part, he goes on to say, for the novice mathematician.

Many of his recommendations are unarguable, and the first sentence of the first section of the first chapter is surely one of them: "In order to write effectively and well, you must have something to say."



The tone of the writing is "popular"—colloquial. To emphasize that "you must know consciously who the audience is," he says, "If you are writing a letter home to Mom, then your audience is Mom and, on a good day, perhaps Pop." Quite a bit later in the book we are told that we are not to "shovel the old BS around."

There are many intentionally inserted examples of incorrect grammar and usage labelled with a conspicuous symbol (in the shape of a heavy ornate cross). The first such example is "As a valued customer of XYZ Co., your call is very important to us."

The book is full of admonitions (positive and negative—do's and don'ts). An early one is "Stop when you have said what you have to say...and then shut up"—to which he adds:

> "'Sticks and stones may break my bones, but words will never hurt me' is perhaps the most foolish sentence ever uttered."

Avoid, he says, unnecessary notation. To support that he mentions (as an example not to be imitated), a statement he attributes to Mary Ellen Rudin, to wit:

> "Let X be a set. Call it Y."

I register a complaint—in several instances he puts in quotations such as that one with no sup-

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porting reference. The fussbudget scholar in me worries about that.

The technical aspects of writing a paper are discussed in detail: put your name even on drafts, he says; put the date on the work, number its pages, write on one side of the paper only—like that. He adds: "Some authors number their theorems from 1 to n, their definitions from 1 to k, their lemmas from 1 to p, their corollaries from 1 to r—each item having its own numbering system…as a reader, I find this method maddening; the upshot is that I can never find anything."

More: plan your notation in advance, use English and thereby minimize the use of cumbersome notation; think about word order. As an exercise, insert the word "only" into all possible positions in the sentence

> I helped Carl prove quadratic reciprocity last week.

Do not use contractions (don't, can't, I'm) in formal writing [I object; why not?]. Observe that there is a shade, but an important shade, of difference between the statements

> Let f be a continuous function

and

> Let f denote a continuous function.

Infer and *imply* mean different things. Use but don't overuse *obviously, clearly, trivially.* Do "different from" and "different than" mean the same ? (You will have to decide which usage you prefer, but do be consistent. According to some authors "different than" is correct only in settings such as "these are more different than those".)

The standard horrors of stylists and grammarians receive attention, of course: *farther* vs. *further*, *hopefully*, and split infinitives. Is a preposition a permissible word to end a sentence with?; do *shall* and *will* mean the same thing? A pertinent standard example is

> "I will drown and no one shall save me"

—is that a statement by a nonswimmer who has lost hope, or is it the declaration of intentions by a would-be suicide?

On how to organize a paper he gives a curious piece of advice that I confess I have never thought of: ask a person before you thank him in public. Here is some other organizational advice: do not necessarily organize in strict logical order (this has a reference to Piaget); strive to hold the statement of a theorem to fewer than ten lines—which you cannot do if you insist on stating twenty-five hypotheses; do not supply too few or too many definitions; in a bibliography the practice of listing abbreviations (as "Knuth, 1992") in lieu of correct bibliographic references is irresponsible.

[Near the beginning of the discussion of what to do with the paper once it is written he says, "Let me back-peddle a minute"—and I say ouch!]

Another key to success is actually making some progress—not like the friend who has a twenty-five step program for proving the Riemann hypothesis: "Count to twenty-four and then prove the Riemann hypothesis."

Collaborative work is discussed; the discussion begins with "I have written a great many collaborative papers, and some collaborative books as well."

At the beginning of Chapter 4 there is a quotation—here it is in full:

> "Sometimes a cigar is only a cigar. Sigmund Freud."

That makes me unhappy—because no reference is given and because, I think, the quotation is not accurate. The reference librarian I called attributed to "The Betrothed", by Rudyard Kipling, the line

> "A woman is only a woman, but a good cigar is a smoke."

Of course, for all I know, Freud could have said what is here attributed to him—but did he?[1]

The chapter goes on to discuss letters of recommendation and has, I think, some small blemishes. One is the word "conundra", which is not in the *American Heritage Dictionary*; another is the frequent use of "funny" made-up names, such as Mergetroyd Mittelschlachenmeyer; and still another is a quotation from a letter that Krantz himself wrote that begins "I consider myself to be a rather good teacher, but I really learned something when watching Mr. Spiro Agnew with his class."

In the discussion of book reviews there is a (quite properly attributed) two-paragraph summary of some of my opinions (the "my" in this sentence refers to the writer of this review), but not only is there no reference to the bibliographical source of that summary—there isn't even a reference to the summary itself in the index of the book.

In this same connection, Krantz mentions the three precepts "Is it new, is it correct, is it surprising?", and that bothers me for two reasons. One is that (a) I am not sure it's accurate, and the other is that (b) it is attributed to Littlewood. In my own writing on what to publish (in the

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[1] *The author and the reviewer are both correct. Kipling's line occurs in stanza 25 of "The Betrothed", published in* Departmental Ditties, *1886 (*Bartlett's Familiar Quotations, *Fifteenth Edition, 1980, p. 707, #6). The other line is attributed to Freud (ibid, p. 679, #8) —Ed.*

Monthly, January 1975) I wrote "Is it new, is it true, is it interesting?", and apparently I thought I was quoting Hardy. After reading Krantz's book, I searched again, but I couldn't find the quotation in the works of either Littlewood or Hardy.

Other technical matters that get discussed include blackboard technique, the use of transparencies, and the best possible "signature" to an e-mail message, which he says should be "something like this", and proceeds to present a complete reproduction of the one he uses.

One piece of advice says that you are not to "consider writing a book until you have tenure and are established somewhere". There is much fond mention of LaTeX. There are suggestions about "what to do with the book once it is written," which lead to a discussion of contracts with publishers.

Are we to write on a computer? Are we to make backups? Are we to use word processors? Is TeX of value? The answers are by and large yes.

The last chapter is very short (essentially only one page of text); its title is "Why is writing important?"

The bibliography is well labelled (but not numbered); I counted forty-nine entries in it; the index is long and detailed (nine pages). The bibliography contains references to the famous University of Chicago *Manual of Style*; to Fowler (*Modern English Usage*); and to some earlier literature about writing mathematics, such as Gillman, Higham, Knuth, Okerson (with the title of her article misprinted as "Who's article is it anyway?"), Steenrod et al., Strunk and White, and van Leunen.

Is this a useful book—should you keep it on your desk? I say yes, and I am 75 percent sure. Its purpose is to make you enjoy writing and be right when you write—and I think that in many cases it will succeed.

Mathematics in the Countries of Southern Africa, Realities and Aspirations

Edward Lungu and Precious Sibanda

> *The following article was submitted to the* Notices *by Herbert Clemens of the University of Utah. Clemens is a member of the Commission on Development and Exchange of the International Mathematical Union and is working with the authors of this article and their European research partners to increase interest in and support for the project MUSA,* described below.

Currently there is a dearth of qualified mathematics teachers both at high school and university levels in the entire southern African region. In a continuing effort to remedy this basic structural problem in our countries, each university in the region aims to train its staff through staff development programs. These are programs where the best students are encouraged to go for M.Sc. degrees in the hope that upon completion they will become members of the university staff. Even these programs are currently hampered by the lack of financial resources. As an example, the University of Zimbabwe used to send its graduates overseas for M.Sc./Ph.D. studies, but cannot afford to do so now because there is no longer any money to fund these students. Locally the facilities for their advanced training are either inadequate or simply nonexistent.

Funding for mathematics education and mathematics programs by the various governments of the region is simply inadequate. Most universities have neither the resources nor the expertise to offer mathematics courses with sufficient specialization at bachelor's-degree level or above. For example, in the region the University of Zimbabwe and the National University of Science and Technology (also in Zimbabwe) are the only two which offer honours degrees in mathematics. As a result, the application of mathematics in modeling industrial, environmental, or other real-life problems is fairly unknown in this part of the world, since there is a dire shortage of qualified personnel.

The governments of our various countries tried hard to train manpower when our economies were "strong". As the economies have declined, less money is being spent on manpower training. For this reason, the universities in the region are pooling their resources by establishing regional programs. Recently, for example, through partnerships with the University of Oslo and with the Austrian government small combined regional masters programs in mathematical modeling and in graph theory have been established at the University of Zimbabwe. To widen the pool of graduates entering these local programs as well as programs abroad, the region requires a "pre-M.Sc." program, through which many people will be raised to the required level.

A 12-month intensive "B.Sc. Honours" program at the University of Botswana is currently being contemplated to bridge the gap between the university preparation in mathematics available in many surrounding countries and advanced programs such as those in Zimbabwe. It can also be used as preparation for various staff development fellows from Southern Africa Development Corporation countries. There are also good students who pursue combined majors in mathematics with another science subject. Upon completion of their studies, these students will not have done enough advanced courses in mathematics. The 12-month program can be used to raise the standard of these students to "pre-M.Sc." level. This program at the University of

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Botswana can and will go a long way towards addressing the problems of advanced undergraduate mathematics education in the region.

With colleagues from Europe who have worked in the region, we are currently attempting to formalize these efforts, incorporate them into a several-year cooperative plan, and, with the help of the international mathematical community, find the financial and human resources that will help us to a full and fruitful implementation. We are calling the project MUSA (Mathematics and its Uses in Southern Africa).

The goal of MUSA is to foster dialogue and cooperative activities involving mathematicians and students of mathematics from a geographically connected region of sub-Saharan Africa, hopefully including Botswana, Malawi, Mozambique, Namibia, Zambia, and Zimbabwe, as well as Lesotho and Swaziland. Ties with the South African mathematical community would also be sought. MUSA will focus on regional development of a vigorous community of mathematicians, students of mathematics, and users of mathematics in government and business. MUSA contemplates three components:

1) A 12-month full-time program called a "B.Sc. with Honours in Mathematics" at the University of Botswana in Gaborone consisting of four year-long courses:
Abstract Algebra/Linear Algebra
Real/Complex Analysis
Topology/Geometry
Functional Analysis/Applied Mathematics

With the help of the international mathematical community, MUSA hopes to generate a scholarship fund to enable qualified students from participating countries to complete this program.

2) The 18-month M.Sc. in Mathematical Modeling program at the University of Zimbabwe, which has been established in recent years under a cooperative agreement with the Norwegian Universities' Committee for Development, Research and Education (NUFU). Again with the help of the international mathematical community, MUSA hopes to generate a scholarship fund for this program. The support of countries in the region will also be sought in the form of continuing the salaries of mathematics teachers and others employed as mathematicians during a leave of absence to complete this program. In addition, visiting students from government, industry, and other countries would be encouraged.

3) The gradual formation and strengthening of a community of researchers/teachers connected with a small number of mathematical research centers in Europe, the Americas, and Asia. We envision the establishment of an annual teaching/research meeting in consultation and cooperation with existing activities of the Southern African Mathematical Sciences Association. The site of this meeting would rotate among the countries having students/teachers/researchers participating in the program at any level. In addition, the content of this meeting would include minicourses, mini-research projects, and research talks, as well as a pedagogical component. The emphasis of each component would change from year to year depending on the mathematical situation of the country in which it is held.

In addition, and again with the help of the international mathematical community, MUSA hopes to establish a series of small pilot programs:

i) A visiting program for research mathematicians from established centers outside the region to participating southern African centers. These visiting mathematicians would teach undergraduate and postgraduate courses and participate in research activities. (Preference would be given to those involved in longer-term joint research or learning projects.)

ii) A program of visits to established centers for the African mathematicians, again with preference for those involved in longer-term joint research or learning projects.

iii) A program of 1–2 year "visiting lectureships" for young mathematicians with degrees from established centers outside the region to work on-site, teaching and collaborating in the above activities. We would design such positions so as to allow the young mathematicians ample time to continue their own research programs during their lectureships.

iv) A program of research and teaching visits for mathematicians from one participating Southern African country to teach advanced undergraduate and postgraduate courses and to do research in other participating countries.

These annual teaching/research meetings and the visiting programs, although long-term projects, would greatly benefit a lot of young mathematicians in the region who after their Ph.D. find themselves overburdened by teaching demands and with no prospects of promotion by authorities requiring "a good research record".

Alone our countries do not yet have the human and financial resources to realize these aspirations for our mathematical community. Indeed, a good part of the program outlined above will require funding from abroad, either in the form of foundation grants or cooperative agreements. In the hope that we can gradually find friends for our efforts in America and other countries, we wish to draw the attention of the American mathematical community to our current work and future aspirations here in southern Africa.

Challenges Facing Mathematics in the Twenty-first Century

Congressman George E. Brown Jr.

As many of you know, I have spent a great deal of time in recent years examining the linkages between math and science policy and the political, social, and economic institutions of the broader society. I hope during this next term to double these efforts and help to produce change in the math, science, engineering, and academic community that will enable you to continue to flourish in these challenging times. I also hope to bring some changes to the political institutions and the way that we deal with math and science issues in Congress.

I would like to explore these areas with you today and hope that this is just the start of a continuing dialogue with you as individuals and with the AMS. To start this discussion, I would like to provide some background and context for the situation in which we find ourselves. I will explore the nature of the changes facing us, try to detail the current policy debates in Washington, which are mostly budget debates, and look at ways that you and your colleagues in other scientific professional organizations can deal with this situation. Finally, I would like to issue a set of challenges to your community that will, I hope, stimulate some debate.

During this talk, I will speak about the mathematics, science, engineering, and academic communities as one broad entity and refer to it with a shorthand reference to the "science community". I know that disciplinary boundaries, institutional differences, and a host of other divisions prevent this from being an actual unified entity, but the issues facing all of the parts of your community demand a unified response. So, for convenience's sake, I will speak as if you were part of one broad, interconnected community. I hope that you realize that by your adopting this view you will increase your chances for success in the policy debates taking place.

The science community finds itself in the midst of great challenge and change. You flourished under the new relationship forged between science and government that was born in World War II and continued for the next forty years during the cold war. The weapons labs from the Manhattan Project evolved into a system of many hundreds of government laboratories that employ thousands of scientists and engineers. The GI Bill following World War II was a statement of the value of higher education and our society's desire to establish universal access to higher education as a national goal. Major investments were made in math and science programs following the Soviet launch of *Sputnik*, investments authorized in legislation entitled the National Defense Education Act. Our space program grew out of a competition with the Soviets to be the first to land on the Moon and thus deny them the ultimate high ground. More recently we made major investments in math and physics, seeking to develop a ballistic missile defense system to guard against Soviet attack. Over the last forty years, nearly all of our federal efforts in support of science and engineering were conducted with the shadow of the Soviet Union in the background.

With the fall of the Berlin Wall and the dissolution of the Soviet Union, the easy justifica-

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This article contains excerpts from an Invited Address presented by Congressman George E. Brown Jr. (D-California) at the Joint Mathematics Meetings in San Diego, California, on January 10, 1997. Brown spoke at the invitation of the AMS Committee on Science Policy.

tions for our national research and development (R&D) investments fell as well. At the same time, the budget deficit, which had tripled during the 1980s due in part to our increased defense spending, became a major political focus.

The loss of a clear political justification for R&D expenditures, coming at a time when budgets are being slashed, has put public outlays in support of the science community at risk. With the exception of funding for the National Institutes of Health (NIH), to which I will return in a moment, federal funding for R&D has been flat to declining over the last three years. And judging from reports on the budget for fiscal year 1998, to be released early next month, this trend will continue.

The moves to balance the budget and the imminent passage of a balanced budget amendment threaten our R&D enterprise. Absent rational reforms to our entitlement programs, the budget cannot be balanced, and programs supporting science and education will be decimated in the process. Let me expand on this statement.

You all probably know that our federal science and education programs are funded out of the discretionary part of the federal budget, the portion of the budget that must be appropriated annually. But these programs make up only about one sixth of total federal spending, so unless we tackle the tough problem of reforming the mandatory spending in federal entitlement programs, payments on the national debt, Medicare outlays, veterans' benefits, and the like we cannot balance the budget and will do irreparable harm to discretionary investment programs like science and education funding.

But even entitlement reform, if poorly done, can end up harming science and education programs. If you look at the recently enacted Welfare Reform Bill, you can see that the so-called "reform" is really a shifting of the fiscal burden to the states. What this does is force higher education, the base upon which academic R&D rests, into a tougher competition for state funds. So we simply shift the burden if we aren't careful and end up hurting our science and education programs in the process.

What I have been discussing is budget policy and its impact upon the science and education programs of importance to all of you. This is what has been happening in Washington for the past few years: budget debates dominate our time, and discussions of science policy become footnotes or afterthoughts. In order to turn this around and put science policy issues first, we must exert considerable effort. And getting mathematics to take its rightful place in these debates will take even more effort.

Mathematics is a wondrous area of study and is unique because it is both a discipline by itself and one of a few "gateway" areas of knowledge. By this I mean that a basic understanding of mathematics is required in all other areas of scientific inquiry. In addition, mathematics frequently provides the basis for advances within scientific disciplines. In the past we have observed this with physics, but now we are on the threshold of breakthroughs in biology, chemistry, geology, and materials sciences thanks to new modeling techniques being applied in those fields. While this unique relationship makes math indispensable to science, it also can make it less visible in policy arenas.

Congressman George E. Brown Jr.

With a low level of scientific literacy in Congress and with a lack of familiarity with the process of scientific discovery, mathematics gets lost as we concentrate on the latest advance in physics, biology, or engineering. For example, a breakthrough in new magnetic resonance imaging (MRI) technologies is announced, but lost in the fanfare is the fact that real-time MRIs are not possible without equally important breakthroughs in mathematics that allow the massive data sets being generated to be organized and presented. Time and again, mathematics receives less attention than it deserves.

Unfortunately, this can result in your getting less support than you deserve. By most measures—federal research support, graduate student, research assistantship, and postdoctoral support—mathematics lags behind the sciences in federal support provided. This is a difficult position to be in during good times. It is a very dangerous position to be in during the rough times ahead. What is to be done about this situation?

Earlier I mentioned that NIH has been the exception to the stagnant funding situation for

R&D at the federal level. In constant dollars, overall federal R&D funding has dropped 1.9 percent over the last three fiscal years. Over this same period, NIH funding has increased 10 percent! The reason for this relative success is the political support and education generated by the biomedical research community. Early proposals to cut NIH mobilized the biomedical research centers, the biotechnology industry, and the various disease victims advocacy organizations, all of whom came before Congress to make the case for NIH funding. This allowed strong congressional supporters of NIH, Representative John Porter in the House and Senator Hatfield in the Senate, to press for increases in NIH funding during a period of unprecedented reductions in the federal budget.

What the biomedical research community did stands as a model for the rest of the scientific community. Efforts to educate and contact policymakers have been started by many scientific and academic groups. Work to organize the science community in the field has also been started by science and engineering societies recognizing that contact at the congressional district and state level is most meaningful. I strongly encourage these education efforts because they create a long-overdue link between congressional policymakers and the science community that will, I hope, become an information exchange that transforms the culture on both ends of the exchange.

For Congress this can promote reasoned debate on science policy and provide a perspective on needed social investments that will prevent simplistic budgetary decisions from being made. For the science community this exchange can help transform a culture of isolation into one of awareness and involvement that will allow you to regain control of your future.

That last statement requires some amplification. For most of the last forty years much of the science community has assumed the role of detached, neutral observers who provide society with unbiased information and needed facts. Peer review has provided internal guidance, and intrusions from outside have been viewed as a threat to the neutrality of the scientific process. This detachment from the broader society served the scientific community well, as long as unquestioned public support was forthcoming. And the technological advances of the last forty years, combined with the need to stay ahead of the Soviets in the knowledge race of the cold war, were ample justification for continued support. In today's climate, that detached distance is rapidly proving to be a danger as public confidence in social institutions begins to fail, causing questions to be raised about all public investments. For much of the science community this turnaround has been a shock. Loss of unquestioned budgetary support, caused by increased pressure on public funding sources, as I noted earlier, has forced retrenchment on campus and in federal laboratories. Private sector downsizing has eliminated science and engineering jobs there. Unemployment is rising among recent Ph.D. graduates, who struggle to obtain a series of postdoctoral positions or an adjunct professorship. Yesterday's numerous tenure-track positions are now occupied by senior faculty holding on to their jobs or have been eliminated by cash-strapped universities, with many schools moving to eliminate entire graduate programs or departments. For mathematicians this was demonstrated by the University of Rochester's proposal last year to downsize its mathematics department and phase out the Ph.D. program there. And if these changes weren't enough, state and federal governmental entities have been casting a critical eye on college and university tuition increases, scientific misconduct, indirect cost reimbursement, and a host of other internal issues in the science community.

The only effective response to this changed environment is a change in the culture of the scientific community. And that involves engaging the broader society more directly on a range of issues. This process needs to start with the political communication and education that I have been urging for some time and then needs to be expanded.

At this point I must note that this image of a detached science community is an illustrative one that is largely true but does not hold across the board. Many of you are actively involved in activities of the kind I have been discussing. But as a whole, the scientific community does not have a political presence anywhere near its importance or size, and this needs to be corrected.

Nor does the scientific community have as broad a perspective as it needs. For example, simply working to defend your favored agency's budget or even working to increase support for R&D funding across the board is not enough. As I discussed earlier, funding for your programs is tied to a complex set of issues involving the entire federal budget. You need to understand those other issues and address them as well.

After spending the last two years fighting to maintain R&D funding in the agencies under the Committee's jurisdiction, I realized the need for a more comprehensive approach to this problem. So I set out to develop a budget plan that results in a balanced budget *and* allows for an increase in R&D funding. In September I released such a budget plan in order to move an R&D investment strategy into the center of the budget debates. While I do not seek your endorsement of this plan, although I would welcome it, I am offering it as an example of the broader thinking that must take place in the science community if we are to meet all of the challenges facing us today. You cannot simply say, "Don't touch my programs." You must also provide a means by which your needs can be met while addressing the larger pressures for a balanced budget.[1]

This broader focus needs to be cultivated within the scientific community on a number of fronts. The AMS is already moving ahead with this, as shown by your plans for Math Awareness Week in April and the other activities that you have undertaken. You should feel proud of the work you have under way and look for more things that could be done.

As you are well aware, a study was recently released on math and science education that showed United States students were not performing as well as their peers in other nations. This study has prompted reviews of math and science teaching methodology and has again raised concerns about our nation's ability to keep pace in an increasingly technological world. I know that you are involved in the follow-on to this report and that the National Council of Teachers of Mathematics has been in the center of this issue for some time. You should view this study as an opportunity for mathematicians to raise their profile on an issue of current social concern.

I know that the issue of curriculum reform is not without controversy within your membership: what one person calls making math more accessible is what another calls "dumbing down" mathematics. But this is an opportunity for you to get involved, as individuals and as a professional society, in an important issue and to raise the profile of mathematics. National Science Foundation director Neal Lane has been calling for scientists and engineers to get involved in education and other important community activities. The AMS has proposed a Working Group on Public Awareness, and this work needs to be emphasized so that there is wider participation and broad development of a "citizen-scientist" or a "citizen-mathematician" ethic within the AMS.

Improved mathematics education is essential in our society. Just as it is a "gateway" to success in the sciences, basic mathematical understanding is a gateway skill to success in today's world. As we make advances and move the boundaries of human knowledge further out, we leave behind those who are merely standing still. Every advance in science and technology has consequences, both good and bad, and we owe it to ourselves to minimize the adverse consequences. This does not mean that every one of you has to solve every problem in society, but you should be aware of the dislocations that progress causes and the new knowledge that is required to keep pace with the progress you create.

Without equity across society in knowledge skills, we cannot have equity in the benefits that social progress brings. This inequity can cause social disruption that threatens the peace and stability that scientific inquiry requires. To find immediate proof of that you need look no further than the current state budget in California, where, for the first time, the cost of the state corrections system exceeds the combined budgets for the University of California and California State College System. Yearly graduate tuition at Stanford is less than the average yearly cost of incarceration in California. These are startling facts that urge broader social involvement by the science community for reasons of enlightened self-interest. That broader involvement can bring greater support for mathematics at a time when you most need it.

I know that this is a great deal to have loaded upon you in such a short period of time, but as I stated earlier, this is just the start of a longer dialogue. I am aware that the AMS has begun to take action in many of these areas, and you are to be complimented. And on an individual level, I know that much of the change that I have discussed is not easy. After all that is required to earn a living and have a personal life, where do you find the time to get involved with math curriculum reform, or student mentoring, or helping with in-service training for high school mathematics teachers, or meeting with local politicians, or doing any of a hundred other things that these changes involve?

But these are challenging times, for you as individuals and as a society. Who, just a few years ago, would have predicted the situations we face in the science community? Who would have foreseen proposals to close entire graduate programs? Who would have predicted that we would be on a steady course to cut science funding? And obviously no one predicted unemployment figures among recent math Ph.D.s in double digits. But all of these things are part of the new reality facing us and are all signs that we must try new ideas and new approaches, and this will require new efforts on all of our parts.

I am willing to help you in these efforts and look forward to working with you as we approach the twenty-first century.

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[1] *A summary of the budget proposal can be found on the Democratic WWW Home Page at* `http://www.house.gov/science_democrats/gebinvst.htm`.

Problem Solving in Complex Societies

Neal F. Lane

Today I want to share a few thoughts about a system that delivers with remarkable consistency. We know our society today is complex, as are the problems we face collectively. But we also know we have a system of problem solving that works. It is tested by history. It is a system based on strong, stable public support for research and education across the spectrum of science and engineering.

Today I intend to first discuss the historical motivation for this highly successful system. This discussion will take us back a few centuries, but it also should bring to light a few points that are especially relevant as we approach a new century.

Then I want to turn to the present day and examine our current conundrum. We can all see that this is a remarkable era for discovery and opportunity in science and engineering, mathematics in particular. Yet we also sense tremendous uncertainty and apprehension—notably regarding the budget outlook and the job market for young (and not-so-young) mathematicians and other scientific professionals. Both of these situations deserve our immediate attention and action.

The National Science Board is currently revisiting the NSF's merit review criteria. Merit and impact form the central focus for the new criteria. This is not new at NSF. Indeed these two concepts loom large over the history of public support for science. To make this clear, I would like to recall the exploits of Admiral Sir Clowdisley Shovell. Who was he, you ask? Admiral Shovell was a heroic commander in the British Navy in the early eighteenth century, but he figures into the history of science, mathematics, and technology for other reasons.

In the fall of 1707 Admiral Shovell led his fleet of five gunships to triumph over the French Mediterranean forces at Gibraltar. In the wake of this victory, he sailed his fleet toward home, expecting a hero's welcome for himself and the thousands of troops under his command.

But when they sailed within twenty miles of the British coast, disaster struck. Four out of five ships were sunk, and over 2,000 lives were lost.

This disaster was not the result of a trap laid by the enemy. It was not caused by storm or sabotage. The culprit in fact was the single greatest challenge facing seafaring nations of the day. It was longitude—or to be more precise, an inability to determine longitude. Unable to navigate by sight because of fog, the ships struck rocky shoals off a small group of offshore islands.

There is much more to this story—including an ironic twist involving Admiral Shovell's own fate as he washed ashore. It is all recounted in a book that has reached the bestseller lists without much fanfare. The book is entitled *Longitude*, and its author is Dava Sobel, a science writer formerly with the *New York Times*.

You will recall from your studies of geography that lines of latitude parallel the equator, and capable sailors can determine latitude at any

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Neal F. Lane is the director of the National Science Foundation (NSF). This article contains excerpts (with minor revisions) from his Invited Address at the Joint Mathematics Meetings in San Diego, California, January 10, 1997. He spoke at the invitation of the AMS Committee on Science Policy.

point on the globe through calculations based on the position and height of the sun above the horizon, say at high noon on a given day. It's a tricky calculation, but the basic methods date back to the third century B.C.

Longitude, by contrast, comprises the great circles of the planet that intersect at the poles. There is no longitudinal analogue to the equator. The prime meridian, now at Greenwich, is set by humans, not by nature. Longitude consequently defies simple determination. Celestial navigation provides one method—but one requiring data, calculations, and difficult shipboard observations—all beyond the abilities of most eighteenth century sailors. Another method requires knowing the exact time at two places on the globe at once.

In the days before quartz watches and instant communication, this was no simple determination. The absence of timepieces that could remain accurate over months at sea proved the undoing of many great sea captains. Sobel writes that every great sea captain of the era of exploration, from da Gama to Balboa and Magellan to Drake, became lost through an inability to gauge longitude, though most were not in such dire straights as Admiral Shovell.

For this reason, the story of longitude is a story of scientific research being enlisted to address a societal challenge. Sobel writes:

> The active quest for a solution to the problem of longitude persisted over four centuries and across the whole continent of Europe...Renowned astronomers approached the longitude challenge by appealing to the clockwork universe: Galileo Galilei, Jean Dominique Cassini, Christian Huygens, Sir Isaac Newton, and Edmund Halley, of comet fame, all entreated the moon and stars for help. Palatial observatories were founded at Paris, London, and Berlin for the express purpose of determining longitude by the heavens...
>
> In the course of their struggle to find longitude, scientists struck upon other discoveries that changed their view of the universe. They include the first accurate determinations of the weight of the earth, the distance to the stars, and the speed of light.

Sobel also pointed out that the quest for longitude also marked the first large-scale investment of public treasuries into science and engineering research. European governments offered generous prizes for workable methods. The British Parliament's Longitude Act of 1714 set a prize of 20,000 pounds for a reliable method—a sum that translates into several million of today's dollars.

Neal F. Lane, director of the National Science Foundation (NSF).

The prize eventually went to John Harrison, a brilliant clockmaker with no formal training, but extraordinary skill and tenacity, in a result that miffed the scientific establishment of the day. Harrison's timepieces earned the name "chronometers", a term still reserved for only the most accurate timepieces. The astronomical approach, based on exhaustive mappings of the heavens, has remained a valuable navigational aid, but it never proved practical as a standalone method for determining longitude. It is nevertheless noteworthy that even after nearly three centuries, the charts Edmund Halley and his contemporaries developed in their quest for longitude remain among the most accurate accountings of the stars and planets ever produced. And obviously mathematics played an important role, but also was stimulated by all this activity, as well.

While I cannot do justice to the richness of this story and the complexity and human struggle behind all of these accomplishments, there is one valuable moral I would like to pull from this story. We see here research responding to society's need and at the same time sparking progress in both fundamental science and the development of new tools and technologies simultaneously—and in a mutually reinforcing way!

This same storyline emerges from countless other great quests we have tackled as a society—such as putting a human on the moon, battling polio and cancer, and securing victory in World

War II. In these and countless other areas, we have risen to the call of great societal challenges, and at the same time opened new frontiers for exploration through research and education.

This storyline runs to the core of the origins and purposes of the highly successful system of research we enjoy here in America. It's no secret that our system of public funding for research emerged from the contributions of science to the Allied victory in the Second World War. This connection between societal goals and scientific progress is also evident in the mission of the National Science Foundation. Our enabling legislation directs us "to promote the progress of science [and engineering]" and "to advance the national health, welfare, and prosperity..."

This duality of purpose is one of the secrets to the success of our system of science and engineering. It allows individual initiative and creativity to flourish without rigid centralized control and at the same time works to achieve larger national objectives.

One often hears terms like "basic" and "applied" attached to research, implying that one form has utility and the other does not—and that we can tell the difference. What we have learned from history is that research defies any such pigeonholing. More often than not research opens new frontiers for exploration and improves the quality of our lives simultaneously. What really matters in discovery is the quality of the researchers and their having the freedom to explore wherever their minds take them.

Mathematics is replete with examples that testify to this. The fundamental mathematics developed to understand surfaces, matrices, and complex geometries made possible advanced computer graphics, visualization, and computer-assisted design technologies among other things. These are what enabled Boeing to roll out its new 777 jumbo jet without ever building a mockup—saving millions along the way while setting new standards for safety and reliability.

Other examples abound. All of us here today know it took giant leaps forward in algorithms and data management in order to view magnetic resonance images of the brain in real time. A team at the Pittsburgh Supercomputing Center did this for the first time this past November, with support from NSF's Division of Mathematical Sciences. In this same way, it took progress in such areas as systems theory and cutting-edge statistics to shed light on population dynamics and the underlying behavior of ecological systems.

Of course, I know that when some people hear about these improbable connections between fundamental research and societal benefits, they say, "that's just luck." They say it's not something you can ever expect, let alone use as an investment strategy for public monies.

I prefer to think of these examples in light of Louis Pasteur's observation that, "chance favors the prepared mind." New York Yankees manager Joe Torre came up with another way to explain this in the wake of his team's surprising World Series victory. To use his words: "The harder you work, the luckier you get."

Innovations emerging from science and technology account for roughly one third, maybe more, of all economic growth over the past half-century.

We have learned from history that the hard work made possible by our system of support for science and engineering brings our nation much more than just good luck. It in fact brings the good fortune of progress and prosperity. There is no need to take my word for this. Consider, for example, the data on U.S. economic growth since World War II. Our real GDP has grown by a factor of six over the past five decades, thanks in large part to scientific and technological progress.

Many top economists, including a number of Nobel laureates, have studied in depth the drivers of this growth—and they've come to one clear conclusion. Innovations emerging from science and technology account for roughly one third, maybe more, of all economic growth over the past half-century. That's strong evidence, but I would argue that it's only the beginning.

That brings me to the last part of my talk and our current conundrum. When we reflect back on the twentieth century, we see an amazing array of advances—air travel, computing, the Internet, rising living standards, increased longevity, and a cleaner and healthier environment, to name but a few. It is hard to believe we can possibly improve on this record, but it looks like the best may be yet to come.

In just the past year, the centuries-long quest to prove Fermat's Last Theorem has met with success, and supercomputers have broken the teraflop barrier, finding ever-larger prime numbers along the way. We've also witnessed the discovery of planets orbiting stars beyond our solar system, gained new insights into the development of life on Earth—and possibly on other planets as well (I won't ask for a show of hands!)—and, we've launched a national effort to move education into the twenty-first century by connecting schools and classrooms to the Internet.

All of this makes our current situation all the more confusing and confounding. We can see that we are standing just a step away from an amazing era of possibility and opportunity. It is all made possible by progress across the spectrum of science and engineering—from computing to cognition and mathematics to manufacturing.

It is therefore both ironic and somewhat frustrating that just as these possibilities have come within reach, all signs are that we are stepping back from the promise they hold and perhaps squandering our best hopes for the future.

Erich Bloch, a former vice president of IBM and one of my distinguished predecessors as NSF director, recently wrote in *Science* magazine that: "The whole U.S. research and development system is in the midst of a crucial transition. Its rate of growth has leveled off and could decline. We cannot assume that we will stay at the forefront of science and technology as we have for fifty years."

Erich's observation comes home to all of us in human terms. At meetings like this one, the queues for job interviews and openings seem to get longer and longer every year.

This is occurring in virtually all of science and engineering. It is perhaps most acute in the mathematical and physical sciences, though no fields are immune. Where twenty years ago the majority of science and engineering Ph.D.s embarked on academic careers after graduation, today a majority pursue careers outside the academy.

I know that the AMS's own surveys suggest the situation has improved over the past year. The latest survey found that some 9.4 percent of the most recent class of Ph.D.s was unemployed as of this past September—not a good number. But, a year ago, the number was close to 15 percent, so it has come down by one third. But one year is not much of a trend, so we can't assume all is well.

In fact, it is the long-term trends that give us the most to think about. The Survey of Earned Doctorates sponsored by NSF's Division of Science Resources Studies makes this clear. This survey brings to light an important set of trends over the past twenty or so years that deserve our attention.

The share of recent mathematics Ph.D.s entering postdocs has jumped from only 5 to 6 percent in the early '70s to roughly one in four today, while the percentage obtaining immediate employment has dropped by a corresponding amount.

We've also seen startling increases in the numbers of students with no definite work or study plans upon graduation. One expects this of high school graduates, but not for superbly capable people who have just spent as many as seven years obtaining an advanced degree in an analytically rigorous and technologically demanding area like mathematics. That's not the way things are supposed to work.

Again, while no one of these trends is in itself alarming, collectively they send a clear wake-up call. Programs and policies at both federal agencies and universities have been slow to recognize and respond to these shifts, but we are now beginning to see promising signs of progress and change.

Most of these efforts are occurring at the disciplinary and departmental level. I know Don Lewis and NSF's Division of Mathematical Sciences encourage these efforts however they can. We've been getting favorable reports, for example, about mechanisms we've established that enable graduate students and postdocs to spend time in industry—such as the GOALI program, short for Grant Opportunities for Academic Liaison with Industry.

Unfortunately, when it comes to developing creative approaches to addressing these and other challenges, we know our hands are tied somewhat. Whatever approaches we adopt must work within the confines of a highly constrained budget environment. That should be old news to everyone in this room. The president will release his proposed budget for fiscal year 1998 in just over three weeks. I can't reveal any budget details, but it's no secret that the push to balance the budget severely limits the prospects for growth in any federal program.

When it comes to research funding, I often tell people the devil is not just in the details, it's in the totals. There is a lot of talk about what the future holds for science funding. You can even find detailed projections being tossed about for what NSF's and other agencies' budgets will look like in the year 2002. While those figures get our attention, they are not the most reliable of projections. We should not place great stock in the levels for individual agencies. The actual funding allocations are revisited each year by the president and the Congress in the budget process.

Nevertheless, the aggregated totals projected for the major categories of federal spending do deserve our attention, particularly the category known as domestic discretionary spending. This includes most of what we think of as the day-to-day running of the government parks, highways, prisons, NSF, NASA, education, and scores of other programs and agencies. You might be surprised to learn that this category makes up less than one sixth of the total federal budget.

Even more surprising and of real concern is that this small slice of the pie is slated to bear the lion's share of the spending reductions needed to balance the budget. In fact, this one-sixth slice of the pie is expected to drop to one seventh of the pie by 2002 according to most projections. That reflects a decline in purchasing power of some 15 to 20 percent, depending on whose CPI you like best.

Again, while we can't predict with any precision how this will affect NSF or any other agency, we do know that there will be increased competition for funds from this shrinking slice of the pie. We also know that for several decades, federal support for research and development has tracked very closely with total domestic discretionary spending.

It would be folly to ignore the possibility that the federal investment in research, including that in universities, could decrease in real terms by up to one fifth over the next five to ten years if trends continue as they are now. In a way, our nation is getting ready to carry out an experiment it has never run before: to see if we can significantly reduce the purchasing power of federal research investments and still be a world leader in the twenty-first century. That is a high-risk experiment.

Let me leave you therefore with a few thoughts on how to approach this confusing and confounding conundrum. We must first recognize that the long-term threat to science is real. The drive to balance the budget will bring some rocky times, and all of us have good reason to feel apprehensive about the future.

The key is that we cannot let our apprehension slow us down. I believe we will have a future golden age of science, but it will be much more than just a reflection of past glory.

I believe that scientific research will continue to explore the most fundamental questions of nature. And mathematics will continue to drive and catalyze progress across all of science and engineering and provide tangible benefits to our society.

I nevertheless predict our system of research and education will do much more than this. In a future golden age, research will also emphasize the integration and dissemination of knowledge beyond publishing in journals and presenting papers. We will rely on yet-to-be-established networks (not just electronic) of discoverers and users. This new partnership will make the benefits of research more apparent and, at least some of the time, more immediate.

Higher education, particularly at the doctoral and masters levels, will include practical knowledge and skills, such as communication, teamwork, management, and leadership that will enable more graduates in science and engineering to excel in a wide range of professions as they face the realities of today's and future job markets.

But perhaps more important is the fact that future leaders in the world of business, law, medicine, and politics will need to understand science and technology to a degree society has never recognized and certainly not required before.

Will all of this come to pass? I don't know. But it will not come to pass unless we expand our views of research, of the university, of connections and partnerships involving the doers and users of science, and of graduate education.

Thanks to your work, our nation has realized the benefits offered by science and technology, and what we've seen to date is only the beginning. We will see even greater returns in the future—provided we muster the national will to press forward and continue extending the frontiers of research and education.

From the story of longitude and countless other examples that include the extraordinary contributions of mathematics to our economy and society, we have learned a valuable lesson. When we extend the frontiers of research, we also move forward as a society, as a civilization, and we plant the vital seeds of human progress and prosperity.

That is an ideal system of problem solving for our complex society. Now, it is up to all of us working together to ensure that this system is better understood and that it remains fully vibrant and vital as we move into the twenty-first century. That is a challenge we must not fail to meet.

Coalition Presses Congress for Increases for Research

On March 4 the presidents of 23 science, engineering, and mathematics organizations released a joint statement warning of the dangers of the decline in federal investment in research. The coalition, which included some large umbrella organizations, comprised a total of 108 professional societies, including the AMS, the Association for Women in Mathematics, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics (SIAM).

This was the first time such a large and diverse group of organizations banded together on the issue of funding for science. It was also the first time that the AMS has been so deeply and publicly involved with such matters: AMS president Arthur Jaffe moderated the press conference at which the statement was released and was a key figure in drafting it and getting organizations to sign on.[1]

Also making statements at the press conference were the presidents of four other organizations: Paul Anderson, American Chemical Society; D. Allan Bromley, American Physical Society; Andrea K. Dupree, American Astronomical Society; and Charles K. Alexander, Institute of Electrical and Electronics Engineers.

The Clinton Administration's budget request for fiscal year 1998, made public in early February, marks the fifth consecutive year of constant-dollar decline in federal funding for scientific research and development. The budget calls for an increase of 2.8% for support of basic research. For the National Science Foundation, the requested increase is 3.0% (an article on the NSF budget request is in preparation for a future issue of the *Notices*).

The joint statement calls for an increase "in the range of 7%" for agencies charged with carrying out scientific research and education. "To constrain still further federal spending on scientific programs would jeopardize the future well-being of our nation," the statement says. With the drive to balance the budget foremost on the Congressional agenda, it is unclear whether such a large increase is possible. But the coalition found a bright spot in a bill recently introduced by Senator Phil Gramm, (R-Texas) which calls for doubling federal spending on basic and medical research over the next ten years.

But the harsh fiscal reality is that an increase for science means a cut somewhere else. The coalition is not going to take a stand on what should be cut, but according to SIAM president John Guckenheimer the scientific community does need to justify the proportion of the budget it is asking for. "One justification may be that revenues will increase, so that funding science is a 'win-win' situation," he says. "But that is an argument that must be substantiated." Jaffe believes the argument can be made, noting that the nation is today reaping the dividends in improved quality of life from investments in science made thirty years ago. "We must reverse the current slow decay of the scientific infrastructure," Jaffe declares. "We are trying to encourage a grassroots movement for science."

The joint statement is just the first step in a longer-range effort to influence the budget as it wends its way through Congress over the summer. The AMS will continue to work with the other organizations and with Congressional representatives and staff to advocate increases for science. The coalition that produced the statement represents more than a million scientists, engineers, and mathematicians. That sounds like an impressive number of voters, but in the past this group has carried more prestige than political weight, so it is unclear if the increase they asked for will materialize. But as James Turner, a staff member for the House Science Committee, put it, "If you don't work hard for an increase, you will get a decrease."

—Allyn Jackson

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[1] *Another example of increasing AMS attention to Washington affairs can be seen in a Congressional briefing on mathematics, held the day after the press conference; see the accompanying article on page 585 of this issue of the* Notices.

AMS Congressional Briefing: Mathematical Transcriptions of the Real World

Capitol Hill may seem an unlikely setting for a lecture on mathematics, but on March 5 an AMS briefing entitled "Mathematical Transcriptions of the Real World" attracted an audience of about seventy-five people, a good-sized crowd for such an event. In attendance were mostly Congressional staffers, scientific society representatives, and program directors from federal funding agencies. Most notable was the appearance of two Congressional representatives, James Sensenbrenner (R-Wisconsin), and Vernon Ehlers, (R-Michigan). Sensenbrenner is chair and Ehlers is a member of the House Committee on Science.

This was the first time ever that a briefing focused exclusively on mathematics was presented to Congress, which typically has dozens of these events going on every week. Often the briefings are attended only by Congressional staff, not the members of Congress themselves, so it was quite a coup that the AMS managed to bring in two. Sensenbrenner left after making a few remarks, but Ehlers, the only member of Congress ever to hold a Ph.D. in physics, stayed for most of the hour-and-a-half affair.

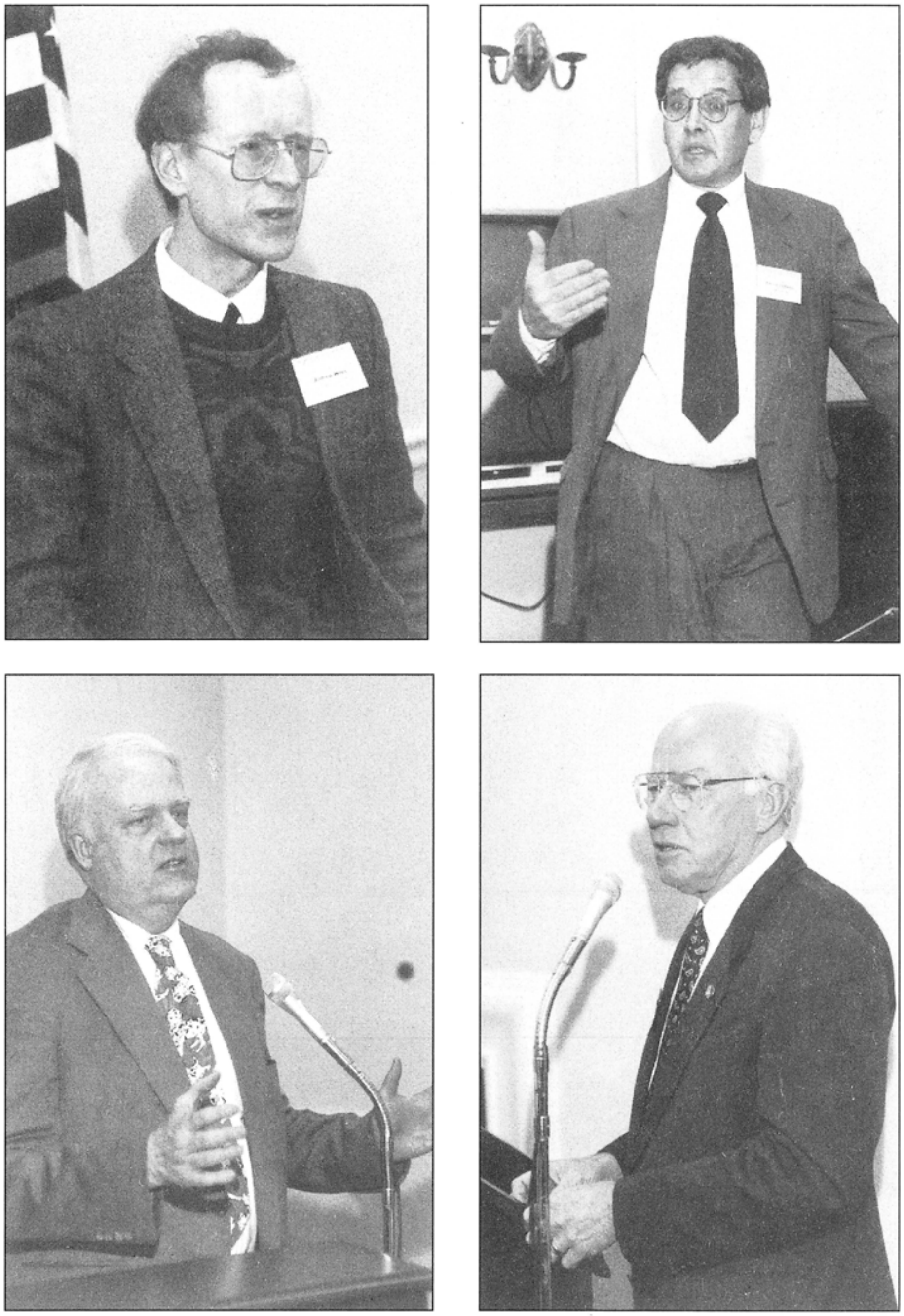
The featured speaker at the event was Ronald Coifman of Yale University, who discussed the use of mathematics in data transmission, analysis, and interpretation. His talk followed brief remarks by Andrew Wiles of Princeton University, who was proclaimed by the event's emcee, AMS president Arthur Jaffe, as the "most famous mathematician in the world." Jaffe was clearly thrilled at the success of the event as well as by the prominent role the AMS played in a press conference on science funding, held the day before (see accompanying article on page 588 of this issue of the *Notices*). "Mathematics is having a greater influence in the political arena than ever before," he said.

In contrast to the press conference, which was explicitly intended to influence government policies, the briefing was purely educational, an attempt on the part of the AMS to convey something of the utility and importance of mathematical research. Afterward there was talk that some Congressional staffers had grumbled that they did not have time to sit through a lecture that had no clear connection to specific policy issues they were working on. But James Turner, who is on the staff of the House Committee on Science (and who, he confessed, was a mathematics major), did not see the need for such an explicit connection. In fact, he had encouraged the AMS to focus on mathematics, rather than try to pursue a policy agenda. "Most people here don't realize how mathematical research affects their lives," he pointed out, "so this was an excellent lecture to have." He also noted that many Congressional staffers did not realize that the developments Coifman discussed "relate to government funding that their bosses voted on."

From Brahms to Oil Exploration

One of the most striking stories from Coifman's talk was an application to music. Brahms, who died in 1897, made a wax cylinder recording of himself playing the piano. The recording was later transferred to 78 rpm disks, but unfortunately the sound was so garbled that it was impossible to tell even which piece was being played. Coifman took the sound from the 78s, digitized it, and worked with musicians to tease the music out of the signal. The musicians were then able to identify the piece and even get an understanding of how had Brahms played it.

This example captured the main theme of Coifman's talk: How do you extract from a mass of data the features that are important? The talk was replete with examples from an impressive variety of areas. Oil companies suffered from data overload in offshore oil explorations. The acoustic data they gathered was so extensive that it could not be processed right away; it had to be loaded onto magnetic tapes, put on a helicopter, and flown back to the mainland for processing. And even then the processing would take a few months. Now mathematical techniques allow them to scoop out of the river of data just the features they need, as little as 1 percent of the data. The amount of data is so much less that not only can it be transmitted by satellite to a processing facility, it can also be processed immediately to guide the ships then and there to where they need to go.

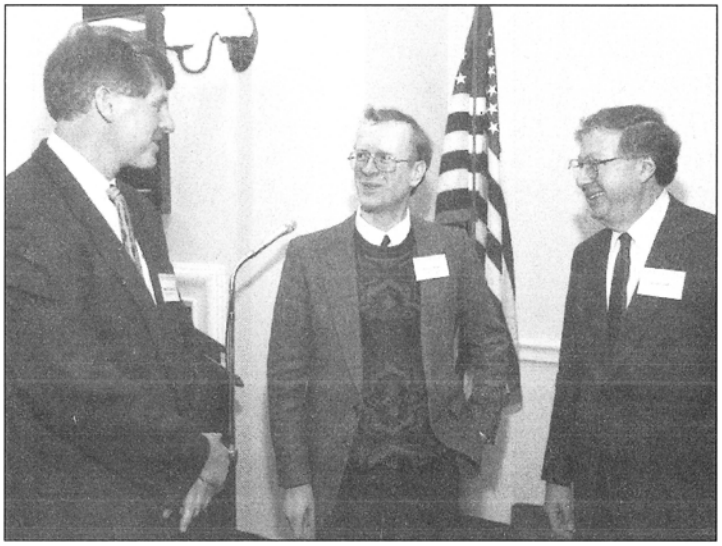


Speaking at AMS Congressional briefing: clockwise from top left, Andrew Wiles, Ronald Coifman, Vernon Ehlers, and James Sensenbrenner.

To give the audience a flavor of how wavelets work, Coifman described the difference between how a piece of music is encoded on a CD and how it is encoded on a score. On a CD every second of music is divided into 40,000 segments, and a sample is taken for every segment. "That's a complete disgrace, in the sense that it means that you are putting together 40K numbers for a piece of music that takes 1 second," Coifman noted. If musicians operated in that fashion, "they would never be able to describe anything." In contrast, a musical score provides a score for each instrument, with information about which notes are played when, at what pitch, for how long, etc. Wavelets provide an analogous way of representing data, be it audio, visual, or electromagnetic.

If we are in a digital age, Coifman said, it is a very "naive" digital age. He compared today's methods of data representation to ancient methods of representing numbers. Those methods were inefficient and did not allow for computations that people needed to do, such as division and taking square roots. It was only when decimal notation was developed that it was possible to automatize such computations. "In some sense we are exactly at that age now," he said. "We have enormous amounts of data, we have very powerful computers—or so we think—and they just don't do what we expect them to do, because we are a little bit naive about how we present and manipulate the data." With examples from music to mammograms, Coifman demonstrated how mathematics works behind the scenes in many aspects of daily life.

Ronald Coifman (left) and Andrew Wiles.



Left to right, Samuel M. Rankin, Andrew Wiles, Arthur Jaffe.

Planning for the briefing began back in October of last year in conversations between Jaffe, Turner, and Samuel M. Rankin of the AMS Washington Office. In addition to the AMS, a number of other scientific societies sponsored the briefing, including the American Chemical Society, the American Physical Society, the Society for Industrial and Applied Mathematics, and the Mathematical Association of America. According to Jaffe, the plan is for a regular series of briefings on a variety of scientific and engineering topics, organized by the other societies, with another one on mathematics in perhaps a year.

Certainly the strains on federal spending on science are part of the motivation behind these efforts. It is not clear how deeply mathematicians will wade into the intensely political waters surrounding questions of federal spending. But briefings like this one, in which mathematicians speak with passion and grace about the subject they love, seems a perfectly natural venue.

—Allyn Jackson

Remarks by Andrew Wiles

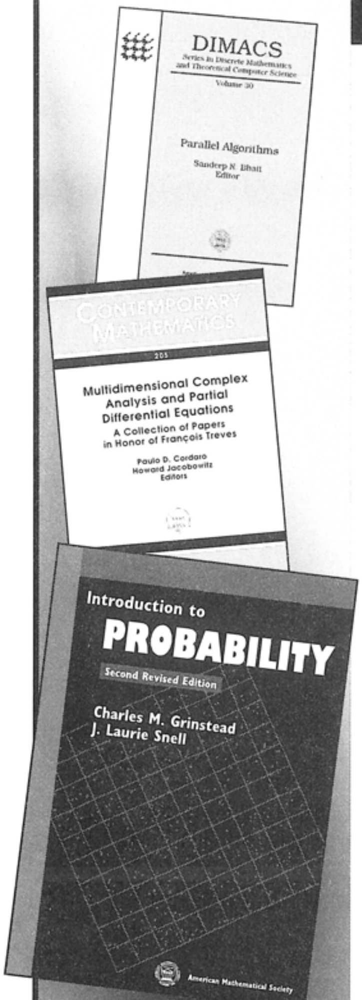
What follows is an excerpt from comments made by Andrew Wiles during the briefing.

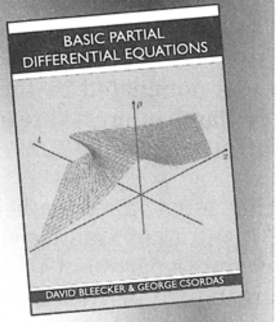
"From the earliest times, mathematics has been pursued in two ways. It's been pursued because of its use, because that was how you plotted the course of the stars so that you could navigate, that was how you measured angles so that you could build, that was how you weighed and measured so that commerce could be undertaken. But at the same time, at least as far as recorded history goes, there have been people who pursued mathematics for its own sake, for the sake of mathematics. And I confess I started out that way and I've stayed that way, from the age of about ten, when I first came across the Fermat problem in a book in a public library. I've been hooked on mathematical problems as intellectual challenges. However, we don't have to worry that it won't be used. Mathematics—even the most pure-seeming mathematics, the most abstruse mathematics that we thought would never be used—is now used every time you use your credit card, every time you use your computer. It's used to preserve secrecy, to transmit data, and as you'll see later, to recover data that you thought you'd lost.

"Perhaps another thing to say about mathematics in this respect is that it's a bit like discovering oil. The people who discovered oil were not the people who were actually designing the motor cars to use it. But mathematics has one great advantage over oil, in that no one has yet—and physicists will show you they never will—found a way that you can keep on using the same oil forever. However, mathematics is never lost, it is always used. And it will always be used, the same mathematics; once it's discovered and understood, it will be used forever. It's a tremendous resource in that respect, and it's not one that we should neglect to develop."

American Mathematical Society

Recently Published Titles from the AMS





Basic Partial Differential Equations

David Bleecker and **George Csordas,** *University of Hawaii, Honolulu*

This undergraduate text is self-contained for students who have had three semesters of calculus. No previous course in ordinary differential equations or linear algebra is necessary. Nevertheless, rigorous proofs of nearly all results are given after ample physical motivation. In particular, students can read and understand the proofs of the maximum principles for solutions of the heat and Laplace equations, along with results on the continuous dependence of solutions with respect to variation of initial and boundary data. Moreover, complete proofs of convergence theorems (e.g., pointwise and uniform) for Fourier series are provided.

This book is for those who believe that a PDE course should do more than disseminate facts and recipes. However, it easily accommodates different levels of rigor which instructors may deem more appropriate for their students. Besides all of the standard topics, there is coverage of traffic flow shocks, evolution of population densities, minimal surfaces, gravitation, quantum mechanics of the hydrogen atom, and vibrations of round drums, spheres and manifolds.

There are approximately 280 examples worked out in detail, and 600 exercises ranging from routine to quite challenging. All graphs of mathematical functions of one or several variables were computer generated, including surfaces of various spherical harmonics, Bessel functions, and nodal curves for vibrating drums. There is a solutions manual with complete solutions (including many intervening steps and calculations) to all but the most straightforward problems.

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

International Press; 1996; 735 pages; Hardcover; ISBN 1-57146-036-5; List $42; All AMS members $34; Order code INPR/23RT75

Introduction to Probability

Second Revised Edition

Charles M. Grinstead, *Swarthmore College, PA,* and **J. Laurie Snell,** *Dartmouth College, Hanover, NH*

This text is designed for an introductory probability course at the university level for sophomores, juniors, and seniors in mathematics, the physical and social sciences, engineering, and computer science. It presents a thorough treatment of probability ideas and techniques necessary for a firm understanding of the subject.

The text is also recommended for use in discrete probability courses. The material is organized so that the discrete and continuous probability discussions are presented in a separate, but parallel, manner. This organization does not emphasize an overly rigorous or formal view of probabililty and therefore offers some strong pedagogical value. Hence, the discrete discussions can sometimes serve to motivate the more abstract continuous probability discussions.

Features:

- Key ideas are developed in a somewhat leisurely style, providing a variety of interesting applications to probability and showing some nonintuitive ideas.
- Over 600 exercises provide the opportunity for practicing skills and developing a sound understanding of ideas.
- Text includes many computer programs that illustrate the algorithms or the methods of computation for important problems.

1997; 484 pages; Hardcover; ISBN 0-8218-0749-8; List $49; All AMS members $39; Order code IPROBRT75

Multidimensional Complex Analysis and Partial Differential Equations

Paulo D. Cordaro, *IME-USP, Sao Paulo, Brazil,* and **Howard Jacobowitz,** *Rutgers University, Camden, NJ,* Editors

This collection of papers by outstanding contributors in analysis, partial differential equations, and several complex variables is dedicated to Professor François Treves in honor of his 65th birthday. There are five important survey articles covering analytic singularities, holomorphically nondegenerate algebraic hypersurfaces, analyticity of CR mappings, removable singularities of vector fields, and local solvability for systems of vector fields. The other papers are original research contributions on topics such as Klein-Gordon and Dirac equations, Toeplitz operators, elliptic structures, complexification of Lie groups, pseudodifferential operators, nonlinear equations, CR and Mizohata structures, analytic hypoellipticity, overdetermined systems, and group invariant convex hypersurfaces.

Contemporary Mathematics, Volume 205; 1997; 276 pages; Softcover; ISBN 0-8218-0509-6; List $55; Individual member $33; Order code CONM/205RT75

Parallel Algorithms

Sandeep N. Bhatt, *Bell Communications Research, Morristown, NJ,* Editor

This volume is the result of the Third DIMACS Implementation Challenge that was conducted as part of the 1993–1994 Special Year on Parallel Algorithms. The Implemenation Challenge was formulated in order to provide a forum for a concerted effort to study effective algorithms for combinatorial problems and to investigate opportunities for massive speedups on parallel computers. The challenge included two problem areas for research study: tree searching algorithms, used in game search and combinatorial optimization, for example, and algorithms for sparse graphs.

Participants at sites in the U.S. and Europe undertook projects from November 1993 through October 1994. The workshop was held at DIMACS in November 1994. Participants were encouraged to share test results, to rework their implementations considering feedback at the workshop, and to submit a final report for the proceedings. Nine papers were selected for this volume.

DIMACS: Series in Discrete Mathematics and Theoretical Computer Science, Volume 30; 1997; 162 pages; Hardcover; ISBN 0-8218-0447-2; List $45; Individual member $27; Order code DIMACS/30RT75

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Mathematics People

Lacey and Thiele Receive Salem Prize

The Salem Prize for 1996 has been awarded jointly to MICHAEL T. LACEY of Indiana University, Bloomington, and to CHRISTOPH THIELE of Christian-Albrechts-Universität, Kiel, for their remarkable work on Calderón's bilinear Hilbert transform and the development of a new method of phase space analysis. The prize, established in 1968, is given each year to a young mathematician who is judged to have done outstanding work in the area in which Raphaël Salem worked, primarily Fourier series and related topics. The selection committee for the 1996 prize consisted of J. Bourgain, C. Fefferman, V. Havin, P. Jones, Y. Katznelson, and J. C. Yoccoz.

—J. Bourgain, Institute for Advanced Study

Presidential Career Awards Announced

Last December, President Clinton named 60 young researchers to receive the first annual Presidential Early Career Awards for Scientists and Engineers (PECASE). The new awards, created in spring 1996, recognize demonstrated excellence and promise of future success in scientific or engineering research and the potential for eventual leadership. The recipients are chosen from nominations made by agencies across the federal government and receive up to $500,000 over a five-year period to further their research. The PECASE program replaces a number of programs, including the Presidential Young Investigator program of the National Science Foundation.

PECASE awards were given to three individuals who work in the mathematical sciences.

ANDREA BERTOZZI of Duke University received the award through a nomination by the Office of Naval Research. Her research interests are applied analysis and scientific computation, thin films and moving contact lines, singularities and scaling in nonlinear partial equations, and hydrodynamic interface motion.

Weinan E of the Courant Institute of Mathematical Sciences at New York University was nominated by the National Science Foundation. His research interests are in applied mathematics, partial differential equations, and numerical analysis.

Roldan Pozo of the Computing and Applied Mathematics Laboratory at the National Institute of Standards and Technology was nominated by the Department of Commerce. His research interests are in high-performance scientific computation, including object oriented techniques for scientific computing, numerical linear algebra, and software environments and tools for parallel computing.

— from White House news release

Deaths

FREDERICK J. ALMGREN, Henry Burchard Fine Professor of Mathematics at Princeton University, died on February 5, 1997. Born July 3, 1933, he was a member of the Society for 36 years.

LOUIS AUSLANDER, professor of mathematics at the Graduate School and University Center, CUNY, died on February 25, 1997. Born July 12, 1928, he was a member of the Society for 45 years.

THOGER S. V. BANG, professor at the University of Copenhagen Mathematical Institute, died on January 18, 1997. Born January 27, 1917, he was a member of the Society for 46 years.

CHARLES L. DOLPH, professor emeritus of the University of Michigan, died in June 1994. Born August 27, 1918, he was a member of the Society for 52 years.

RUDOLF ZUHEIR DOMIATY, professor at Graz Technical University, Graz, Austria, died on October 22, 1996. Born June 25, 1938, he was a member of the Society for 3 years.

THOMAS E. HULL, professor emeritus of the University of Toronto, died on August 15, 1996. Born June 5, 1922, he was a member of the Society for 47 years.

JOHN A. KELINGOS, associate professor of mathematics at Vanderbilt University, died on October 28, 1996. Born January 22, 1936, he was a member of the Society for 35 years.

JOHN A. LEWIS, retired from AT&T Bell Labs, Summit, NJ, died on December 12, 1996. Born January 12, 1923, he was a member of the Society for 46 years.

ROBERT K. MCCONNELL, of Fanwood, NJ, died on November 29, 1996. Born May 12, 1912, he was a member of the Society for 47 years.

NIELS VIGAND PEDERSEN, lecturer at the University of Copenhagen Mathematical Institute, died on November 24, 1996. Born March 12, 1949, he was a member of the Society for 15 years.

GORDON M. PETERSEN, professor emeritus of the University of Canterbury, Christchurch, New Zealand, died on November 9, 1996. Born November 25, 1921, he was a member of the Society for 45 years.

DANIEL SHANKS, of the University of Maryland, College Park, died on September 6, 1996. Born January 17, 1917, he was a member of the Society for 47 years.

KERMIT N. SIGMON, of the University of Florida, Gainesville, died on January 14, 1997. Born April 18, 1936, he was a member of the Society for 33 years.

CHARLES S. SUTTON, professor emeritus of The Citadel, Charleston, SC, died on January 1, 1997. Born July 15, 1913, he was a member of the Society for 59 years.

JAMES A. WARD, of Tallahassee, FL, died on January 28, 1997. Born May 19, 1910, he was a member of the Society for 58 years.

American Mathematical Society

Monotone Operators in Banach Space and Nonlinear Partial Differential Equations

R. E. Showalter, *University of Texas, Austin*

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

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

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

Mathematical Surveys and Monographs, Volume 49; 1997; 278 pages; Hardcover; ISBN 0-8218-0500-2; List $75; Individual member $45; order code SURV/49NA

Recent Developments in Optimization Theory and Nonlinear Analysis

Yair Censor, *University of Haifa, Israel,* and **Simeon Reich,** *The Technion-Israel Institute of Technology, Haifa,* Editors

This volume contains the refereed proceedings of the special session on Optimization and Nonlinear Analysis held at the Joint American Mathematical Society-Israel Mathematical Union Meeting which took place at the Hebrew University of Jerusalem in May 1995. Most of the papers in this book originated from the lectures delivered at this special session. In addition, some participants who did not present lectures and invited speakers who were unable to attend contributed their work.

The fields of optimization theory and nonlinear analysis continue to be very active. This book presents not only the wide spectrum and diversity of the results, but also their manifold connections to other areas, such as differential equations, functional analysis, operator theory, calculus of variations, numerical analysis, and mathematical programming.

In reading this book one encounters papers that deal, for example, with convex, quasiconvex and generalized convex functions, fixed and periodic points, fractional-linear transformations, moduli of convexity, monotone operators, Morse lemmas, Navier-Stokes equations, nonexpansive maps, nonsmooth analysis, numerical stability, products of projections, steepest descent, the Leray-Schauder degree, the turnpike property, and variational inequalities.

Contemporary Mathematics, Volume 204; 1997; 278 pages; Softcover; ISBN 0-8218-0515-0; List $49; Individual member $29; order code CONM/204NA

All prices subject to change. Charges for delivery are $3.00 per order. For 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. For credit card orders, fax (401) 331-3842 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

Annual Competition for Fulbright Grants Opens

The United States Information Agency, the J. William Fulbright Foreign Scholarship Board, and the Institute of International Education announce the official opening on May 1, 1997, of the 1998–1999 competition for Fulbright Grants for graduate study or research abroad. The purpose of the grants is to increase mutual understanding between the people of the U.S. and other countries through the exchange of persons, knowledge, and skill.

An applicant must be a U.S. citizen at the time of application and hold a bachelor's degree or its equivalent by the beginning date of the grant. All applicants are required to have sufficient proficiency in the language of the host country to carry out the proposed study or research. The grants provide travel, maintenance for the duration of the grant, a research allowance, and tuition waivers, if applicable.

Further information is contained in the brochure "Fulbright and Related Grants for Graduate Study and Research Abroad, 1998–99", available from the Institute of International Education, 809 United Nations Plaza, New York, NY 10017; telephone 212-984-5327.

—from IEE News Release

NRC Twinning Program 1997–1999

With funding from the National Science Foundation, the Office for Central Europe and Eurasia of the National Research Council is accepting proposals for collaborative research programs which link individual U.S. scientists with their counterparts in Estonia, Latvia, and Lithuania.

The grants awarded under this round of the Twinning Program will begin in September 1997 and run through December 1999. Subject to the availability of funding, support will be provided for travel and living expenses for research visits by U.S. grantees and junior scientists from the same institution to the three countries listed above, and for visits by their foreign counterparts to the U.S. Applicants may also request modest funding for scientific supplies, telecommunications fees, and publications costs.

Applications will be accepted from U.S. citizens, nationals of a possession of the U.S., or permanent residents. While scientists of any age are eligible, those who have received their doctoral degrees within the past six years or who are entering an international collaboration for the first time are strongly encouraged to apply. Grants will generally be in the $12,000–$15,000 range.

Applications must be postmarked no later than **May 16, 1997**. For further information, contact: Office for Central Europe and Eurasia (FO2014), National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-2644; fax 202-334-2614; e-mail `ocee@nas.edu`.

—from National Research Council Announcement

From the AMS

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Except for the members-at-large of the Council, the month and year of the first term and the end of the present term are given. For members-at-large of the Council, the last year of the present term is listed.

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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.

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.

Academic Employment in Mathematics

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Address *through June 1997*

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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 the 1991 Mathematics Subject Classification printed on the back of this form. If listing more than one number, list first the one number which best describes your current primary interest.*

Primary Interest ____________________

Secondary Interests *optional* ____________________

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

____

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

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.*

☐ ____________________

☐ ____________________

☐ ____________________

☐ ____________________

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

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.*

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To contact the Division of Mathematical Sciences at the NSF:

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4201 Wilson Blvd., Room 1025
Arlington, VA 22230
Telephone: 703-306-1870
`http://www.nsf.gov/mps/dms/`

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To contact the MSEB:

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Washington, DC 20418
Telephone: 202-334-3294
e-mail: `mseb@nas.edu`
World Wide Web: `http://www.nas.edu/mseb/mseb.html`

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(Terms expire on June 30 of the year indicated.)

Avner Friedman, chair 1997
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Peter E. Castro 1997
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e-mail: `bms@nas.edu`
World Wide Web: `http://www2.nas.edu/bms/`

Contact information for (some of) the major mathematics institutes in North America:

Center for Discrete Mathematics and Theoretical Computer Science (DIMACS)
Rutgers University
P.O. Box 1179
Piscataway, NJ 08855-1179
Telephone: 908-445-5928
Fax: 908-445-5932
e-mail: `center@dimacs.rutgers.edu`
World Wide Web: `http://dimacs.rutgers.edu/`
Director: Fred S. Roberts, `froberts@dimacs.rutgers.edu`

Centre de Recherches Mathématiques (CRM)
Université de Montréal
C.P. 6128, Succ. Centre-ville
Montréal, Quebec, Canada H3C 3J7
Telephone: 514-343-7501
Fax: 514-343-2254
e-mail: `activites@crm.umontreal.ca`
Director: Luc Vinet, `vinet@crm.umontreal.ca`
World Wide Web: `http://www.crm.umontreal.ca/`

The Fields Institute
222 College Street
Toronto, ON, Canada M5T 3J1
Telephone: 416-348-9710
Fax: 416-348-9714
e-mail: `geninfo@fields.utoronto.ca`
World Wide Web: `http://www.fields.utoronto.ca/`
Director: Donald Dawson, `ddawson@fields.utoronto.ca`

The Geometry Center
University of Minnesota, Twin Cities Campus
Institute of Technology
1300 South Second Street, Suite 500
Minneapolis, MN 55454
Telephone: 612-626-0888
Fax: 612-626-7131
e-mail: `admin@geom.umn.edu`
World Wide Web: `http://www.geom.umn.edu/`
Director: Richard McGehee, `mcgehee@geom.umn.edu`

Institute for Advanced Study (IAS)
School of Mathematics
Olden Lane
Princeton, NJ 08540
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Fax: 609-951-4459
World Wide Web: `http://www.math.ias.edu/`
Administrative Officer: Mary Jane Hayes, `mhayes@math.ias.edu`

Institute for Mathematics and its Applications (IMA)
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206 Church Street, SE
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e-mail: `ima-staff@ima.umn.edu`
World Wide Web: `http://www.ima.umn.edu/`
Associate Director: Bob Gulliver, `gulliver@ima.umn.edu` or

Mathematical Sciences Institute (MSI)
Cornell University
409 College Avenue
Ithaca, NY 14850
Telephone: 607-255-8005
Fax: 607-255-9003
Director: Anil Nerode, `anil@math.cornell.edu`

Mathematical Sciences Research Institute (MSRI)
1000 Centennial Drive #5070
Berkeley, CA 94720-5070
Telephone: 510-642-0143
Fax: 510-642-8609
e-mail: `inquiries@msri.org`
World Wide Web: `http://www.msri.org/`
Director: William P. Thurston, `wpt@msri.org`

Upcoming Deadlines

April 25, 1997: Deadline for applications to participate in Project NExT in 1997–1998. Application forms are available on the Project NExT home page (`http://archives.math.utk.edu/projnext/`) or from James R. C. Leitzel, Dept. of Math, Univ. of New Hampshire, Kingsbury Hall, 33 College Rd., Durham, NH 03824.

May 16, 1997: Deadline for applications for NRC Twinning Program 1997-1999. Office for Central Europe and Eurasia (FO2014), National Research Council, 2101 Constitution Ave., NW, Washington, DC 20418; telephone 202-334-2644; e-mail `ocee@nas.edu`.

June 1, 1997: Closing date for nominations for the Vasil A. Popov Prize. Ronald A. DeVore, Dept. of Mathematics, University of South Carolina, Columbia, SC 29208.

Where to Find It

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

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AMS proposed amendments to the Bylaws
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Mathematics Research Institutes Contact Information: The Fields Institute, The Geometry Center, Institute for Advanced Study (IAS), Institute for Mathematics and its Applications (IMA), Mathematical Sciences Institute (MSI), Mathematical Sciences Research Institute (MSRI), Center for Discrete Mathematics and Theoretical Computer Science (DIMACS), Centre de Recherches Mathématiques (CRM)
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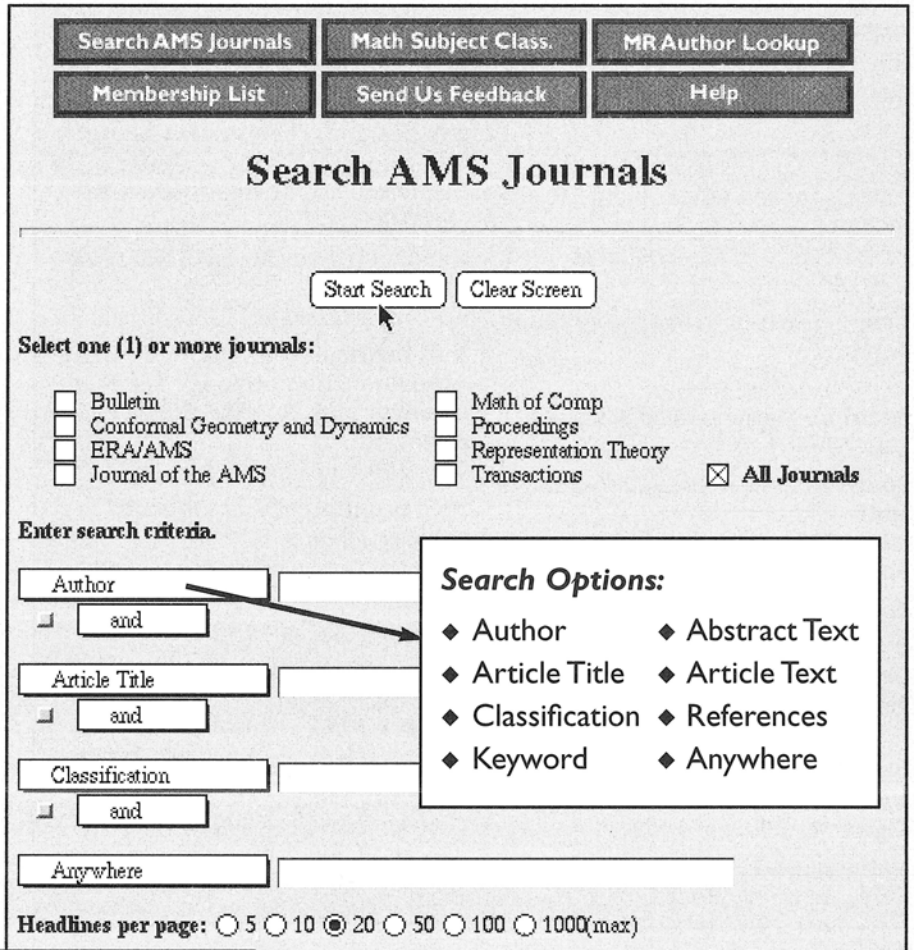

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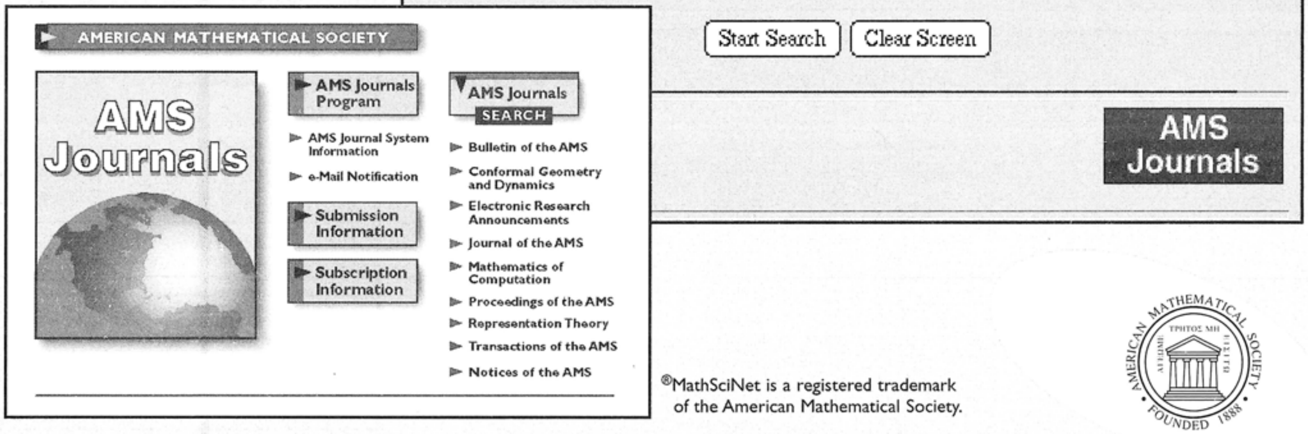

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Mathematics Calendar

May 1997

*2–4 **Cornell Topology Festival**, Cornell University, Ithaca, NY.

Speakers: L. Carbone (Columbia U.), B. Dwyer (Notre Dame U.), M. Hopkins (M.I.T.), B. Kleiner (U. of Pennsylvania), M. Sageev (U. of Southhampton), Z. Sela (Columbia U.), Z. Szabo (Princeton U.)

Information: The festival will begin on Friday, May 2, with tea at 3:45 p.m. followed by the first talk at 4:30 p.m. There will be a banquet Friday evening and four talks on Saturday, followed by a picnic late Saturday afternoon. There will be two talks on Sunday morning. The Festival will end about noon on Sunday. For further information, see `http://math.cornell.edu/~vogtmann/topfest/topf.html`.

*3 **The Fourth East Coast Computer Algebra Day**, Northeastern University, Boston, Massachusetts.

Topics: Symbolic, algebraic, and symbolic-numerical algorithms; computer algebra systems, software systems, experience with implementations of significant algorithms; applying symbolic, algebraic, and symbolic-numerical algorithms to problems in the sciences, engineering, economics, and other areas.

Information: `http://www.ccs.neu.edu/home/gene/eccad97.html` or please direct any questions to `eccad97@ccs.neu.edu`.

*20–23 **Methods in Ring Theory**, Grand Hotel Bellavista, Levico Terme (Trento), Italy.

Sponsor: The Centro Internazionale per la Ricerca Matematica (C.I.R.M.) of Trento.

Scientific Organizers: V. Drensky (Sofia), A. Giambruno (Palermo), and S. K. Sehgal (Alberta).

Information: The two main areas covered by the conference will be rings with polynomial identities and group rings. Deadline for applications is March 31, 1997.

Confirmed main lecturers: Y. Bahturin (Moscow), A. A. Bovdi (Debrecen), E. Formanek (University Park), E. Jespers (St. John's), A. R. Kemer (Ulyanovsk), Z. Marciniak (Warsaw), D. S. Passman (Madison), C. Procesi (Roma I), Y. P. Razmyslov (Moscow), A. E. Zalesskii (Norwich).

*26–30 **III Italian Conference on Mathematical Finance**, IRST Povo (Trento), Italy.

Sponsor: The Centro Internazionale per la Ricerca Matematica (C.I.R.M.) of Trento.

Scientific Organizers: R. Avesani (Brescia), W. Runggaldier (Padova), and L. Tubaro (Trento).

Provisional list of speakers: G. Barone-Adesi (Edmonton), T. Bjoerk (Stockholm), F. Delbaen (Zürich), P. Embrechts (Zürich), M. Frittelli (Milano), H. Geman (Paris Dauphine and ESSEC), A. Grorud (Marseille), J. Jacod (Paris VI), F. Jamshidian (London), M. Jeanblanc-Picqué (Evry), E. Jouini (Malakoff), Y. Kabanov (Besançon), D. Lamberton (Noisy-Le-Grand), C. Martini (Sophia-Antipolis), F. Moriconi (Perugia), M. Musiela (Kensington), F. Ortu (Trieste), E. Platen (Canberra), S. Pliska (Chicago), M. Pontier (Orleans), M. Pratelli (Pisa), W. Schachermayer (Wien), D. Sondermann (Bonn), M. Taksar (Stony Brook), D. Talay (Sophia-Antipolis), and T. Vorst (Rotterdam).

Information: `http://alpha.science.unitn.it/~tubaro/cirm_ec.html`. Deadline for applications is March 31, 1997.

June 1997

*3–7 **Viability and Control - II**, Grand Hotel Bellavista, Levico Terme (TN), Italy.

Sponsor: The Centro Internazionale per la Ricerca Matematica (C.I.R.M.) of Trento.

Scientific Organizers: J.-P. Aubin (Paris Dauphine), P. Cannarsa (Roma II), H. Frankowska (Paris Dauphine), and M. Iannelli (Trento).

Provisional list of speakers: S. Anita (Iasi),

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 listing of meetings of the Society, and of meetings sponsored by the Society, will be found on the first page of the Meetings and Conferences section.

An announcement will be published in the *Notices* if it contains a call for papers and specifies the place, date, subject (when applicable), and the speakers; a second announcement will be published only if there are changes or necessary additional information. Once an announcement has appeared, the event will be briefly noted in every third issue until it has been held and a reference will be given in parentheses to the month, year, and page of the issue in which the complete information appeared. Asterisks (*) mark those announcements containing new or revised information.

In general, announcements of meetings and conferences held in North America carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. Meetings held outside the North American area may carry more detailed information. In any case, if there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editor of the *Notices* in care of the American Mathematical Society in Providence or electronically to `notices@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.)

V. Barbu (Iasi), M. Bardi (Padova), E.N. Barron (Chicago), P. Bernhard (Sophia-Antipolis), I. Capuzzo Dolcetta (Roma I), P. Cardaliaguet (Paris IX), A. Cellina (Trieste), G. Da Prato (Pisa), J. Demongeot (Saint Martin d'Heres), O. Dordan (Bordeaux 2), L. Doyen (Paris-Dauphine), D. Flockerzi (Würzburg), D. Gabay (Paris-Dauphine), F. Gozzi (Pisa), K.P. Hadeler (Tübingen), H.W. Knobloch (Würzburg), W. Kryszewski (Toruń), A. Kurzhanski (Moscow), M. Langlais (Bordeaux 2), C. Lobry (Nice), H. Maurer (Münster), B. Mordukhovich (Detroit), J. Müller (Tübingen), B. Piccoli (Trieste), M. Quincampoix (Brest), F. Rampazzo (Padova), P. Saint-Pierre (Paris-Dauphine), A. Schiaffino (Roma II), N. Seube (Brest), C. Sinestrari (Roma II), S. Stojanovic (Cincinnati), V. Veliov (Wien), R.B. Vinter (London), J. Zabczyk (Warsaw), S. Zagatti (Trieste), and T. Zolezzi (Genova).

Information: Deadline for applications is April 30, 1997.

*10–13 **Complex Analysis and Geometry - XIII**, Grand Hotel Bellavista, Levico Terme (Trento), Italy.

Sponsor: The Centro Internazionale per la Ricerca Matematica (C.I.R.M.) of Trento.

Scientific Organizers: V. Ancona (Firenze) and A. Silva (Roma I).

Information: Deadline for applications is April 30, 1997.

*16–20 **Seventh UN/ESA Workshop on Basic Space Science**, Tegucigalpa, M.D.C., Honduras.

Sponsors: United Nations (UN), European Space Agency (ESA), The Planetary Society (TPS), German Space Agency (DARA), International Centre for Theoretical Physics (ICTP), U.S. National Aeronautics and Space Administration (NASA), Institute of Space and Astronautical Science of Japan (ISAS), Austrian Space Agency (ASA), International Astronomical Union (IAU), Committee on Space Research (COSPAR).

Workshop Topics: This workshop was organized for the benefit of Third World countries in five regions: Asia and the Pacific (India 1991, Sri Lanka 1995), Latin America and the Caribbean (Costa Rica and Colombia 1992), Africa (Nigeria 1993), Western Asia (Egypt 1994), and Europe (Germany 1996). Continuing this series, the workshop program will address selected topics of small astronomical telescopes and satellites for education and research. A full account of the past workshops is provided in the homepage at `http://ecf.hq.eso.org/~ralbrech/un/un-homepage.html`. The 7th Workshop will also cover numerical (particularly the use of Mathematica and IDL) and analytical techniques applied to problems in astronomy and planetary science. A major objective of the workshop is to bring together scientists from industrialized and Third World countries.

Call for Papers: Deadline for abstracts: May 1, 1997.

Information: H.J. Haubold, UN Outer Space Office, Vienna International Centre, P.O. Box 500, A-1400 Vienna, Austria, phone: (43)-1-21131-4949, fax: (43)-1-21345-5830, e-mail: `haubold@eunet.co.at`.

*26–28 **Conference on Probabilities and Stochastic Analysis**, Cadi Ayyad University F.S.S., (Marrakech), Morocco.

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

Invited Speakers: E. Pardoux (Marseille), B. Djehich (Stockholm), N. El Karoui (Paris), M. N'zi (Abidjan), A. Sulaymen Ustunel (France), A. Millet (Paris), B. Roynette (Nancy), S. Ogawa (Japan), D. Nualart (Barcelona), P. Baldi (Rome), and B. Oksendal (Oslo).

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

Information: Y. Ouknine, Département de Mathématiques, Faculté des sciences, Semlalia B.P. S 15, Marrakech, Morocco; fax (212) 4 43 74 09; e-mail: `yo@mbox.azure.net` or A. Dermoune, Université du Maine, Laboratoire de Statistique et processus, B.P. 535, 72017 Le Mans, France; fax 43.83.35.79; e-mail: `dermoune@aviion.univ-lemans.fr`.

*26–July 1 **Mathematical Analysis: Geometric Analysis on Singular and Noncompact Manifolds**, San Feliu de Guixois, Spain.

Information: For information and application forms (application deadline is 3–4 months before a conference), contact the head of the EURESCO Unit: J. Hendekovic, European Science Foundation, 1 quai Lezay-Marnésia, 67080 Strasbourg Cedex, France; tel: +33 388 76 71 35; fax: +33 388 36 69 87; e-mail: `euresco@esf.org`. On-line information and application at `http://www.esf.org/euresco/`.

July 1997

*2–5 **Workshop on Abstract Algebraic Logic**, Universitat Autònoma de Barcelona, Bellaterra, Spain.

Topic: The general theory of logics with regard to the various processes of algebraization viewed as abstractions of the Lindenbaum-Tarski process. Possible topics include: Studies of the algebraization process itself, its various forms and their relationships; the connection between metalogical and algebraic properties; solving logical problems by algebraic methods, and vice versa; studies of individual logics, of special classes of logics and/or of particular classes of algebras in the context of abstract algebraic logic. The term 'logic' in the above description is to be understood in a wide sense, that is, encompassing several existing formalizations, such as Hilbert-type formal systems, Gentzen-type ones, consequence operations, semantically defined logics, etc.

Sponsor: Ministry of Education and Culture of Spanish government, Research Department of Generalitat of Catalonia, Polytechnic University of Catalonia, Institut d'Estudis Catalans.

Organizing committee: J. Maria Font (Univ. of Barcelona), R. Jansana (Univ. of Barcelona), D. Pigozzi (Iowa State Univ., Ames).

Participation: There are no registration fees. To attend simply send a message to: `crm@crm.es`, or visit the Web page: `http://www.crm.es/info/waal97.htm`.

*14–August 16 **The Fifth Annual Canada/USA Mathcamps**, Babson College, Wellesley, Massachusetts.

Description: This Fifth Annual Mathcamp is being held in honor of Prof. Paul Erdős. R. Graham will deliver the inaugural address. Canada/USA Mathcamps are for mathematically talented high school students who are 13 years or older.

Information: Additional information at `http://www.mathcamp.org/`. (Please provide a link from the title of the listing to our URL.)

*31–August 3 **Seventh Annual International Conference of the Society for Chaos Theory in Psychology & Life Sciences**, Marquette University, Milwaukee, Wisconsin.

Scope: This conference concerns itself with the application of chaos theory, complex systems theory, fractals, nonlinear dynamics, and related principles applied to any of the various psychological subdisciplines, neuro-science, biology, physiology and other areas of medical research, economics, sociology, anthropology, physics, political science, organizations and their management, other business applications, education, art, philosophy, and literature.

Call for papers: Papers may be submitted to any of the following sessions: Foundations and Philosophy, Cognition, Perception and Psychophysics, Clinical, Organizations and Economics, Theory and Methodology. Authors should submit a 200 word abstract to the address below by the submission deadline of April 30, 1997.

Information: For information about submissions, registration, accommodation, contact W. Sulis, 255 Townline Rd. E., RR5, Cayuga, Ontario, Canada, N0A 1E0; e-mail: `sulisw@mcmail.cis.mcmaster.ca`; fax: 905-521-7948.

August 1997

*1–4 **MAA Mathfest**, Renaissance Atlanta Hotel, Atlanta, Georgia.

Program: Invited lectures, contributed paper sessions, student contributed paper sessions, minicourses, short course, exhibits and book sale.

Information: For additional information about the 1997 MAA Mathfest, go to MAA Online at `http://www.maa.org/`.

September 1997

*27–October 2 **Combinatorics – Algebraic, Geometric and Probabilistic Aspects**, San Feliu de Guixols, near Barcelona, Spain.

Sponsor: European Science Foundation and the European Mathematical Society.
Preliminary program: The emphasis will be on the following areas: enumeration and groups; geometric combinatorics; codes, designs, and finite geometry; linear-algebraic and probabilistic methods.
Confirmed speakers: N. Alon (Tel Aviv) & L. Lovász (Budapest and Yale), C. Bessenrodt (Magdeburg) & J. Matoušek (Prague), A. Blokhuis (Eindhoven) & C. McDiarmid (Oxford), A. Brouwer (Eindhoven) & A. Schrijver (Amsterdam), M. Bousquet-Melou (Bordeaux) & N.J.A. Sloane (AT&T Labs, Murray Hill), F. Brenti (Perugia) & V. Sós (Budapest), P. Cameron (London) & R. Stanley (MIT, Cambridge), G. Kalai (Jerusalem) & J. Thas (Ghent), A. Lascoux (Paris) & D. Welsh (Oxford), M. Laurent (Amsterdam) & G. Ziegler (Berlin).
Information: European Science Foundation, 1 Quai Lezay-Marnésia, F-67080 Strasbourg Cedex, France; tel. 33 388 76 71 35, fax: 33 388 36 69 87, e-mail: `euresco@esf.org`, `http://www.esf.org/euresco/`.

*30–October 2 **Logic and Mathematical Reasoning**, Mexico City, Mexico.
Plenary Lecturers: J. Dhombres (Univ. de Nantes), S. Feferman (Stanford Univ.), M. Otte (Univ. of Bielefeld), H. Sinaceur (CNRS Paris), J. M. Salanskis (Univ. de Lille), and D. Struppa (George Mason Univ.).
Information: C. Alvarez, Depto. de Matemáticas, Fac. de Ciencias, UNAM, Ciudad Universitaria, 04510 México D.F.; e-mail: `alvarji@servidor.unam.mx`; or M. Panza, Centre F. Viète, Univ. de Nantes, Fac. des Sciences, 2 rue de la Houssinière, 44072 Nantes 03, France; e-mail: `panza@unantes.univ-nantes.fr`.

October 1997

*6–11 **INCOWASCOM 97–9th International Conference on Waves and Stability in Continuous Media**, Bari, Italy.
Objective: The main goal of the meeting is to provide a forum for the exchange of ideas, methods, and results about the recent advances in Waves and Stability in Continuous Media.
Program: The general program will include about thirty main lectures delivered by 15 Italian and 15 foreign invited speakers and a limited number of short communications. The contributions of the lectures and the communications will be published in a Proceedings volume.
Information: M. Maiellaro and A. Labianca, fax +39 - 080 - 5460612, e-mail: `ARCLAB@SUN.DM.UNIBA IT`.

*19–24 **IEEE Visualization Ninety-Seven**, Sheraton Crescent Hotel, Phoenix, Arizona.
Program: Visualization is a vital research and applications frontier shared by a variety of scientific, medical, engineering, business, and entertainment fields. The eighth IEEE Visualization conference focuses on the algorithms, technologies, and applications that support collaboration among the developers and users of visualization across all of science, engineering, medicine, and commerce. The conference week will include tutorials, symposia, and mini-workshops Sunday through Tuesday, and papers, panels, case studies, and late-breaking hot topic presentations Wednesday through Friday.
Information: For further information about the IEEE Visualization '97 Conference, contact one of the conference co-chairs listed below or see `http://www.erc.msstate.edu/vis97/`: R. Moorhead, `rjm@erc.msstate.edu`, Mississippi State University, tel: 601-325-2850, or N. Johnston, `NEJohnston@lbl.gov`, Lawrence Berkeley National Laboratory, tel: 510-486-5093, fax: 510-486-8615.

*24–29 **Number Theory and Arithmetical Geometry: Arithmetical Applications of Modular Forms**, San Feliu de Guixois, Spain.
Information: For information and application forms (application deadline is 3–4 months before a conference), contact the Head of the EURESCO Unit: J. Hendekovic, European Science Foundation, 1 quai Lezay-Marnésia, 67080 Strasbourg Cedex, France; tel: +33 388 76 71 35; fax: +33 388 36 69 87; e-mail: `euresco@esf.org`. On-line information and application at `http://www.esf.org/euresco`.

November 1997

*7–9 **Third Midwest-Southeastern Atlantic Joint Regional Conference on Differential Equations**, Vanderbilt University, Nashville,Tennessee.
Aim: This is the third in a series of joint conferences on differential equations, combining the activities of two conference series which have been held for many years in the southeastern and midwestern regions of the country.
Invited Speakers: A. Bertozzi (Duke Univ.), C. Chicone (Univ. of Missouri), P. Fife (Univ. of Utah), J. Goldstein (Univ. of Memphis), and L. Markus (Univ. of Minnesota).
Program: In addition to the five plenary talks, the conference program will include contributed sessions and special sessions.
Organizing Committee: M. Horn (chair), U. Mayer, G. Simonett, and G. Webb.
Information: Further information may be obtained by contacting: Differential Equations, Department of Mathematics, Vanderbilt University, Nashville, TN 37240; tel: 615-322-6672; fax: 615-343-0215; e-mail: `diffeq@math.vanderbilt.edu`; Web: `http://math.vanderbilt.edu/~diffeq/`.

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

June 1998

*1–5 **Fifth International Conference on p-Adic Functional Analysis**, A. Mickiewicz University of Poznań, Poland.
Program: Research talks concerning analysis over valued fields other than the real or complex numbers (such as p-adic numbers field).
Topics: Fréchet and Banach spaces, locally convex spaces and modules, operators, spaces of continuous and analytic functions, distributions and measure, function theory, classical and harmonic analyis. Applications in mathematical physics.
Organizers: J. Kąkol and W. Wnuk (Poznań).
Scientific Committee: N. De Grande-De Kimpe (Brussels, Belgium), J. Kąkol (Poznań, Poland), C. Perez-Garcia (Santander, Spain).
Speakers (preliminary list): J. Araujo, S. Borrey, G. Cristol, S. De Smmedt, B. Diarra, A. Escassut, M. Endo, N. De Grande-De Kimpe, J. Kąkol, A. Katsaras, H. Keller, A. Khrennikov, L. Narici, P. Natatajan, H. Ochsenius, S. Oortwigin, C. Perez-Garcia, J. Prolla, G. Rangan, A. Robert, A.C.M. van Rooij, M.-C. Sarmant, W. Schikhof, L. Van Hamme, A. Verdoodt, I. Volovich, E. Zelenov, and V. Vladimirov.
Information: J. Kąkol, e-mail: `kakol@math.amu.edu.pl`, and W. Wnuk, e-mail: `wnukwit@math.amu.edu.pl`; addresses: Faculty of Mathematics and Computer Science, A. Mickiewicz University, Matejki 48/49, 60-769 Poznań, Poland.

*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.
Sponsors: The Sobolev Institute of Mathematics, the Institute of Informatics Systems, the Institute for Computational Technology, and the Computer Center of the Siberian Branch of the Russian Academy of Sciences, together with Novosibirsk State University, Novosibirsk State Technical University, and the Siberian Society for Promotion of Science and Education (SIBOS) convene the International Congress INPRIM-98.
Information: V. Vaskevich, the Sobolev Institute of Mathematics, 630090 Novosibirsk, Russia, phone: +7-3832-351560, fax: +7-3832-350652, e-mail: `vask@math.nsc.ru`.

August 1998

*10–14 **From Individuals to Populations**, Ceske Budejovice, Czech Republic.
Topics: The workshop is an interdisciplinary meeting of biologists and mathematicians focused on effects of individual behavioral decisions of animals on population dynamics. Such decisions include, for example: optimal prey selection, optimal patch selection, ideal free distribution, optimal antipredatory behavior, effect of refuges on population dynamics, various trade-offs in behavior of parasitoids, and other game-theoretical models.
Scientific Committee: P. Antonelli, C. Clark, D. Cohen, Ch. Godfray, W. Gurney, M. Man-

American Mathematical Society

Fermat's Last Theorem: Unlocking the Secret of an Ancient Mathematical Problem

Amir D. Aczel, *Bentley College, Waltham, MA*

... Aczel sets out the whole story clearly and concisely ... there's a surprising amount of drama... [Wiles' proof] employs a staggering range of abstract devices, which Mr. Aczel is a dab hand at explaining ... [Mathematics] operates very close to religion ... Maybe that is the final justification for the quest Mr. Aczel chronicles so well ...

—The Wall Street Journal

Maps the strange, beautiful byways of modern mathematical thought

—Publishers Weekly

Perhaps I could best describe my experience of doing mathematics in terms of entering a dark mansion. You go into the first room and it's dark, completely dark. You stumble around, bumping into the furniture. Gradually, you learn where each piece of furniture is. And finally, after six months or so, you find the light switch and turn it on. Suddenly, it's all illuminated and you can see exactly where you were. Then you enter the next dark room ...

—Professer Andrew Wiles describing his seven-year quest for the "mathematicians' Holy Grail"

Wiles spent seven years working on his solution and another year fine-tuning it. He was obsessed with finding a solution that had eluded mathematicians for centuries.

In this book, Aczel celebrates Wiles' achievement. He explains complex mathematical developments and relates previously untold stories of the personalities, emotions, and motivations associated with a theorem that spans mathematical history.

In preparing this book, Aczel spent 18 months studying the mathematics that lay between Fermat's margin note and Wiles' solution. Aczel's investigation and references are presented in clear terms and are fully accessible to a general audience. Key points are elucidated with real-life analogies and simple line drawings. Published by Four Wall Eight Windows.

1997; 147 pages; Hardcover; ISBN 1-56858-077-0; List $18; All AMS members $14; order code FERMATNA

Geometry and Nature

Hanna Nencka, *University of Madeira, Portugal,* and **Jean-Pierre Bourguignon,** *IHES, Bures-sur-Yvette, France*

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

Contemporary Mathematics, Volume 203; 1997; 296 pages; Softcover; ISBN 0-8218-0607-6; List $65; Individual member $39; order code CONM/203NA

Proceedings of the Norbert Wiener Centenary Congress, 1994

V. Mandrekar, *Michigan State University, East Lansing,* and **P. R. Masani,** *University of Pittsburgh, PA*

One of the great mathematicians of this century, Norbert Wiener was a universal thinker of colossal proportions. This book contains the proceedings of the Norbert Wiener Centenary Congress held at Michigan State University on November 27–December 2, 1994. The aim of the Congress was to reveal the depth and strong coherence of thought that runs through Wiener's legacy, and to exhibit its continuation in ongoing research.

Proceedings of Symposia in Applied Mathematics, Volume 52; 1997; 566 pages; Hardcover; ISBN 0-8218-0452-9; List $99; Individual member $59; order code PSAPM/52NA

All prices subject to change. Charges for delivery are $3.00 per order. For 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. For credit card orders, fax (401) 331-3842 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.

gel, W. Murdoch, G. Nachman, R. Nisbet, D. Rubenstein, A. Stewart-Oaten, W. Sutherland.

Information: Current information on the workshop including registration form can be found at the WWW home page: `http://www.fitop.entu.cas.cz/`. Please address any other inquiries to V. Krivan, Institute of Entomology AS CR, Branisovska 31, CZ-370 05 Ceske Budejovice, Czech Republic; e-mail: `krivan@entu.cas.cz`.

*30–September 5, 1998 **Algebraic Number Theory and Diophantine Analysis**, Graz, Austria.

Organizers: F. Halter-Koch (Univ. of Graz) and R. F. Tichy (Graz Technical Univ).

Program: A satellite conference of ICM-98, Berlin. Topics include algebraic number theory, diophantine equations, transcendence, uniform distribution as well as computational and analytic aspects. There will be one-hour survey lectures as well as twenty-minute contributed talks (open to everybody) and a special session on diophantine equations.

Information: e-mail: `nt98@weyl.math.tu-graz.ac.at`.

New Publications Offered by the AMS

General Interest

The MathResource™ Interactive Math Dictionary

This math visualizing program was designed by mathematics teachers for mathematics teachers and their students and covers a comprehensive list of topics—from algebra to optimization theory.

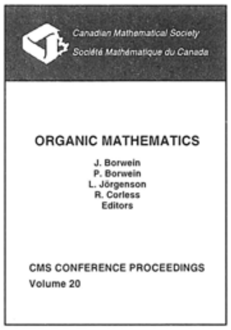
The Interactive Math Dictionary is an interactive database of mathematical topics that combines the attributes of a dictionary with the functionality of a CD-ROM. This powerful tool can work equally well for classroom display or for studying. Each topic has its own guide for quick and easy access to the database. The 4,500 entries include the mathematical examples that can be explored with sample data or by inputting your own. Computation, plotting, and graphing are powered by the Maple™ computer algebra system. The CD-ROM operates within Windows™ 3.1 and Windows™ '95.

The Interactive Math Dictionary allows you to ...

- Input your own data and do "What if?" analyses.
- Generate numerical and graphical solutions.
- Access the information contained in **The MathResource** via the following search options:
  - Word search
  - Alphabetical search
  - Curriculum guide search: Each topic, such as algebra, calculus, linear algebra, etc., has its own table of contents. Simply click on the item and the dictionary opens to the appropriate topic.

Published by MathResources, Inc., Halifax, NS, Canada, and distributed worldwide by the American Mathematical Society.

December 1996, 1991 *Mathematics Subject Classification*: 00-XX, **All AMS members $85**, List $95, Order code MRIMDN



Canadian Mathematical Society
Société Mathématique du Canada

ORGANIC MATHEMATICS

J. Borwein
P. Borwein
L. Jörgenson
R. Corless
Editors

CMS CONFERENCE PROCEEDINGS
Volume 20

Organic Mathematics

J. Borwein, *Simon Fraser University, Burnaby, BC, Canada*, **P. Borwein**, *Simon Fraser University, Burnaby, BC, Canada*, **L. Jörgenson**, *Center for Experimental and Constructive Mathematics, Burnaby, BC, Canada*, and **R. Corless**, *University of Western Ontario, London, ON, Canada*, Editors

This volume is the hardcopy version of the electronic manuscript, "Proceedings of the Organic Mathematics Workshop" held at Simon Fraser University in December 1995 (www.cecm.sfu.ca/organics). The book provides a fixed, easily referenced, and permanent version of what is otherwise an evolving document.

Contained in this work is a collection of articles on experimental and computational mathematics contributed by leading mathematicians around the world. The papers span a variety of mathematical fields—from juggling to differential equations to prime number theory. The book also contains biographies and photos of the contributing mathematicians and an in-depth characterization of organic mathematics.

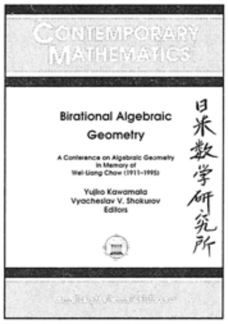
Members of the Canadian Mathematical Society may order at the AMS member price.

Contents: *Invited Articles:* **J. M. Borwein, P. B. Borwein, R. M. Corless, L. Jörgenson, and N. Sinclair**, What is organic mathematics?; **G. E. Andrews**, Pfaff's method (III): Comparison with the WZ method; **D. H. Bailey, J. M. Borwein, and P. B. Borwein**, Ramanujan, modular equations, and approximations to pi or how to compute one billion digits of pi; **D. H. Bailey and S. Plouffe**, Recognizing numerical constants; **J. M. Borwein and F. G. Garvan**, Approximations to π via the Dedekind eta function; **D. W. Boyd**, The beta expansion for Salem numbers; **J. Buhler, D. Eisenbud, R. Graham, and C. Wright**, Juggling drops and descents; **A. M. Cohen and D. B. Wales**, $GL(4)$-orbits in a 16-dimensional module for characteristic 3; **K. Belabas and H. Cohen**, Binary cubic forms and cubic number fields; **R. M. Corless**, Continued fractions and chaos; **P. J. Forrester and A. M. Odlyzko**, A nonlinear equation and its application to nearest neighbor spacings for zeros of the zeta function and eigenvalues of random matrices; **A. Granville**, Arithmetic properties of binomial coefficients I: Binomial coefficients modulo prime powers; **J. H. Hubbard, J. M. McDill, A. Noonburg, and B. H. West**, A new look at the airy equation with fences and funnels; **J. C. Lagarias**, The $3x+1$ problem and its generalizations; **C. W. H. Lam**, The search for a finite projective plane of order 10; **S. Wagon**, New visualization ideas for differential equations; *Associated Articles:* **S. P. Braham**, Internet, executable content, and the future of mathematical science communication; **W. Haga and S. Robins**, On Kruskal's principle.

Conference Proceedings, Canadian Mathematical Society, Volume 20

June 1997, approximately 416 pages, Softcover, ISBN 0-8218-0668-8, LC 97-179, 1991 *Mathematics Subject Classification*: 00B20, **Individual member $47**, List $79, Institutional member $63, Order code CMSAMS/20N

Algebra and Algebraic Geometry



Birational Algebraic Geometry

Yujiro Kawamata, *University of Tokyo, Japan,* and **Vyacheslav V. Shokurov**, *Johns Hopkins University, Baltimore, MD,* Editors

This book presents proceedings from the Japan-U.S. Mathematics Institute (JAMI) Conference on Birational Algebraic Geometry in Memory of Wei-Liang Chow, held at the Johns Hopkins University in Baltimore in April 1996.

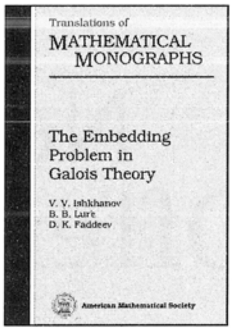
These proceedings bring to light the many directions in which birational algebraic geometry is headed. Featured are problems on special models, such as Fanos and their fibrations, adjunctions and subadjunction formuli, projectivity and projective embeddings, and more.

Some papers reflect the very frontiers of this rapidly developing area of mathematics. Therefore, in these cases, only directions are given without complete explanations or proofs.

Contents: M. C. Beltrametti and A. J. Sommese, On the second adjunction mapping and the very ampleness of the triadjoint bundle; **F. A. Bogomolov and B. de Oliveira**, Stein small deformations of strictly pseudoconvex surfaces; **I. Cheltsov**, On the rationality of non-Gorenstein $\mathbb{Q}$-Fano 3-folds with an integer Fano index; **R. Donagi, L. Ein, and R. Lazarsfeld**, Nilpotent cones and sheaves on K3 surfaces; **S. Ishii**, Minimal, canonical and log-canonical models of hypersurface singularities; **Y. Kawamata**, Subadjunction of log canonical divisors for a subvariety of codimension 2; **S. Kovács**, Relative De Rham complex for non-smooth morphisms; **K. Oguiso**, A note on moderate abelian fibrations; **Y. G. Prokhorov**, On extremal contractions from threefolds to surfaces: the case of one non-Gorenstein point; **V. V. Shokurov**, Letters of a birationalist. I. A projectivity criterion.

Contemporary Mathematics

June 1997, 146 pages, Softcover, ISBN 0-8218-0769-2, LC 97-7968, 1991 *Mathematics Subject Classification*: 14-06, 14E15, 14E30, 14J40, 14J45, 14J60, 32E10, **Individual member $21**, List $35, Institutional member $28, Order code CONM-SHOKUROVN



The Embedding Problem in Galois Theory

V. V. Ishkhanov, *Russian Academy of Sciences, St. Petersburg, Russia,* **B. B. Lur′e**, *Russian Academy of Sciences, St. Petersburg, Russia,* and **D. K. Faddeev**, *Russian Academy of Sciences, St. Petersburg, Russia*

The central problem of modern Galois theory involves the inverse problem: given a field k and a group G, construct an extension L/k with Galois group G. The embedding problem for fields generalizes the inverse problem and consists in finding the conditions under which one can construct a field L normal over k, with group G, such that L extends a given normal extension K/k with Galois group G/A. Moreover, the requirements applied to the object L to be found are usually weakened: it is not necessary for L to be a field, but L must be a Galois algebra over the field k, with group G. In this setting the embedding problem is rich in content. But the inverse problem in terms of Galois algebras is poor in content because a Galois algebra providing a solution of the inverse problem always exists and may be easily constructed. The embedding problem is a fruitful approach to the solution of the inverse problem in Galois theory.

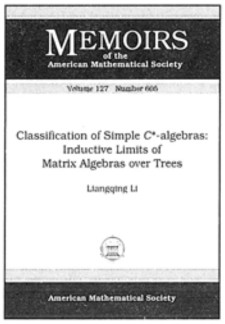
This book is based on D. K. Faddeev's lectures on embedding theory at St. Petersburg University and contains the main results on the embedding problem. All stages of development are presented in a methodical and unified manner.

Contents: Preliminary information about the embedding problem; The compatibility condition; The embedding problem with Abelian kernel; The embedding problem for local fields; The embedding problem with non-Abelian kernel for algebraic number fields; Appendix; Bibliography; Subject index.

Translations of Mathematical Monographs

May 1997, approximately 200 pages, Hardcover, ISBN 0-8218-4592-6, 1991 *Mathematics Subject Classification*: 12F12; 11R32, 11S20, **Individual member $53**, List $89, Institutional member $71, Order code MMONO-FADDEEVN

Analysis



Classification of Simple C^*-algebras: Inductive Limits of Matrix Algebras over Trees

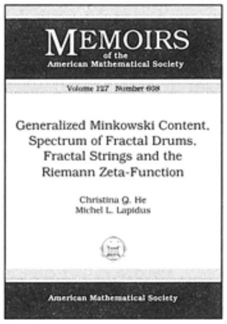
Liangqing Li, *The Fields Institute, Toronto, ON, Canada*

In this book, it is shown that the simple unital C^*-algebras arising as inductive limits of sequences of finite direct sums of matrix algebras over $C(X_i)$, where X_i are arbitrary variable trees, are classified by K-theoretical and tracial data. This result generalizes the result of George Elliott of the case of $X_i = [0, 1]$. The added generality is useful in the classification of more general inductive limit C^* -algebras.

Contents: Introduction; Diagonalization, distinct spectrum and injectivity; Berg technique; Approximate divisibility; Uniqueness theorem; Existence theorem and classification.

Memoirs of the American Mathematical Society, Volume 127, Number 605

May 1997, 123 pages, Softcover, ISBN 0-8218-0596-7, LC 97-421, 1991 *Mathematics Subject Classification*: 46L05, 46L35; 19K14, 47L80, **Individual member $23**, List $39, Institutional member $31, Order code MEMO/127/605N



MEMOIRS of the American Mathematical Society

Volume 127 Number 608

Generalized Minkowski Content, Spectrum of Fractal Drums, Fractal Strings and the Riemann Zeta-Function

Christina Q. He
Michel L. Lapidus

American Mathematical Society

Generalized Minkowski Content, Spectrum of Fractal Drums, Fractal Strings and the Riemann Zeta-Function

Christina Q. He, *University of California, Riverside, CA*, and **Michel L. Lapidus**, *University of California, Riverside, CA*

This memoir provides a detailed study of the effect of non power-like irregularities of (the geometry of) the fractal boundary on the spectrum of "fractal drums" (and especially of "fractal strings").

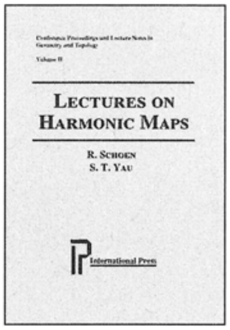
In this work, the authors extend previous results in this area by using the notion of generalized Minkowski content which is defined through some suitable "gauge functions" other than power functions. (This content is used to measure the irregularity (or "fractality") of the boundary of an open set in R^n by evaluating the volume of its small tubular neighborhoods.) In the situation when the power function is not the natural "gauge function", this enables the authors to obtain more precise estimates, with a broader potential range of applications than in previous papers of the second author and his collaborators.

This text will also be of interest to those working in mathematical physics.

Contents: Introduction; Statement of the main results; Sharp error estimates and their converse when $n = 1$; Spectra of fractal strings and the Riemann zeta-function; The complex zeros of the Riemann zeta-function; Error estimates for $n \geq 2$; Examples; Appendix: Examples of Gauge functions; References.

Memoirs of the American Mathematical Society, Volume 127, Number 608

May 1997, 97 pages, Softcover, ISBN 0-8218-0597-5, LC 97-422, 1991 *Mathematics Subject Classification*: 35P20, 11M06, 28A12, 28A80, 34B24, 58F19; 11M26, 26B15, 28A75, 35J20, 47A75, 78A40, 78A45, **Individual member $22**, List $37, Institutional member $30, Order code MEMO/127/608N



LECTURES ON HARMONIC MAPS

R. SCHOEN
S. T. YAU

International Press

Lectures on Harmonic Maps

R. Schoen, *Stanford University, CA*, and **S.-T. Yau**, *Harvard University, Cambridge, MA*

This volume presents important results from two well-known researchers in this field. The book can serve as an important reference tool for students working in this area. Included is a chapter on "Harmonic Maps and Superrigidity" written by J. Jost and S.-T. Yau.

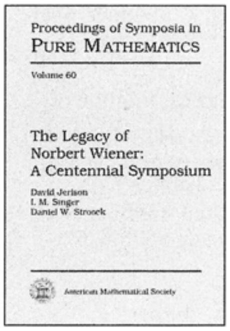
This text will also be of interest to those working in geometry and topology.

The *International Press* series is distributed worldwide, except in Japan, by the American Mathematical Society.

Contents: *Part I.* Harmonic maps; Compactifications of Teichmüller space; Harmonic maps of Kähler manifolds with constant negative holomorphic sectional curvature; Minimal surfaces in a Kähler surface; Stable minimal surfaces in Euclidean space; The existence of minimal immersions of 2-spheres; Manifolds with positive curvature on totally isotropic two-planes; Compact Kähler manifolds of positive bisectional curvature; *Part II.* Analytic aspects of the harmonic map problem; Sobolev spaces and harmonic maps for metric space targets; Moduli spaces of harmonic maps, compact group actions and the topology of manifolds with non-positive curvature; Harmonic maps and the topology of stable hypersurfaces and manifolds with non-negative Ricci curvature; Harmonic maps and superrigidity by Jürgen Jost and Shing-Tung Yau.

International Press, Volume 10

February 1997, Hardcover, ISBN 1-57146-002-0, 1991 *Mathematics Subject Classification*: 53-01, **All AMS members $34**, List $42, Order code INPR/10N



Proceedings of Symposia in PURE MATHEMATICS

Volume 60

The Legacy of Norbert Wiener: A Centennial Symposium

David Jerison
I. M. Singer
Daniel W. Stroock

American Mathematical Society

The Legacy of Norbert Wiener: A Centennial Symposium

David Jerison, *Massachusetts Institute of Technology, Cambridge, MA*, **I. M. Singer**, *Massachusetts Institute of Technology, Cambridge, MA*, and **Daniel W. Stroock**, *Massachusetts Institute of Technology, Cambridge, MA*, Editors

This book contains lectures presented at the MIT symposium on the 100th anniversary of Norbert Wiener's birth held in October 1994. The topics reflect Wiener's main interests while emphasizing current developments.

In addition to lectures dealing directly with problems on which Wiener worked, such as potential theory, harmonic analysis, Wiener-Hopf theory, and Paley-Wiener theory, the book discusses the following topics:

- Fourier integral operators with complex phase (a contemporary successor to the Paley-Wiener theory)

- statistical aspects of quantum mechanics and of liquid crystals
- financial markets, including the new trading strategies for options based on Wiener processes
- statistical methods of genetic research
- models of the nervous system, pattern recognition, and the nature of intelligence

The volume includes reviews on Norbert Wiener's contributions from historical and current perspectives.

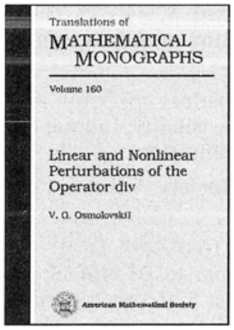
This book gives mathematical researchers an overview of new mathematical problems presented by other areas and gives researchers in other fields a broad overview of the ways in which advanced mathematics might be useful to them.

This text will also be of interest to those working in applications.

Contents: *Biographical and Historical Remarks.* **D. Jerison and D. W. Stroock**, Norbert Weiner; **P. Elias**, The rise and fall of cybernetics in the US and the USSR; **D. Struik**, Reminiscences of Norbert Wiener; Speech by Fagi Levinson; **P. A. Samuelson**, Some memories of Norbert Wiener; *Scientific Articles.* **J. Bourgain**, Gibbs measures, quasi-periodic solutions, and nonlinear partial differential equations; **L. Carleson**, Wiener's Tauberian theorem; **L. Ehrenpreis**, The role of Paley-Wiener theory in partial differential equations; **V. Guillemin**, Paley-Wiener on manifolds; **T. Kailath**, Norbert Wiener and the development of mathematical engineering; **N. Kopell**, Oscillating networks of Neurons: Mathematics and function; **E. S. Lander**, Mapping heredity: Using probabilistic models and algorithms to map genes and genomes; **A. W. Lo**, A nonrandom walk down Wall Street; **P. Malliavin**, Filtered Wiener space versus abstract Wiener space; **Maz' ya**, Unsolved problems connected with the Wiener criterion; **R. C. Merton**, On the role of the Wiener process in finance theory and practice: The case of replicating portfolios; **S. K. Mitter**, Inference, learning, and recognition; **D. Mumford**, Issues in the mathematical modeling of cortical functioning and thought; **D. R. Nelson and R. D. Kamien**, Polymer braids and iterated Moiré maps; **T. Poggio**, Networks that learn and how the brain works; **C. S. Sanford, Jr. and D. Borge**, The risk management revolution; **I. Segal**, Complex noncommutative infinite dimensional analysis and Fermion-Boson interactions; **J. Sjöstrand**, Complex integral transforms, diffraction, resonances and phase space tunneling; **T. Spencer**, Scaling, the free field and statistical mechanics; **H. Widom**, Weiner-Hopf integral equations.

Proceedings of Symposia in Pure Mathematics, Volume 60

May 1997, 405 pages, Hardcover, ISBN 0-8218-0415-4, LC 97-297, 1991 *Mathematics Subject Classification*: 01A06, 31-06, 34-06, 35-06, 40-06, 42-06, 45-06, 46-06, 60-06, 62-06, 68-06, 81-06, 82-06, 92-06, 94-06, **Individual member $48**, List $80, Institutional member $64, Order code PSPUM/60N



Translations of
MATHEMATICAL
MONOGRAPHS
Volume 160
Linear and Nonlinear
Perturbations of the
Operator div
V. G. Osmolovskii
American Mathematical Society

Linear and Nonlinear Perturbations of the Operator div

V. G. Osmolovskiĭ, *St. Petersburg State University, Russia*

The perturbation theory for the operator div is of particular interest in the study of boundary-value problems for the general nonlinear equation $F(\dot{y}, y, x) = 0$. Taking as linearization the first order operator $Lu = C_{ij}u^i_{x_j} + C_i u^i$, one can under certain conditions regard the operator L as a compact perturbation of the operator div.

This book presents results on boundary-value problems for L and the theory of nonlinear perturbations of L. Specifically, necessary and sufficient solvability conditions in explicit form are found for various boundary-value problems for the operator L. An analog of the Weyl decomposition is proved.

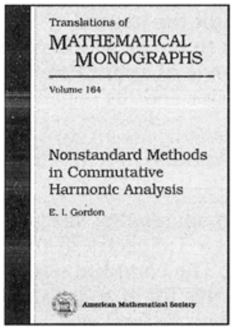
The book also contains a local description of the set of all solutions (located in a small neighborhood of a known solution) to the boundary-value problems for the nonlinear equation $F(\dot{y}, y, x) = 0$ for which L is a linearization. A classification of sets of all solutions to various boundary-value problems for the nonlinear equation $F(\dot{y}, y, x) = 0$ is given.

The results are illustrated by various applications in geometry, calculus of variations, physics, and continuum mechanics.

Contents: Notation; Linear perturbations of the operator div; Nonlinear perturbations of the operator div; Appendix; References.

Translations of Mathematical Monographs, Volume 160

March 1997, 104 pages, Hardcover, ISBN 0-8218-0586-X, LC 96-40489, 1991 *Mathematics Subject Classification*: 35F15, 35F30; 35Q35, **Individual member $35**, List $59, Institutional member $47, Order code MMONO/160N



Translations of
MATHEMATICAL
MONOGRAPHS
Volume 164
Nonstandard Methods
in Commutative
Harmonic Analysis
E. I. Gordon
American Mathematical Society

Nonstandard Methods in Commutative Harmonic Analysis

E. I. Gordon, *Nizhny Novgorod State University, Nizhnii Novgorod, Russia*

This monograph discusses nonstandard analysis (NSA) and its applications to harmonic analysis on locally compact Abelian (LCA) groups. A new notion of approximation of topological groups by finite groups is introduced and investigated. Based on this notion, new results are obtained on convergence of finite Fourier transformations (FT) to the FT on an LCA group. These results, formulated in standard terms in the Introduction, are proved by means of NSA. The book also includes new results on the theory of relatively standard elements and extensions of results of S-integrable liftings in Loeb measure spaces to the case of σ-finite Loeb measures. Basic concepts of NSA are included.

Contents: Basic concepts of nonstandard analysis; Nonstandard analysis of operators acting in spaces of measurable functions; Nonstandard analysis of locally compact Abelian groups.

Translations of Mathematical Monographs, Volume 164

May 1997, 166 pages, Hardcover, ISBN 0-8218-0419-7, LC 97-7187, 1991 *Mathematics Subject Classification*: 43-02, 03-01, 26E35, 43A25, 03H05; 28E05, 47S20, 42A38, 22B05, 22E35, 54J05, 03E70, 46S10, 46F99, **Individual member $59**, List $99, Institutional member $79, Order code MMONO/164N

MEMOIRS of the American Mathematical Society

Volume 127 Number 607

Operators of Class C_0 with Spectra in Multiply Connected Regions

Adele Zucchi

American Mathematical Society

Operators of Class C_0 with Spectra in Multiply Connected Regions

Adele Zucchi, *Indiana University, Bloomington, IN*

Let Ω be a bounded finitely connected region in the complex plane, whose boundary Γ consists of disjoint, analytic, simple closed curves. The author considers linear bounded operators on a Hilbert space H having $\overline{\Omega}$ as spectral set, and no normal summand with spectrum in Γ. For each operator satisfying these properties, the author defines a weak*-continuous functional calculus representation on the Banach algebra of bounded analytic functions on Ω. An operator is said to be of class C_0 if the associated functional calculus has a non-trivial kernel. In this work, the author studies operators of class C_0, providing a complete classification into quasisimilarity classes, which is analogous to the case of the unit disk.

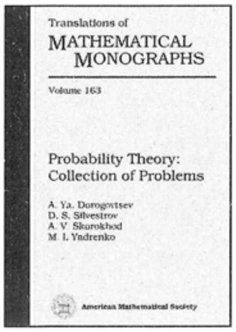
Contents: Introduction; Preliminaries and notation; The class C_0; Classification theory; Bibliography.

Memoirs of the American Mathematical Society, Volume 127, Number 607

May 1997, 52 pages, Softcover, ISBN 0-8218-0626-2, LC 97 3959, 1991 *Mathematics Subject Classification*: 47A45; 47A60, 30D55, **Individual member $20**, List $33, Institutional member $26, Order code MEMO/127/607N

Probability

Supplementary Reading



Translations of MATHEMATICAL MONOGRAPHS

Volume 163

Probability Theory: Collection of Problems

A. Ya. Dorogovtsev
D. S. Silvestrov
A. V. Skorokhod
M. I. Yadrenko

American Mathematical Society

Probability Theory: Collection of Problems

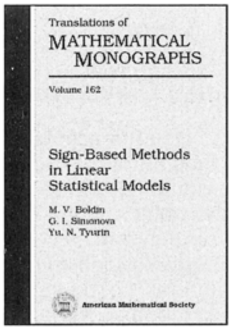
A. Ya. Dorogovtsev, *Kiev, Ukraine*, **D. S. Silvestrov**, *Kiev State University, Ukraine*, **A. V. Skorokhod**, *Ukrainian Academy of Sciences, Kiev, Ukraine*, and **M. I. Yadrenko**, *Kiev State University, Ukraine*

This book of problems is intended for students in pure and applied mathematics. There are problems in traditional areas of probability theory and problems in the theory of stochastic processes, which has wide applications in the theory of automatic control, queueing and reliability theories, and many other modern science and engineering fields. Answers to most of the problems are given, and for more complicated problems, the book provides hints and solutions.

Contents: Random events; Random variables; Sequences of random events and sequences of random variables; Simplest Markov processes; Limit theorems of probability theory; Solutions, hints, answers.

Translations of Mathematical Monographs, Volume 163

May 1997, 347 pages, Hardcover, ISBN 0-8218-0372-7, LC 97-5939, 1991 *Mathematics Subject Classification*: 60-01, **Individual member $71**, List $119, Institutional member $95, Order code MMONO/163N



Translations of MATHEMATICAL MONOGRAPHS

Volume 162

Sign-Based Methods in Linear Statistical Models

M. V. Boldin
G. I. Simonova
Yu. N. Tyurin

American Mathematical Society

Sign-Based Methods in Linear Statistical Models

M. V. Boldin, *Moscow State University, Russia*, **G. I. Simonova**, *Moscow State University, Russia*, and **Yu. N. Tyurin**, *Moscow State University, Russia*

For nonparametric statistics, the last half of this century was the time when rank-based methods originated, were vigorously developed, reached maturity, and received wide recognition. The rank-based approach in statistics consists in ranking the observed values and using only the ranks rather than the original numerical data. In fitting relationships to observed data, the ranks of residuals from the fitted dependence are used.

The signed-based approach is based on the assumption that random errors take positive or negative values with equal probabilities. Under this assumption, the sign procedures are distribution-free. These procedures are robust to violations of model assumptions, for instance, to even a considerable number of gross errors in observations. In addition, sign procedures, have fairly high relative asymptotic efficiency, in spite of the obvious loss of information incurred by the use of signs instead of the corresponding numerical values.

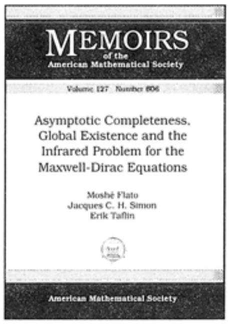
In this work, sign-based methods in the framework of linear models are developed. In the first part of the book, there are linear and factor models involving independent observations. In the second part, linear models of time series, primarily autoregressive models, are considered.

Contents: Introduction; *Part 1. Linear models of independent observations.* Sign-based analysis of one-parameter linear regression; Sign tests; Sign estimators; Testing linear hypotheses; *Part 2. Linear models of time series.* Least squares and least absolute deviations procedures in the simplest autoregressive model; Sign-based analysis of one-parameter autoregression; Sign-based analysis of the multiparameter autoregression; Bibliography.

Translations of Mathematical Monographs, Volume 162

April 1997, 234 pages, Hardcover, ISBN 0-8218-0371-9, LC 97-3452, 1991 *Mathematics Subject Classification*: 62G; 62G05, 62G10, 62G20, 62G35, 62M10, Individual member $59, List $99, Institutional member $79, Order code MMONO/162N

Mathematical Physics



Asymptotic Completeness, Global Existence and the Infrared Problem for the Maxwell-Dirac Equations

Moshé Flato, *Université de Bourgogne, Dijon, France,* **Jacques C. H. Simon**, *Université de Bourgogne, Dijon, France,* and **Erik Taflin**, *Université de Bourgogne, Dijon, France*

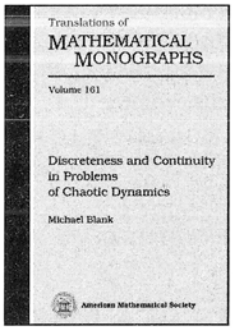
The purpose of this work is to present and give full proofs of new original research results concerning integration of and scattering for the classical Maxwell-Dirac equations. These equations govern first quantized electrodynamics and are the starting point for a rigorous formulation of quantum electrodynamics. The presentation is given within the formalism of nonlinear group and Lie algebra representations, i.e. the powerful new approach to nonlinear evolution equations covariant under a group action.

The authors prove that the nonlinear Lie algebra representation given by the manifestly covariant Maxwell-Dirac equations is integrable to a global nonlinear representation of the Poincaré group on a differentiable manifold of small initial conditions. This solves, in particular, the small-data Cauchy problem for the Maxwell-Dirac equations globally in time. The existence of modified wave operators and asymptotic completeness is proved. The asymptotic representations (at infinite time) turn out to be nonlinear. A cohomological interpretation of the results in the spirit of nonlinear representation theory and its connection to the infrared tail of the electron are developed.

Contents: Introduction; The nonlinear representation T and spaces of differentiable vectors; The asymptotic nonlinear representation; Construction of the approximate solution; Energy estimates and $L^2 - L^\infty$ estimates for the Dirac field; Construction of the modified wave operator and its inverse; Appendix.

Memoirs of the American Mathematical Society, Volume 127, Number 606

May 1997, 311 pages, Softcover, ISBN 0-8218-0683-1, LC 97-3960, 1991 *Mathematics Subject Classification*: 35Q; 81Q05, 81V10, 35L70, 22E70, **Individual member $34**, List $57, Institutional member $46, Order code MEMO/127/606N



Discreteness and Continuity in Problems of Chaotic Dynamics

Michael Blank, *Russian Academy of Sciences, Moscow, Russia*

This book presents the study of ergodic properties of so-called chaotic dynamical systems. One of the central topics is the interplay between deterministic and quasi-stochastic behavior in chaotic dynamics and between properties of continuous dynamical systems and those of their discrete approximations. Using simple examples, the author describes the main phenomena known in chaotic dynamical systems, studying topics such as the operator approach in chaotic dynamics, stochastic stability, and the so-called coupled systems. The last two chapters are devoted to problems of numerical modelling of chaotic dynamics.

Contents: Introduction; Operator approach in chaotic dynamics; Random perturbations of dynamical systems; Weakly coupled dynamical systems; Phase space discretization in dynamical systems; Ergodic properties of some methods for numerical modeling of chaotic dynamics; Bibliography; Index.

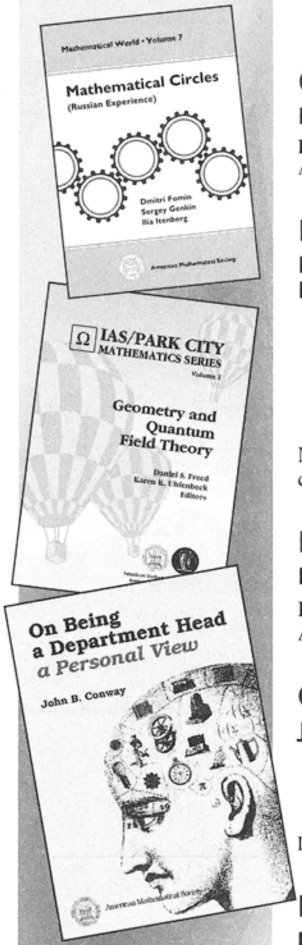
Translations of Mathematical Monographs, Volume 161

March 1997, 161 pages, Hardcover, ISBN 0-8218-0370-0, LC 97-551, 1991 *Mathematics Subject Classification*: 28D05, 58F13; 58F10, 58F14, 58F15, 58F30, Individual member $53, List $89, Institutional member $71, Order code MMONO/161

AMERICAN MATHEMATICAL SOCIETY

PUBLICATIONS *of* CONTINUING INTEREST

Bestsellers from the AMS



Geometry and Quantum Field Theory

Daniel S. Freed and **Karen K. Uhlenbeck**, *University of Texas, Austin*, **Editors**

IAS/Park City Mathematics Series, Volume 1, ISBN 0-8218-0400-6, 459 pages (hardcover), 1995, List $44*, All AMS members $35; order code PCMS/1NP

Mathematical Circles

Dmitri Fomin, *St. Petersburg State University, Russia*, **Sergey Genkin**, *Microsoft Corporation*, and **Ilia Itenberg**, *Institut de Recherche Mathématique de Rennes, France*

> *... a rich collection of good problems ... useful notes for teachers ... Appendix A ... will be especially interesting for those who are dealing with all forms of cooperative learning ... may be very useful wherever there are classes devoted to solving non-standard problems.*
>
> ***— American Mathematical Monthly***

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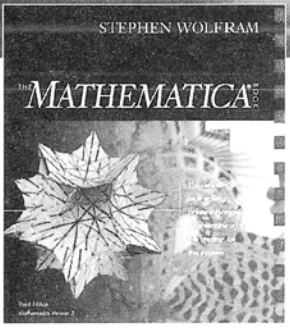

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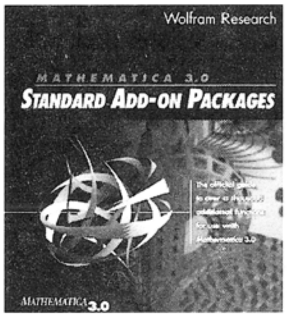

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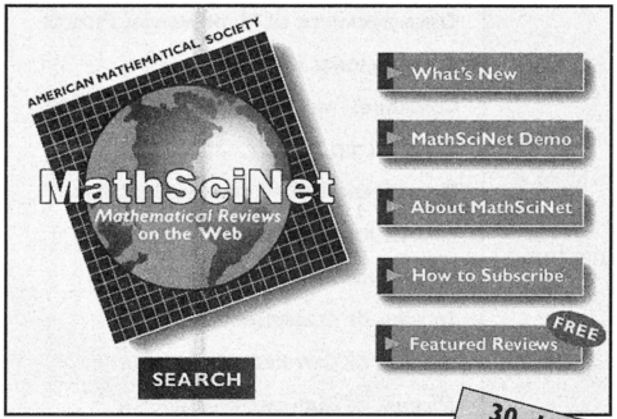

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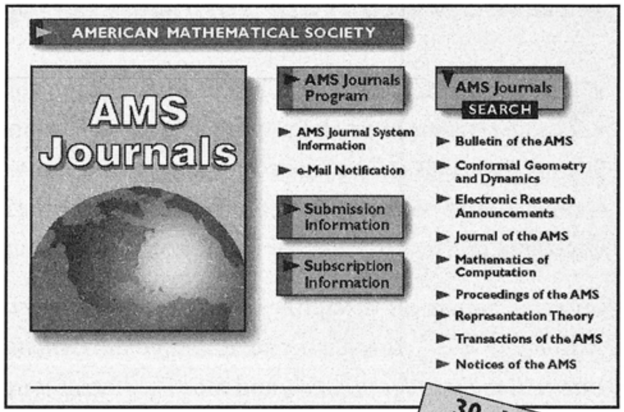

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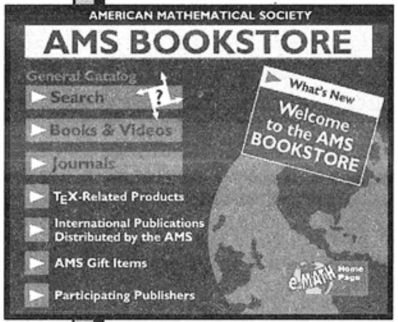

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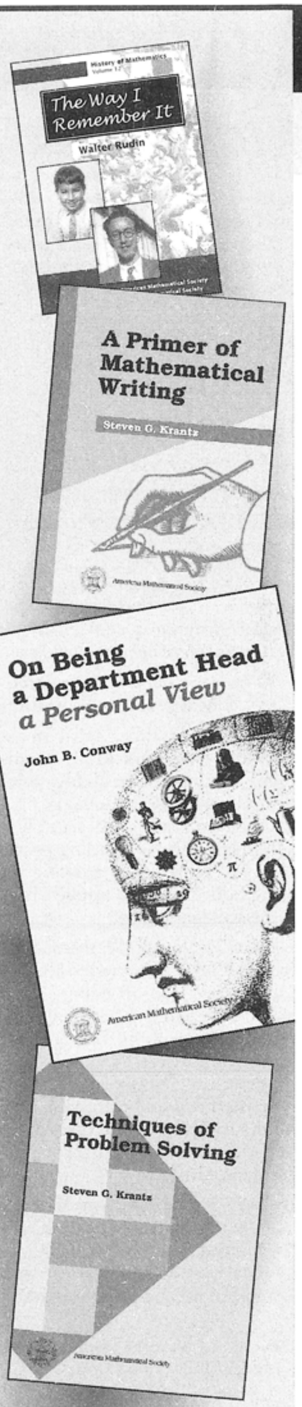

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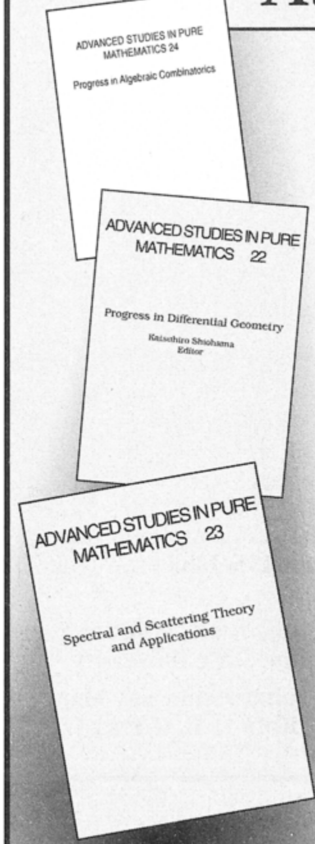

Advanced Studies in Pure Mathematics contains survey articles as well as original papers of lasting interest. Each volume grows out of a series of symposia and workshops on a specific topic of current interest. *Advanced Studies in Pure Mathematics* is published for the Mathematical Society of Japan by Kinokuniya, Tokyo, and starting with Volume 20 is distributed worldwide, except in Japan, by the American Mathematical Society.

Aspects of Low Dimensional Manifolds

Y. Matsumoto and **S. Morita**, Editors

This volume contains ten original papers written by leading experts in various areas of low-dimensional topology. The topics covered here are among those showing the most rapid progress in topology today: knots and links, three-dimensional hyperbolic geometry, conformally flat structures on three-manifolds, Floer homology, and the geometry and topology of four-manifolds. Offering both original results and up-to-date survey papers, *Aspects of Low Dimensional Manifolds* will interest mathematicians, physicists, graduate students, and others seeking a good introduction to the field.

Volume 20; 1992; 376 pages; Hardcover; ISBN 4-314-10077-X;
List $70; Individual member $42; Order code ASPM/20NA

Progress in Algebraic Combinatorics

E. Bannai and **A.Munemasa,** *Kyushu University, Fukuoka, Japan,* Editors

This volume consists of thirteen papers on algebraic combinatorics and related areas written by leading experts around the world. There are four survey papers illustrating the following currently active branches of algebraic combinatorics: vertex operator algebras, spherical designs, Kerdock codes and related combinatorial objects, and geometry of matrices. The remaining nine papers are original research articles covering a wide range of disciplines, from classical topics such as permutation groups and finite geometry, to modern topics such as spin models and invariants of 3-manifolds. Two papers occupy nearly half the volume and present a comprehensive account of new concepts: "Combinatorial Cell Complexes" by M. Aschbacher and "Quantum Matroids" by P. Terwilliger.

Terwilliger's theory of quantum matroids unites a part of the theory of finite geometries and a part of the theory of distance-regular graphs—great progess is expected in this field. K. Nomura's paper bridges the classical and the modern by establishing a connection between certain bipartite distance-regular graphs and spin models. All contributors to this volume were invited speakers at the conference "Algebraic Combinatorics" in Fukuoka, Japan (1993) and participated in the Research Institute in the Mathematical Sciences (RIMS) research project on algebraic combinatorics held at Kyoto University in 1994.

Volume 24; 1996; 453 pages; Hardcover; ISBN 4-314-10119-9;
List $88; Individual member $53; Order code ASPM/24NA

Progress in Differential Geometry

Katsuhiro Shiohama, Editor

This volume brings together twenty-five research papers and two survey articles on differential geometry and global analysis, areas in which Japanese differential geometers have recently made great progress. Urakawa's paper is a deep and comprehensive survey on recent results and open problems in differential geometry, including Green functions and Liouville type theorems. Yamaguchi's survey deals with the Lie algebra of all infinitesimal automorphisms of a differential system on a manifold and presents basic material on the geometry of differential systems and simple graded Lie algebras over the real or complex numbers. The research articles cover such topics as minimal surfaces, submanifold theory, analysis on manifolds, L^2-cohomology theory, and Riemannian geometry. This book will appeal to mathematicians interested in modern differential geometry, as well as to graduate students who are looking for a good overview of some of the main trends in this field.

Volume 22; 1993; 505 pages; Hardcover; ISBN 4-314-10105-9;
List $97; Individual member $58; Order code ASPM/22NA

Spectral and Scattering Theory and Applications

K. Yajima, Editor

This book contains the proceedings from a conference on Spectral and Scattering Theory, held in July 1992 at Tokyo Institute of Technology, in celebration of the sixtieth birthday of ShigeToshi Kuroda. The book is an up-to-date guide to recent results in spectral and scattering theory and applications to linear and nonlinear equations. Among the application areas covered are Schrödinger and wave equations, Boltzmann and MHD equations, and elliptic and parabolic equations. Abstract spectral theory is also discussed. This book presents many interesting and important new results as well as comprehensive surveys by leading experts in the field. This book is aimed at mathematicians and graduate students in operator theory, partial differential equations, mathematical physics, and applied mathematics, in addition to physicists and chemists working in such areas as atomic or molecular physics.

Volume 23; 1994; 322 pages; Hardcover; ISBN 4-314-10107-5;
List $83; Individual member $50; Order code ASPM/23NA

Zeta Functions in Geometry

N. Kurokawa and **T. Sunada,** Editors

This book contains accounts of work presented during the research conference, "Zeta Functions in Geometry" held at the Tokyo Institute of Technology in August 1990. The aim of the conference was to provide an opportunity for the discussion of recent results by geometers and number theorists on zeta functions in several different categories. The exchange of ideas produced new insights on various geometric zeta functions, as well as the classical zeta functions. The zeta functions covered here are the Selberg zeta functions, the Ihara zeta functions, spectral zeta functions, and those associated with prehomogeneous vector spaces. Accessible to graduate students with background in geometry and number theory, *Zeta Functions in Geometry* will prove useful for its presentation of new results and up-to-date surveys.

Volume 21; 1992; 450 pages; Hardcover; ISBN 4-314-10078-8;
List $80; Individual member $48; Order code ASPM/21NA

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Meetings & Conferences of the AMS

Detroit, Michigan

Wayne State University

May 2–4, 1997

Meeting #922

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: March 1997
Program issue of *Notices*: May 1997
Issue of *Abstracts*: Volume 18, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
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Invited Addresses

Harold P. Boas, Texas A & M University, *The football player and the infinite series.*

Carlos E. Kenig, University of Chicago, *Harmonic measure of locally flat domains.*

Ernest E. Shult, Kansas State University, *Geometric hyperplanes of classical geometries of Lie type.*

Alexander L. Volberg, Michigan State University, *Singular integrals and multivariate stochastic processes: New problems and methods.*

Special Sessions

Algebraic Combinatorics, **Devadatta M. Kulkarni**, Oakland University.

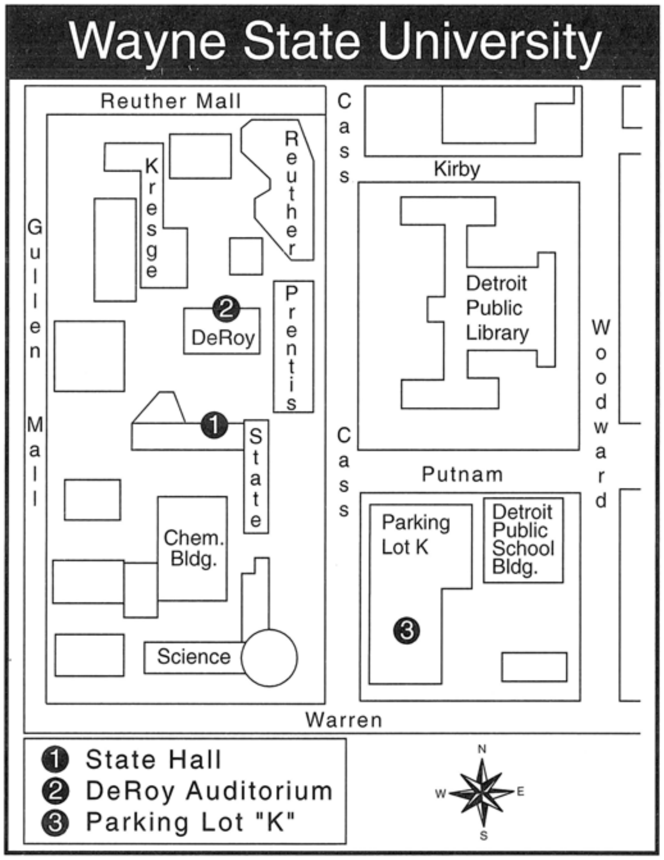
Algebraic Topology, **Robert R. Bruner** and **David Handel**, Wayne State University.

Analysis and Geometry, **Carlos E. Kenig**, University of Chicago, and **Tatiana Toro**, University of Washington.

C-Algebras*, **Jerry Kaminker**, Indiana University-Purdue University at Indianapolis, and **Claude L. Schochet**, Wayne State University.

Differential Geometry and Its Applications, **Daniel S. Drucker** and **Chorng-Shi Houh**, Wayne State University.

Groups and Geometries, **Daniel E. Frohardt** and **Kay Magaard**, Wayne State University, and **Robert L. Griess Jr.**, University of Michigan.



Optimization and Variational Analysis, **Boris S. Mordukhovich**, Wayne State University, and **Jay S. Treiman** and **Qiji Zhu**, Western Michigan University.

Partial Differential Equations: Theories, Applications and Numerical Approaches, **Frank J. Massey III** and **Jennifer Zhao**, University of Michigan-Dearborn, and **Daoqi Yang**, Wayne State University.

Recent Advances in Noncommutative Ring Theory, **Peter Malcolmson** and **Frank Okoh**, Wayne State University.

Representation Theory of Finite Groups and Related Topics, **David Howard Gluck**, Wayne State University.

Stochastic Processes in Finance and Control, **Raoul LePage**, Michigan State University, and **Bert M. Schreiber**, Wayne State University.

VOA's Monstrous Moonshine and Related Topics, **Chongying Dong**, University of California Santa Cruz, and **Robert L. Griess Jr.**, University of Michigan.

Wavelets and Applications, **Gregory F. Bachelis** and **Tze-Chien Sun**, Wayne State University, and **Grant Gerhart**, Tardec, Tacom, U.S. Army.

Pretoria, Republic of South Africa

University of Pretoria

June 26–28, 1997

Meeting #923

Joint meeting of the American Mathematical Society and South African Mathematical Society, with sponsorship of the London Mathematical Soceity.
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: March 1997
Program issue of *Notices*: June 1997
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: April 30, 1997

Information

For up-to-date information on accommodations, social events, or the scientific program it is best to consult the Web pages maintained by the South African Mathematical Society (`http://science.up.ac.za` or follow the links from the Meetings & Conferences page on e-MATH).

Invited Addresses

Hyman Bass, Columbia University, *Tree lattices.*

Armand Borel, Institute for Advanced Study, *Compactifications of symmetric spaces: applications.*

Percy Deift, Courant Institute of Mathematical Sciences, New York University, *Riemann-Hilbert problems in pure and applied mathematics.*

G. F. R. Ellis, University of Cape Town, South Africa, *Understanding the evolution of cosmological models: The state space and evolutionary trajectories.*

David Epstein, University of Warwick, United Kingdom, *Finite state automata and group theory.*

W. Goddard, University of Natal, Durban, South Africa, *Generalised colorings of graphs.*

Doron Lubinsky, University of Witwatersrand, South Africa, *A non-random walk from continued fractions to orthogonal polynomials.*

Robert Mackay, University of Cambridge, United Kingdom, *Discrete breathers.*

Peter Sarnak, Princeton University, *The distribution of zeros of zeta functions.*

Special Sessions

Algebraic K-Theory, **Eric M. Friedlander**, Northwestern University, and **Aderemi O. Kuku**, ICTP, Trieste, Italy.

Commutative Algebra and Algebraic Geometry, **James W. Brewer**, Florida Atlantic University, **Barry Green**, University of Stellenbosch, South Africa, and **Sylvia Margaret Wiegand**, University of Nebraska.

Dynamical Systems and Ergodic Theory, **Harvey B. Keynes**, University of Minnesota, **Michael Sears**, University of Witwatersrand, South Africa, and **Lionel Slammert**, University of Western Cape, South Africa.

Finite Groups and Representation Theory, **Jamshid Moori**, University of Natal, South Africa, and **Kenechukwu Kenneth Nwabueze**, Mathematical Sciences Research Institute.

Fluid Dynamics, **Susan J. Friedlander**, University of Illinois at Chicago, **Andrew Gilbert**, University of Exeter, United Kingdom, and **David Mason**, University of Witwatersrand, South Africa.

Geometry, Topology and Physics, **Steven B. Bradlow**, University of Illinois-Urbana, **George Ellis**, University of Cape Town, South Africa, **Nigel J. Hitchin**, University of Cambridge, England, and **Joao Rodrigues**, University of Witwatersrand, South Africa.

Graph Theory and Combinatorics, **Wayne Goddard**, University of Natal, South Africa, and **Manley Perkel**, Wright State University.

Harmonic Analysis, **H. A. M. Dzityiweyi**, University of Zimbabwe, Harare, Zimbabwe, and **Dumisani Vuma**, University of Zimbabwe.

Invariant Subspaces and Collections of Operators, **Peter Rosenthal**, University of Toronto, and **Graeme Philip West**, University of Witwatersrand, South Africa.

Logic, Algebra and Formal Aspects of Computer Science, **Valentin F. Goranko**, Rand Afrikaans University, Johannesburg, South Africa, **Peter Jipsen**, University of Cape Town, South Africa, **Ralph N. McKenzie**, Vanderbilt University, and **James G. Raftery**, University of Natal, South Africa.

Non-commutative Algebra, **Carlton J. Maxson**, Texas A & M University, and **Leon Van Wyk**, University of Stellenbosch.

Number Theory, **John Knopfmacher**, University of Witwatersrand, South Africa, and **Peter Sarnak**, Princeton University.

Numerical Analysis and Approximation Theory, **Peter Graves-Morris**, Bradford University, Bradford, England, **Dirk P. Laurie**, Potchefstroom University, South Africa, **Doron S. Lubinsky**, University of Witwatersrand, South Africa, and **Andre Weideman**, Oregon State University.

Operator Spaces and Related Structures, **David P. Blecher**, University of Houston, **Allan M. Sinclair**, University of Edinburgh, United Kingdom, and **Johan Swart**, University of Pretoria, South Africa.

Operator Theory and its Applications, **Joseph A. Ball**, Virginia Polytech Institute & State University, **Ronald W. Cross**, University of Cape Town, South Africa, **Gilbert J. Groenewald**, University of the Western Cape, South Africa, and **Marinus A. Kaashoek**, Vrije University, Amsterdam, The Netherlands.

Partial Differential Equations, **Percy Alec Deift** and **Jalal Shatah**, Courant Institute, New York University.

Ramsey Theory and Set Theory, **William Fouche**, University of Pretoria, South Africa, **Pieter Maritz**, University of Stellenbosch, South Africa, and **Marion Scheepers**, Boise State University.

Secondary and Postsecondary Curriculum Reform, **Johann Engelbrecht**, University of Pretoria, South Africa, **Deborah Hughes Hallet**, Harvard University, and **Harvey B. Keynes**, University of Minnesota.

Montreal, Quebec Canada

University of Montreal

September 26–28, 1997

Meeting #924

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 1997
Program issue of *Notices*: October 1997
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: May 1, 1997
For abstracts: June 26, 1997

Invited Addresses

Jacob E. Goodman, City University of New York, City College, *Title to be announced.*

Dieter Kotschick, University of Basel, Switzerland, *Title to be announced.*

Francois Lalonde, University of Quebec at Montreal, *Title to be announced.*

I. Moerdijk, University of Utrecht, Netherlands, *Title to be announced.*

Special Sessions

Algebraic Methods in Statistics (Code: AMS SS H1), **Gerard G. Letac**, Université Paul Sabatier, France.

Category Theory and Its Applications (Code: AMS SS E1), **Michael Barr**, McGill University, **Ieke Moerdijk**, University of Utrecht, Netherlands, and **Myles Tierney**, Rutgers University.

Combinatorial Geometry (Code: AMS SS C1), **David Avis**, McGill University, **Jacob E. Goodman**, City University of New York, City College, and **Richard Pollack**, Courant Institute, New York University.

Commutative Algebra (Code: AMS SS D1), **Irena V. Peeva**, Massachusetts Institute of Technology, and **Hema Srinivasan**, University of Missouri.

Geometric Analysis and Spectral theory (Code: AMS SS I1), **John Andrew Toth**, McGill University.

History of Mathematics (Code: AMS SS J1), **Israel Kleiner**, York University, and **James J. Tattersall**, Providence College.

Invariant Theory (Code: AMS SS G1), **Abraham Broer**, University of Montreal, **Yannis Y. Papageorgiou**, C.R.M., University of Montreal, and **David L. Wehlau**, Royal Military College and Queen's University.

Non-Euclidean and Spacetime Geometries (Code: AMS SS K1), **Abraham A. Ungar**, North Dakota State University.

Number Theory and Arithmetic Geometry (Code: AMS SS F1), **Henri Rene Darmon** and **Adrian Iovita**, McGill University and CICMA, and **Chantal David**, Concordia University and CICMA.

Potential Theory (Code: AMS SS A1), **Kohur Gowri Sankaran**, McGill University, and **David H. Singman**, George Mason University.

Symplectic Geometry and Differential Topology (Code: AMS SS B1), **Jacques C. Hurtubise** and **Lisa Claire Jeffrey**, McGill University, and **Francois Lalonde**, University of Quebec at Montreal.

Claremont, California

Claremont Colleges

October 4, 1997

Meeting #925

Joint meeting with the Mathematical Association of America.
Western Section
Associate secretary: William A. Harris Jr
Announcement issue of *Notices*: August 1997
Program issue of *Notices*: October 1997
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: May 2, 1997
For abstracts: June 27, 1997

Note: New Dates

Atlanta, Georgia

Georgia Institute of Technology

October 17–19, 1997

Meeting #926

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: August 1997
Program issue of *Notices*: October 1997
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: May 14, 1997
For abstracts: July 9, 1997

Invited Addresses

Irene Fonseca, Carnegie Mellon University, *Title to be announced.*

Michael T. Lacey, Georgia Institute of Technology, *Title to be announced.*

Marek T. Rychlik, University of Arizona, *Title to be announced.*

J. Ernest Wilkins Jr., Clark Atlanta University, *Title to be announced.*

Special Sessions

Applications of Symbolic Computation to Differential Equations (Code: AMS SS N1), **James Herod**, Georgia Tech, and **Maria Clara Nucci**, University of Perugia, Italy.

Complex and Algebraic Dynamics and Applications (Code: AMS SS K1), **Marek R. Rychlik**, University of Arizona.

Computer Proofs in Set Theory and Logic (Code: AMS SS E1), **Johan G. F. Belinfante**, Georgia Institute of Technology.

Concrete Aspects of Real Polynomials (Code: AMS SS H1), **Victoria Ann Powers**, Emory University, and **Bruce A. Reznick**, University of Illinois, Champaign-Urbana.

Discrete Conformal Geometry (Code: AMS SS G1), **Philip Lee Bowers**, Florida State University.

Discrete and Combinatorial Geometry (Code: AMS SS L1), **András Bezdek** and **Wlodzimierz Kuperberg**, Auburn University.

Harmonic Analysis and Its Applications (Code: AMS SS D1), **Michael Lacey**, Georgia Institute of Technology.

Modern Banach Space Theory (Code: AMS SS C1), **Stephen Dilworth** and **Maria K. Girardi**, University of South Carolina.

Nonlinear Dynamics and Applications (Code: AMS SS I1), **Wenxian Shen**, Auburn University, and **Yingfei Yi**, Georgia Institute of Technology.

Recent Developments in PDEs, Calculus of Variations, and Applications to Problems in Materials Science (Code: AMS SS M1), **Irene Fonseca**, Carnegie Mellon University, **Daniel Phillips**, Purdue University, and **Vladimir Sverak**, University of Minnesota.

Second-Generation Wavelets (Code: AMS SS J1), **Christopher E. Heil** and **Yang Wang**, Georgia Institute of Technology.

Set-Theoretic Techniques in Topology and Analysis. (Code: AMS SS A1), **Gary F. Gruenhage** and **Piotr Koszmider**, Auburn University.

Stochastic Inequalities and Their Applications (Code: AMS SS F1), **Theodore P. Hill** and **Christian Houdré**, Georgia Institute of Technology.

The Dynamics and Topology of Low Dimensional Flows (Code: AMS SS B1), **Robert W. Ghrist**, University of Texas at Austin, and **Michael C. Sullivan**, Southern Illinois University at Carbondale.

Milwaukee, Wisconsin

University of Wisconsin

October 24–26, 1997

Meeting #927

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: August 1997
Program issue of *Notices*: October 1997
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: May 21, 1997
For abstracts: July 16, 1997

Invited Addresses

Spencer J. Bloch, University of Chicago, *Title to be announced.*

Henri Moscovici, Ohio State University, *Title to be announced.*

Wei Ming Ni, University of Minnesota, *Title to be announced.*

Andrei Suslin, Northwestern University, *Title to be announced.*

Special Sessions

Analysis with Wavelets (Code: AMS SS M1), **Gilbert G. Walter**, University of Wisconsin-Milwaukee, and **Ahmed I. Zayed**, University of Central Florida.

Applications of Model Theory to Analysis and Topology (Code: AMS SS Q1), **Paul J. Bankston**, Marquette University, and **H. Jerome Keisler**, University of Wisconsin.

Computability Theory (Code: AMS SS A1), **Steffen Lempp**, University of Wisconsin, Madison, and **Robert I. Soare**, University of Chicago.

Concentration Phenomena in Differential Equations (Code: AMS SS E1), **Lia Bronsard**, McMaster University, and **Wei Ming Ni**, University of Minnesota.

Differential Geometry (Code: AMS SS N1), **Hongyou Wu**, Northern Illinois University.

Eigenvalue Problems for Differential Equations (Code: AMS SS K1), **Paul A. Binding**, University of Calgary, and **Hans W. Volkmer**, University of Wisconsin-Milwaukee.

Enveloping Algebras and Quantum Groups (Code: AMS SS J1), **Ian M. Musson** and **Yi Ming Zou**, University of Wisconsin-Milwaukee.

Geometric Topology and Geometric Group Theory (Code: AMS SS H1), **Fredric Davis Ancel** and **Craig R. Guilbault**, University of Wisconsin-Milwaukee.

Harmonic Analysis and Its Applications (Code: AMS SS F1), **Lung-Kee Chen**, Oregon State University, **Dashan Fan**, University of Wisconsin-Milwaukee, and **Yi-Biao Pan**, University of Pittsburgh.

K-Theory and Motives (Code: AMS SS B1), **Daniel Richard Grayson**, University of Illinois, Urbana-Champaign.

Low Dimensional Dynamics (Code: AMS SS C1), **Karen M. Brucks**, University of Wisconsin-Milwaukee, and **Beverly E. J. Diamond**, University of Charleston.

Mathematics in Industry (Code: AMS SS R1), **Michael Benedikt**, Lucent Technologies.

Number Theory and Cryptography (Code: AMS SS D1), **Eric Bach** and **Rene Peralta**, University of Wisconsin-Milwaukee.

Operator Theory and Function Spaces (Code: AMS SS G1), **Željko Čučković**, University of Toledo.

Rings and Modules (Code: AMS SS I1), **Karl Andrew Kosler** and **Shubhangi S. Stalder**, University of Wisconsin Centers-Waukesha.

Semigroups and Their Applications (Code: AMS SS P1), **Karl E. Byleen** and **Peter R. Jones**, Marquette University.

Symplectic Topology and Quantum Cohomology (Code: AMS SS L1), **Yong-Geun Oh**, University of Wisconsin, and **Yongbin Ruan**, University of Utah.

Albuquerque, New Mexico

University of New Mexico

November 8–9, 1997

Meeting #928

Western Section
Associate secretary: William A. Harris Jr
Announcement issue of *Notices*: September 1997
Program issue of *Notices*: November 1997
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 12, 1997
For abstracts: August 7, 1997

Oaxaca, Mexico

Oaxaca, Mexico

December 4–6, 1997

Meeting #929

Third Joint Meeting of the American Mathematical Society and the Sociedad Mathematica Mexicana.
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: September 1997
Program issue of *Notices*: December 1997
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: June 20, 1997
For abstracts: August 1, 1997

Special Sessions

Algebraic Geometry and Commutative Algebra, **Leticia Brambila**, UAM-Iztapalapa, and **Rick Miranda**, Colorado State University.

Applications of Non-linear Analysis to Continuous Media, **Gustavo Cruz**, IIMAS-UNAM, **Susan J. Friedlander**, University of Illinois at Chicago, **Rafael de la Llave**, University of Texas at Austin, and **Pablo Padilla**, University Nacional Autonoma de Mexico.

Complex and Functional Analysis, **William Abikoff**, University of Connecticut, **Raul E. Curto**, University of Iowa, **Salvador Perez-Esteva**, University Nacional Autonoma de Mexico, and **Michael Porter**, CINVESTAV-IPN.

Differential Geometry and Topology, **Luis Hernandez**, CIMAT, **Max Neumann**, IMATE-UNAM, and **Peter Scott**, University of Berkeley and University of Michigan.

General Topology, **Charles L. Hagopian**, California State University Sacramento, and **Isabel Puga**, FC-UNAM.

Graphs and Combinatorial Geometry, **Janos Pach**, City College, City University of New York, and **Eduardo Rivera**, IMATE-UNAM and UAM-I.

Mathematical Physics, **Micho Durdevich**, IMATE-UNAM, and **Roberto Quezada**, UAM-I.

Nonlinear Models in Biology and Celestial Mechanics, **Eudez Perez** and **Jorge X. Velasco**, UAM-I, and **Stephen R. Wiggins**, California Institute of Technology.

Numerical Analysis, **Jean P. Hennart**, IIMAS-UNAM.

Representation Theory of Algebras and Groups, **Martha Takane** and **Ernesto Vallejo**, IMATE-UNAM, and **Dan Zacharia**, Syracuse University.

Rings and Category Theory, **Sergio Roberto Lopez-Permouth**, Ohio University, and **Jose Rios** and **Leopoldo Roman**, IMATE-UNAM.

Stochastic Systems, **Guillermo Segundo Ferreyra**, Louisiana State University, and **Daniel Hernandez**, CINVESTAV-IPN.

Baltimore, Maryland

Baltimore Convention Center

January 7–10, 1998

Meeting #930

Joint Mathematics Meetings, including the 104th Annual Meeting of the AMS, 81st Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: October 1997
Program issue of *Notices*: January 1998
Issue of *Abstracts*: Volume 19, Issue 1

Deadlines

For organizers: April 8, 1997
For consideration of contributed papers in Special Sessions: August 7, 1997
For abstracts: October 2, 1997
For summaries of papers to MAA organizers: September 5, 1997

Invited Addresses

Melvin Hochster, University of Michigan (AMS Invited Address).

Bradley Lucier, Purdue University, West Lafayette, Indiana, *Title to be announced* (AMS Invited Address).

Tudor Stefan Ratiu, University of California, Santa Cruz, *Title to be announced* (AMS Invited Address).

Edward Witten, Institute for Advanced Study (AMS Josiah Willard Gibbs Lecture).

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*: March 1998
Issue of *Abstracts*: Volume 19, Issue 2

Deadlines

For organizers: June 20, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Banach Space Theory (Code: AMS SS F1), **Patrick N. Dowling** and **Beata Randrianantoanina**, Miami University, Ohio.

Boundary Value Problems for Differential Equations (Code: AMS SS J1), **Paul W. Eloe**, University of Dayton.

Combinatorics and Enumerative Geometry (Code: AMS SS A1), **Kequan Ding**, University of Illinois, Urbana-Champaign, and **Chi Wang**, University of Louisville.

Combinatorics and Graph Theory (Code: AMS SS B1), **Andre E. Kezdy**, **Grzegorz Kubicki**, and **Jenoe Lehel**, University of Louisville.

Discrete Mathematics, Classification Theory and Consensus (Code: AMS SS C1), **Robert C. Powers**, University of Louisville.

Fractal Geometry and Related Topics (Code: AMS SS D1), **Ka-Sing Lau**, University of Pittsburgh, and **Weibin Zeng**, University of Louisville.

Functional Equations and Inequalities (Code: AMS SS E1), **Thomas Riedel** and **Prasanna Sahoo**, University of Louisville.

Real Analysis (Code: AMS SS G1), **Udayan B. Darji** and **Lee Larson**, University of Louisville.

Semigroups, Algorithms, and Universal Algebra (Code: AMS SS H1), **Ralph N. McKenzie**, Vanderbilt University, and **Steven Seif**, University of Louisville.

Spectral Geometry (Code: AMS SS K1), **Ruth Gornet**, Texas Tech University, and **Peter Anton Perry**, University of Kentucky.

Spectral Theory, Mathematical Physics and Disordered Media (Code: AMS SS L1), **Peter David Hislop**, University of Kentucky, and **Gunter H. Stolz**, University of Alabama at Birmingham.

The Use of the History of Mathematics and Science in the University and School Classroom (Code: AMS SS I1), **Richard M. Davitt**, University of Louisville.

Manhattan, Kansas

Kansas State University

March 27–28, 1998

Meeting #932

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 26, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Partial Differential Equations and Inverse Problems (Code: AMS SS A1), **Alexander G. Ramm**, Kansas State University.

Philadelphia, Pennsylvania

Temple University

April 4–6, 1998

Meeting #933

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 2, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Tobias H. Colding, Courant Institute, New York University.

Martin Davis, University of California, Berkeley.

Ezra Getzler, Max Planck Institute and Northwestern University.

Yanyan Li, Rutgers University, New Brunswick.

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), **Boris Datskovsky** and **Marvin I. Knopp**, 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.

The History of American Mathematics (Code: AMS SS D1), **Karen H. Parshall**, University of Virginia, and **David E. Zitarelli**, Temple University.

Topology of Manifolds (Code: AMS SS F1), **Georgia Triantafillou**, Temple University.

Davis, California

University of California

April 25–26, 1998

Meeting #934

Western Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: February 1998
Program issue of *Notices*: April 1998
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 24, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Chicago, Illinois

DePaul University-Chicago

September 12–13, 1998

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: December 12, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Stochastic Analysis (Code: AMS SS A1), **Richard B. Sowers**, University of Illinois-Urbana.

Tucson, Arizona

University of Arizona-Tucson

November 14–15, 1998

Western Section
Associate secretary: William A. Harris Jr
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: February 12, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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), and annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 1998
Program issue of *Notices*: January 1999
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

Las Vegas, Nevada

University of Nevada-Las Vegas

April 10–11, 1999

Western Section
Associate secretary: William A. Harris Jr
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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*: February 1999
Program issue of *Notices*: April 1999
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

American Mathematical Society

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Washington, District of Columbia

Sheraton Washington Hotel and Omni Shoreham Hotel

January 19–22, 2000

Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: William A. Harris Jr
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

New Orleans, Louisiana

New Orleans Marriott and ITT Sheraton New Orleans Hotel

January 10–13, 2001

Joint Mathematics Meetings, including the 107th Annual Meeting of the AMS, 84th Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Presenters of Papers

Detroit, Michigan; May 2–4, 1997

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Program of the Sessions

Detroit, Michigan, May 2–4, 1997

Friday, May 2

Registration

11:00 AM – 4:00 PM **Lobby Area, State Hall Building**

AMS Exhibit and Book Sale

11:00 AM – 4:00 AM **Lobby Area, State Hall Building**

Invited Address

1:30 PM – 2:20 PM **Auditorium, Upper Deroy Building**

▸ (1) *The football player and the infinite series.* Preliminary report.
Harold P. Boas, Texas A&M University (922-30-26)

Special Session on Partial Differential Equations: Theories, Applications and Numerical Approaches, I

3:00 PM – 6:50 PM **Room 114, State Hall Building**

Organizers: **Jennifer Zhao**, University of Michigan-Dearborn
Frank J. Massey, III, University of Michigan-Dearborn
Daoqi Yang, Wayne State University

3:00PM (2) *A second order integro-differential equation in whole space.*
J. L. Menaldi, Wayne State University (922-35-167)

3:30PM (3) *Nonlinear vibration and stabilization of elastic panel.*
P. L. Chow, Wayne State University (922-35-171)

4:00PM (4) *Approximation of the solution of the Darboux-Ionescu problem.*
Viorica Mureşan, Technical University of Cluj-Napoca, Romania (922-35-153)

4:30PM (5) *On the connections between the Wasserstein metric and diffusions.*
Richard K. Jordan, University of Michigan (922-35-32)

5:00PM (6) *A maximum principle for hyperbolic systems.*
Anton S. Mureşan, Babeş-Bolyai University Cluj-Napoca, Romania (922-35-152)

5:30PM (7) *Polynomial expansions of solutions of a class of Cauchy problems that involve one space variable.* Preliminary report.
Louis R. Bragg, Oakland University (922-35-05)

6:00PM (8) *On analytic semigroups and cosine functions in Banach spaces.*
V. Keyantuo*, University of Puerto Rico, and **P. Vieten**, Fachbereich Mathematik der Universität Kaiserslautern, Germany (922-35-87)

6:30PM (9) *A comparison principle for quasilinear elliptic equations and its application.*
Zhiren Jin* and **Kirk Lancaster**, Wichita State University (922-35-108)

Special Session on Representation Theory of Finite Groups and Related Topics, I

3:00 PM – 5:20 PM **Room 129, State Hall Building**

Organizer: **David Howard Gluck**, Wayne State University

3:00PM (10) *Homogeneous integral table algebras.* Preliminary report.
Harvey I. Blau* and **Bangteng Xu**, Northern Illinois University (922-20-107)

3:30PM (11) *Some remarks on blocks of special linear groups.* Preliminary report.
Harvey I. Blau and **Harald E. Ellers***, Northern Illinois University (922-20-223)

4:00PM (12) *A decomposition theorem for K-theory of a group algebra.* Preliminary report.
Sarah J. Witherspoon, University of Toronto and University of California, Berkeley (922-20-144)

4:30PM (13) *Quillen stratification for the stable module category.*
Wayne W. Wheeler, University of Georgia (922-20-68)

The time limit for each contributed paper in the sessions is ten minutes. In the Special Sessions the time limit varies from session to session and within sessions. To maintain the schedule, time limits will be strictly enforced.

For papers with more than one author, an asterisk follows the name of the author who plans to present the paper at the meeting.

Papers flagged with a solid triangle (▸) have been designated by the author as being of possible interest to undergraduate students.

Abstracts of papers presented in the sessions at this meeting will be found in Volume 18, Issue 2 of *Abstracts of papers presented to the American Mathematical Society*, ordered according to the numbers in parentheses following the listings. The middle two digits, e.g., 897-**20**-1136, refer to the Mathematical Reviews subject classification assigned by the individual author. Groups of papers for each subject are listed chronologically in the *Abstracts*. The last one to four digits, e.g., 897-20-**1136**, refer to the receipt number of the abstract; abstracts are further sorted by the receipt number within each classification.

5:00PM (14) *Hochschild cohomology is really representation theory.* Preliminary report.
Stephen F. Siegel*, University of Massachusetts, Amherst, and **Sarah J. Witherspoon**, University of California, Berkeley (922-20-250)

Special Session on Differential Geometry and Its Applications, I

3:00 PM – 5:50 PM **Room 123, State Hall Building**

Organizers: **Daniel S. Drucker**, Wayne State University
Chorng-Shi Houh, Wayne State University

3:00PM (15) *Rigidity of actions of abelian and semisimple groups.*
Ralf J. Spatzier, Univ of Michigan (922-53-110)

3:30PM (16) *Compactifications of Hermitian locally symmetric spaces and aconjecture of Harris-Zucker.*
Lizhen Ji, University of Michigan (922-53-30)

4:00PM (17) *Hermitian conformal classes and almost Kähler structures on 4-manifolds.*
Vestislav Apostolov, Institute of Mathematics, Bulgarian Academy of Science, and **Tedi Draghici***, Michigan State University (922-53-94)

4:30PM ▶ (18) *Twistor spaces for homogeneous spaces and applications to harmonic maps.* Preliminary report.
J. A. Jiménez, Penn State Hazleton (922-53-129)

5:00PM (19) *Length spectrum of circles in a complex projective space.*
Sadahiro Maeda*, Shimane University, Japan, and **Toshiaki Adachi**, Nagoya Institute of Technology, Japan (922-53-15)

5:30PM (20) *The space of harmonic two-spheres in a unitary group or complex Grassmannian.* Preliminary report.
Martin A. Guest, University of Rochester (922-53-22)

Special Session on Algebraic Topology, I

3:00 PM – 5:20 PM **Room 125, State Hall Building**

Organizers: **Robert R. Bruner**, Wayne State University
David Handel, Wayne State University

3:00PM (21) *Exponential relations in the Steenrod algebra for BP cohomology.* Preliminary report.
Michael D. Slack, Western Michigan University (922-55-47)

3:30PM (22) *The real Brown-Peterson spectrum and the $Z/2$-equivariant Steenrod algebra.*
Igor Kriz, University of Michigan at Ann Arbor (922-55-253)

4:00PM (23) *Complex oriented equivariant cohomology theories and their formal group laws.* Preliminary report.
Michael Cole, University of Michigan at Ann Arbor (922-55-252)

4:30PM (24) *Phantom maps out of iterated loop spaces.* Preliminary report.
Frederic R. Cohen, **Hà Minh Le*** and **Charles A. McGibbon**, Wayne State University (922-55-49)

5:00PM (25) *On G-sequences and fiber spaces.*
Moo Ha Woo, Korea University, Seoul, Korea (922-55-258)

Special Session on Groups and Geometries, I

3:00 PM – 5:50 PM **Room 131, State Hall Building**

Organizers: **Daniel E. Frohardt**, Wayne State University
Robert L. Griess Jr., University of Michigan
Kay Magaard, Wayne State University

3:00PM (26) *Applications of group geometries to group cohomology.* Preliminary report.
Stephen D. Smith, University of Illinois at Chica (922-20-90)

3:30PM (27) *Extensions of Kac-Moody twin buildings using quasi-real roots.* Preliminary report.
Curtis D. Bennett, Bowling Green State University (922-20-118)

4:00PM (28) *The Quillen complex of $Sp_{2n}(q)$.* Preliminary report.
Kaustuv M. Das, Eastern Illinois University (922-20-34)

4:30PM (29) *Geometry and cohomology of certain 2-groups.* Preliminary report.
Alejandro Adem, University of Wisconsin-Madison (922-20-277)

5:00PM (30) *Actions of $SL(2,7)$ and $PSL(2,7)$ subgroups of the complex lie group of type E_8 on 2^k-torsion subgroups of a maximal torus.*
Michael J. Kantor, Knox College (922-20-244)

5:30PM (31) *Cameron-Liebler classes of lines in $PG(3,q)^*$.*
Aiden Bruen* and **Keldon Drudge**, University of Western Ontario (922-15-281)

Special Session on Recent Advances in Noncommutative Ring Theory, I

3:00 PM – 4:50 PM **Room 127, State Hall Building**

Organizers: **Peter Malcolmson**, Wayne State University
Frank Okoh, Wayne State University

3:00PM (32) *Lie modules with bounded multiplicities.* Preliminary report.
Daniel J. Britten and **Frank W. Lemire***, University of Windsor (922-17-45)

3:00PM (33) *Cofinite Lie algebras.* Preliminary report.
Richard E. Phillips and **Jeanne Wald***, Michigan State University (922-17-86)

4:00PM ▶ (34) *Ideals in tensor powers of the enveloping algebra $U(sl_2)$.*
Stefan Catoiu, University of Wisconsin-Madison (922-16-20)

4:30PM (35) *Finite group actions on affine semigroup algebras.* Preliminary report.
Martin W. Lorenz, Temple University, Philadelphia, PA 19122-6094 (922-16-97)

Special Session on Stochastic Processes in Finance and Control, I

3:00 PM – 5:40 PM **Room 115, State Hall Building**

Organizers: **Raoul LePage**, Michigan State University
Bert M. Schreiber, Wayne State University

3:00PM (36) *Bid-ask spread and incomplete markets.*
Per A. Mykland, The University of Chicago (922-60-81)

3:30PM (37) *Hedging options with transaction costs.*
Shlomo Levental, Michigan State University, East Lansing (922-60-178)

4:00PM (38) *Parameter estimation for some financial market models.*
Andrius Jankunas, Wayne State University (922-60-119)

4:30PM (39) *Continuous time analogue of the multiplicative update algorithm and on-line portfolio selection.*
Alexander White, Michigan State University, East Lansing (922-60-216)

5:00PM (40) *Some risk sensitive control models in finance.*
Wendell H. Fleming, Brown University (922-60-174)

Special Session on C-Algebras, I*

3:00 PM – 5:50 PM **Room 116, State Hall Building**

Organizers: **Jerry Kaminker**, Indiana University-Purdue University at Indianapolis
Claude L. Schochet, Wayne State University

3:00PM (41) *On a certain class of simple C^*-algebras.*
Xinhui Jiang, The Fields Institute (922-46-76)

3:30PM (42) *Finite group actions on AF algebras.* Preliminary report.
Marius D. Dadarlat, Purdue University, West Lafayette (922-46-127)

4:00PM (43) *The natural topology on the Kasparov groups.*
Claude L. Schochet, Wayne State University (922-46-212)

4:30PM (44) *K-Theory of certain simple C^*-algebras.* Preliminary report.
Shuang Zhang, University of Cincinnati (922-46-236)

5:00PM (45) *Commutators of free random variables.*
Alexandru M. Nica*, University of Michigan, Ann Arbor, and **Roland Speicher**, Universitat Heidelberg, Germany (922-47-242)

5:30PM (46) *Hilbert C^*-modules: A useful tool.*
Sze-kai Jack Tsui, Oakland University (922-46-74)

Special Session on VOA's Monstrous Moonshine and Related Topics, I

3:00 PM – 5:50 PM **Room 135, State Hall Building**

Organizers: **Robert L. Griess Jr.**, University of Michigan
Chongying Dong, University of California Santa Cruz

3:00PM (47) *Quantum analogs of generalized Verma modules.* Preliminary report.
Viatcheslav M. Futorny, Kiev University, Kiev, Ukraine, and **Duncan J. Melville***, St. Lawrence University (922-17-231)

3:30PM (48) *Automorphisms of genus 2 curves and Kummer surfaces.* Preliminary report.
Charles B. Thomas, University of Cambridge, United Kingdom (922-20-239)

4:00PM (49) *Replicable functions and the monster.* preliminary report.
Simon P. Norton, Cambridge, England (922-30-112)

4:30PM (50) *Higher genus modular equations.* Preliminary report.
Chris Cummins (922-11-161)

5:00PM (51) *A vector-valued function generalizing the elliptic modular function ($j(z)$).* Preliminary report.
Mihai Cipu and **John McKay***, Centre Interuniversitaire en Calcul Mathématique Algébrique (922-11-255)

5:30PM (52) *Mirror pairs of finite groups.* Preliminary report.
Geoffrey Mason, University of California, Santa Cruz (922-20-271)

Special Session on Algebraic Combinatorics, I

3:00 PM – 5:50 PM **Room 137, State Hall Building**

Organizer: **Devadatta M. Kulkarni**, Oakland University

3:00PM (53) *The Tutte dichromate and Whitney homology of matroids.*
David G. Wagner, University of Waterloo (922-05-10)

3:30PM (54) *How many quartic graphs have integral spectra?*
Allen J. Schwenk, Western Michigan University (922-05-276)

4:00PM (55) *Distribution invariants of association schemes.*
Nachimuthu Manickam, DePauw University (922-05-70)

4:30PM (56) *Combinatorics of paraunitary groups.* Preliminary report.
Hyungju Alan Park, Oakland University (922-05-265)

5:00PM (57) *Strongly regular graphs and alternating spaces.* Preliminary report.
Chris D. Godsil, University of Waterloo (922-05-139)

5:30PM (58) *Symplectic matroids.*
Alexandre V. Borovik, UMIST, United Kingdom, **Israel M. Gelfand**, Rutgers University, New Brunswick, and **Neil L. White***, University of Florida, Gainesville (922-05-130)

Special Session on Optimization and Variational Analysis, I

3:00 PM – 5:50 PM **Room 117, State Hall Building**

Organizers: **Boris S. Mordukhovich**, Wayne State University
Jay S. Treiman, Western Michigan University
Qiji Zhu, Western Michigan University

3:00PM (59) *Partially smooth variational analysis.*
Jonathan M. Borwein, Simon Fraser University (922-49-37)

3:30PM (60) *Convex spectral functions of compact operators.*
J. M. Borwein, CECM, Simon Fraser University, **Adrian S. Lewis***, University of Waterloo, and **J. Read**, CECM, Simon Fraser University (922-49-141)

4:00PM (61) *More on limiting Frechet ϵ-subdifferentials.*
Michel Thera, Université de Limoges, France (922-49-36)

4:30PM (62) *Sufficient conditions for weakminima of order two and directional derivatives of the value function.*
Doug E. Ward, Miami University (922-90-17)

5:00PM (63) *Limits of partial viscosity subderivatives.*
Jay S. Treiman, Western Michigan University (922-49-143)

5:30PM (64) *Some applications of partially smooth variational principles.*
Qiji Jim Zhu, Western Michigan University (922-49-53)

Special Session on Wavelets and Applications, I

3:00 PM – 5:20 PM **Room 111, State Hall Building**

Organizers: **Gregory F. Bachelis**, Wayne State University
Grant Gerhart, Tardec, Tacom, Army
Tze-Chien Sun, Wayne State University

3:00PM (65) *Positive density estimation with wavelets.* Preliminary report.
Gilbert G. Walter* and **Xiaoping Shen**, University of Wisconsin-Milwaukee (922-42-91)

3:30PM (66) *Hardy spaces and a Walsh model for the bilinear Hilbert transform.* Preliminary report.
John E. Gilbert, The University of Texas at Austin (922-42-268)

4:00PM (67) *Wavelet packet models of event-related potentials.* Preliminary report.
Jonathan A. Raz, University of Michigan, Ann Arbor (922-62-46)

4:30PM ► (68) *Wavelet analysis and acoustic classification.* Preliminary report.
Robert E. Karlsen*, **David Gorsich**, **Grant R. Gerhart** and **Thomas J. Meitzler**, US Army - TACOM (922-62-211)

5:00PM (69) *Multiresolution based optical flow calculation.*
David J. Gorsich*, **Robert Karlsen** and **Grant Gerhart**, U.S. Army (922-68-218)

Special Session on Analysis and Geometry, I

3:30 PM – 5:20 PM **Room 113, State Hall Building**

Organizers: **Carlos E. Kenig**, University of Chicago
Tatiana Toro, University of Washington

3:30PM (70) *On geometric branched covers.*
Juha Heinonen, University of Michigan, Ann Arbor (922-35-274)

4:00PM (71) *Dirichlet to Neumann maps and conformal deformations.*
Ziqi Sun, Wichita State University (922-35-137)

4:30PM (72) *Harmonic function theory on manifolds.*
William P. Minicozzi, II*, Johns Hopkins University, and **Tobias H. Colding**, Courant Institute, New York University (922-58-246)

5:00PM (73) *Harmonic map flows between certain singular spaces.* Preliminary report.
Changyou Wang, University of Chicago (922-58-251)

Saturday, May 3

Registration

7:30 AM – 3:00 PM **Lobby Area, State Hall Building**

AMS Exhibit and Book Sale

7:30 AM – 3:00 PM **Lobby Area, State Hall Building**

Special Session on Partial Differential Equations: Theories, Applications and Numerical Approaches, II

8:00 AM – 10:50 AM **Room 114, State Hall Building**

Organizers: **Jennifer Zhao**, University of Michigan-Dearborn
Frank J. Massey, III, University of Michigan-Dearborn
Daoqi Yang, Wayne State University

8:00AM (74) *Output least-squares minimization for recovering elastic moduliin an isotropic membrane.* Preliminary report.
Steven J. Cox, Rice University, and **Mark S. Gockenbach***, University of Michigan (922-35-219)

8:30AM (75) *An accelerated domain decomposition procedure based on Robin transmission conditions.*
Jim Douglas, Purdue Universsity, West Lafayette, and **Chieh-Sen Huang***, Purdue University, West Lafayette (922-65-180)

9:00AM (76) *A numerical model for solution behaviour in a hyperbolic quenching p.d.e. studied by Chang and Levine.*
John W. Mooney, Glasgow Caledonian University, Scotland, United Kingdom (922-35-66)

9:30AM (77) *Relations between time and space step-sizes in numerical schemes for PDE's that follow from positivity condition.*
Ronald Mickens, Clark Atlanta University (922-35-169)

10:00AM (78) *Poisson's equation on a triangulated domain.* Preliminary report.
Michael Lachance, University of Michigan-Dearborn (922-35-232)

10:30AM (79) *A multiple-porosity model for a single-phase flow through naturally-fractured porous media.*
Anna M Spagnuolo*, **Jim Douglas Jr.**, Purdue University, **Paulo Jorge S. Paes-Leme**, and **Mauricio Kischinhevsky**, Purdue University (922-86-181)

Special Session on Algebraic Combinatorics, II

8:00 AM – 10:50 AM **Room 137, State Hall Building**

Organizer: **Devadatta M. Kulkarni**, Oakland University

8:00AM (80) *k-Sperner sets: A snapshot of modern combinatorics.* Preliminary report.
Timothy Y. Chow*, University of Michigan, Ann Arbor, and **Philip J. Lin**, Tellabs Research Center (922-05-44)

8:30AM ► (81) *New polyhedral formulae for affine problems.*
J. Maurice Rojas, MIT (922-05-280)

9:00AM (82) *The characteristic polynomials of interpolations between Coxeter arrangements.*
Ping Zhang, Western Michigan University (922-05-104)

9:30AM (83) *The Whitehouse module in the homology of partition posets.* Preliminary report.
Sheila Sundaram, Wesleyan University (922-05-75)

10:00AM (84) *Posets with flag-symmetry and local actions of the symmetric group.*
Rodica Simion, The George Washington University (922-05-282)

10:30AM (85) *The* **cd***-index and zonotopes.*
Richard Ehrenborg, Cornell University (922-05-72)

Special Session on Optimization and Variational Analysis, II

8:00 AM – 10:50 AM **Room 117, State Hall Building**

Organizers: **Boris S. Mordukhovich**, Wayne State University
Jay S. Treiman, Western Michigan University
Qiji Zhu, Western Michigan University

8:00AM (86) *Lipschitzian stability in optimization.*
Asen L. Dontchev, Northeastern University (922-49-40)

8:30AM (87) *Necessary optimality conditions for optimization problems with variational inequality constraints.*
Jane J. Ye, University of Victoria (922-49-54)

9:00AM (88) *Optimality conditions for dynamic stochastic programs with applications to stochastic scheduling.*
John R. Birge, University of Michigan (922-49-263)

9:30AM (89) *New developments in interval methods for global optimization.*
Ronald Van Iwaarden, Hope College (922-49-52)

10:00AM (90) *Proximal-like regularization of cutting-plane methods.*
Stephen E. Wright, Miami University (922-49-262)

10:30AM (91) *Maximization of linear integral functionals in $H^{\omega}[a,b]$ and perfect ω-splines.*
Sergey Bagdasarov, Ohio State University (922-49-41)

Special Session on VOA's Monstrous Moonshine and Related Topics, II

8:30 AM – 10:50 AM **Room 135, State Hall Building**

Organizers: **Robert L. Griess Jr.**, University of Michigan
Chongying Dong, University of California Santa Cruz

8:30AM (92) *An equivalence of categories of modules for generalized Kac-Moody algebras.*
Elizabeth G. Jurisich, The University of Chicago (922-17-259)

9:00AM (93) *Multibraces on topological vertex operator algebras.* Preliminary report.
Füsun Akman, Utah State University (922-17-126)

9:30AM (94) *Note on free bosonic vertex algebra and its conformal vectors.* Preliminary report.
Kiyokazu Nagatomo* and **Atsushi Matsuo**, Osaka University, Japan (922-17-296)

10:00AM (95) *Vertex Lie algebras, poisson algebras and vertex operator algebras.* Preliminary report.
Chongying Dong, University of California-Santa Cruz, **Haisheng Li***, Institute for Advanced Study, and **Geoffrey Mason**, University of California-Santa Cruz (922-17-249)

10:30AM (96) *Vertex operator algebras in topology.* Preliminary report.
Hirotaka Tamanoi, University of California at Santa Cruz (922-55-270)

Special Session on Representation Theory of Finite Groups and Related Topics, II

9:00 AM – 10:20 AM **Room 129, State Hall Building**

Organizer: **David Howard Gluck**, Wayne State University

9:00AM (97) *Hall polynomials for classical groups.*
Miller Maley, M. S. R. I. (922-20-06)

9:30AM (98) *Faithful representations and homomorphic images of linear groups.* Preliminary report.
Richard E. Phillips and **Julianne G. Rainbolt***, Michigan State University (922-20-116)

10:00AM (99) *On the cohomology of finite Chevalley groups.*
Corneliu Gabriel Hoffman, University of Southern California (922-20-61)

Special Session on Differential Geometry and Its Applications, II

9:00 AM – 10:50 AM **Room 123, State Hall Building**

Organizers: **Daniel S. Drucker**, Wayne State University
Chorng-Shi Houh, Wayne State University

9:00AM (100) *Affine isometric embedding for surfaces.* Preliminary report.
Thomas A. Ivey, Case Western Reserve University (922-53-100)

9:30AM (101) *Curvature of Θ-metrics near the boundary.*
Matthew B. Stenzel, Ohio State University, Newark Campus (922-53-96)

10:00AM (102) *Differential geometry and the red blood cell.*
H. W. Vayo, University of Toledo (922-53-203)

10:30AM (103) *On planar crystalline evolution.*
Alina Stancu, Case Western Reserve University (922-53-114)

Special Session on Algebraic Topology, II

9:00 AM – 10:50 AM **Room 125, State Hall Building**

Organizers: **Robert R. Bruner**, Wayne State University
David Handel, Wayne State University

9:00AM (104) *The stable type of a classifying space of a direct product.* Preliminary report.
John R. Martino*, Western Michigan University, and **Stewart B. Priddy**, Northwestern University (922-55-109)

9:30AM (105) *Homological group actions and splittings iterated products of certain loop-spaces after a single suspension.* Preliminary report.
Ran Levi* and **Stewart B. Priddy**, Northwestern University (922-55-221)

10:00AM (106) *The homology of certain subgroups of Σ_n with coefficients in $\mathcal{L}\rangle\rbrack(\backslash)$.*
Gregory Z. Arone, University of Chicago (922-55-227)

10:30AM (107) *The "Hopf invariant" of the odd primary η_j element.*
Norihiko Minami, The University of Alabama (922-55-228)

Special Session on Groups and Geometries, II

9:00 AM – 10:50 AM **Room 131, State Hall Building**

Organizers: **Daniel E. Frohardt**, Wayne State University
Robert L. Griess Jr., University of Michigan
Kay Magaard, Wayne State University

9:00AM (108) *The 5-modular characters of the Harada-Norton group.* Preliminary report.
Alexander J. Ryba, Marquette University, Milwaukee, Wisconsin 53201-1881 (922-20-290)

9:30AM (109) *On the restriction of $O_n(\mathbf{C})$ modules to A_{n+1}.* Preliminary report.
William J. Husen, Wayne State University (922-20-201)

10:00AM (110) *Permutation modules, dual polar spaces, and Hermitian forms graphs.* Preliminary report.
M. K. Bardoe* and **A. A. Ivanov**, Imperial College of Science, Technology, and Medicine, United Kingdom (922-20-230)

10:30AM (111) *Symplectic groups, symplectic spreads, linear codes and integral lattices.*
Rudolph Scharlau, University of Dortmund, Dortmund, Germany, and **Pham Huu Tiep***, Ohio State University, Columbus (922-20-29)

Special Session on Recent Advances in Noncommutative Ring Theory, II

9:00 AM – 10:50 AM **Room 127, State Hall Building**

Organizers: **Peter Malcolmson**, Wayne State University
Frank Okoh, Wayne State University

9:00AM ▶ (112) *Comments on a conjecture of M. Auslander.* Preliminary report.
Ronald S. Gentle, Eastern Washington University (922-16-65)

9:30AM (113) *Tiled orders and global dimension.*
Charles J. Odenthal, University of Toledo (922-16-69)

10:00AM (114) *Rings associated with holoids.*
H. H. Brungs, University of Alberta, Edmonton, Canada (922-16-79)

10:30AM (115) *Valuation methods in group rings and division rings.*
Alexander Lichtman, University of Wisconsin-Parkside (922-16-210)

Special Session on Stochastic Processes in Finance and Control, II

9:00 AM – 10:50 AM **Room 115, State Hall Building**

Organizers: **Raoul LePage**, Michigan State University
Bert M. Schreiber, Wayne State University

9:00AM (116) *Ergodic boundary control of semilinear stochastic systems.* Preliminary report.
Tyrone E. Duncan*, University of Kansas, Lawrence, **Bohdan Maslowski**, Institute of Mathematics, Czech Academy of Sciences, Prague, Czech Republic, and **Bozenna J. Pasik-Duncan**, University of Kansas, Lawrence (922-60-186)

9:30AM (117) *Optimal policies for capital risk management.*
Thaleia Zariphopoulou-Souganidis*, University of Wisconsin, Madison, and **Helyette E. Geman**, ESSEC and University of Paris, Dauphone, France (922-60-190)

10:00AM (118) *Pricing and hedging of contingent claims in imperfect markets.*
Steven Kou, University of Michigan, Ann Arbor (922-90-134)

10:30AM (119) *Robust hedging strategies.*
Glen H. Swindle*, Cornell University, and **Hyungsok Ahn**, UCSB (922-60-175)

Special Session on C-Algebras, II*

9:00 AM – 10:50 AM **Room 116, State Hall Building**

Organizers: **Jerry Kaminker**, Indiana University-Purdue University at Indianapolis
Claude L. Schochet, Wayne State University

9:00AM (120) *C*-algebras associated with expansive automorphisms of solenoids.*
Berndt A. Brenken, University of Calgary (922-46-217)

9:30AM (121) *Duality for expansive automorphisms.* Preliminary report.
Jack Spielberg*, Arizona State University, **Jerry Kaminker**, IUPUI, and **Ian Putnam**, University of Victoria (922-46-202)

10:00AM ▶ (122) *Harmonic analysis of fractal processes via C*-algebras.*
Palle E.T. Jorgensen, The University of Iowa (922-42-215)

10:30AM (123) *Ergodic quantum maps.* Preliminary report.
Slawomir Klimek, IUPU (922-47-209)

Special Session on Analysis and Geometry, II

9:00 AM – 10:50 AM **Room 113, State Hall Building**

Organizers: **Carlos E. Kenig**, University of Chicago
Tatiana Toro, University of Washington

9:00AM (124) *A geometric proof of the circular maximal theorem.*
Wilhelm Schlag, Institute for Advanced Study (922-42-80)

9:30AM (125) *Some connections between oscillatory integrals and geometric maximal operators.* Preliminary report.
Terence C. Tao, University of California, Los Angeles (922-42-113)

10:00AM (126) *Polynomial bound for Sobolev norms of solutions for Schrodinger equations.*
Gigliola Staffilani, Stanford University (922-35-247)

10:30AM (127) *On bounds of $N(\lambda)$ for a magnetic Schrödinger operator.*
Zhongwei Shen, University of Kentucky (922-35-136)

Invited Address

11:00 AM – 11:50 AM **Auditorium, Upper Deroy Building**

(128) *Geometric hyperplanes of classical geometries of Lie type.*
Ernest E. Shult, Kansas State University (922-00-04)

Invited Address

1:30 PM – 2:20 PM **Auditorium, Upper Deroy Building**

(129) *Harmonic measure of locally flat domains.*
Carlos E. Kenig, University of Chicago (922-35-02)

Special Session on Partial Differential Equations: Theories, Applications and Numerical Approaches, III

3:00 PM – 6:50 PM **Room 114, State Hall Building**

Organizers: **Jennifer Zhao**, University of Michigan-Dearborn
Frank J. Massey III, University of Michigan-Dearborn
Daoqi Yang, Wayne State University

3:00PM (130) *The dispersionless Toda lattice and infinite dimensional Lie algebras.*
Anthony Michael Bloch*, University of Michigan, **Hermann Flaschka**, University of Arizona, and **Tudor S. Ratiu**, University of California, Santa Cruz (922-35-117)

3:30PM (131) *New solutions of the Einstein-Yang/Mills equations.* Preliminary report.
Joe Smoller* and **Arthur Wasserman**, University of Michigan (922-35-120)

4:00PM (132) *Overview of vortex sheet dynamics.*
Robert Krasny, University of Michigan (922-76-111)

4:30PM (133) *Stability of standing waves for nonlinear wave equations.* Preliminary report.
Zhengfang Zhou*, Michigan State University, **Baisheng Yan**, University of Minnesota, and **Xinming Zhao**, Michigan State University (922-35-233)

5:00PM (134) *A continuum of model equations with globally defined flux.*
Anne C. Morlet, Cleveland State University (922-35-197)

5:30PM (135) *On existence and regularity of weak solutions to the displacement boundary value problem in nonlinear elastostatics.*
Salim Haidar, Grand Vallet State University (922-35-170)

6:00PM (136) *Some mathematical issues of ocean/atmosphere dynamics.*
Shouhong Wang, Indiana University (922-35-256)

6:30PM (137) *A nonlinear parabolic equation modelling surfactant diffusion.*
Chen Xinfu, University of Pittsburgh, **Chaocheng Huang***, Wright State University, Dayton, and **Jennifer Zhao**, University of Michigan-Dearborn (922-35-279)

Special Session on Representation Theory of Finite Groups and Related Topics, III

3:00 PM – 5:20 PM **Room 129, State Hall Building**

Organizer: **David Howard Gluck**, Wayne State University

3:00PM (138) *Character degrees and normal subgroups in finite groups.*
I. M. Isaacs*, University of Wisconsin, Madison, and **Greg Knutson**, (deceased) (922-20-101)

3:30PM (139) *New results on the Taketa-problem.*
Thomas Michael Keller, University of Wisconsin, Madison (922-20-25)

4:00PM (140) *Character degrees and local subgroups of pi-separble groups.*
Tom Wolf*, Ohio University, and **Gabriel Navarro**, Universiatat Valencia, Burjasso (922-20-214)

4:30PM (141) *Derived lengths and character degrees.*
Mark L. Lewis, Kent State Univesrity (922-20-21)

5:00PM (142) *Character degrees of finite solvable groups.*
J. P. Zhang, Peking University, Beijing, China (922-20-164)

Special Session on Differential Geometry and Its Applications, III

3:00 PM – 5:50 PM **Room 123, State Hall Building**

Organizers: **Daniel S. Drucker**, Wayne State University
Chorng-Shi Houh, Wayne State University

3:00PM (143) *Low type submanifolds of complex space forms.* Preliminary report.
Ivko M. Dimitric, Penn State University (922-53-106)

3:30PM (144) *Some new obstructions to minimal and Lagrangian immersions.*
Bang-yen Chen, Michigan State University (922-53-13)

4:00PM (145) *Elliptic functions, theta function and hypersurfaces satisfying a basic equality.*
Jie Yang, Michigan State University (922-53-115)

4:30PM (146) *Variational methods in complex contact geometry.*
Brendan J. Foreman, Case Western Reserve University (922-53-58)

5:00PM (147) *Normality on the complex contact metric manifolds.*
Belgin Karaman (922-53-176)

5:30PM (148) *Special directions on contact metric manifolds of negativeξ-sectional curvature.* Preliminary report.
David E. Blair, Michigan State University (922-53-16)

Special Session on Algebraic Topology, III

3:00 PM – 5:20 PM **Room 125, State Hall Building**

Organizers: **Robert R. Bruner**, Wayne State University
David Handel, Wayne State University

3:00PM (149) *Andre-Quillen cohomology of S-algebras.* Preliminary report.
Maria Basterra, University of Chicago (922-55-235)

3:30PM (150) *Homotopy categories of spaces and S-modules.*
Anthony D. Elmendorf, Purdue University, Calumet (922-55-195)

4:00PM (151) *A comparison of various categories of spectra.* Preliminary report.
Brooke Shipley, University of Chicago (922-55-220)

4:30PM (152) *Some homotopical properties of gradient flows.*
Octavian Cornea, Universide de Lille 1, France (922-55-31)

5:00PM (153) *A special case of Ganea's conjecture via essential category weight.*
Jeffrey A. Strom, University of Wisconsin-Madison (922-55-198)

Special Session on Groups and Geometries, III

3:00 PM – 5:20 PM **Room 131, State Hall Building**

Organizers: **Daniel E. Frohardt**, Wayne State University
Robert L. Griess Jr., University of Michigan
Kay Magaard, Wayne State University

3:00PM (154) *Finite projective planes with abelian transitive collineation groups.* Preliminary report.
Chat Yin Ho, University of Florida (922-51-243)

3:30PM (155) *Symmetric dual pairs.*
Ronald M. Solomon, Ohio State University, Columbus (922-20-162)

4:00PM (156) *Recent progress in classifying Alt_5 and $SL(2,5)$ subgroups ofexceptional complex Lie groups up to conjugacy.*
Darrin D. Frey, Winona State University (922-20-269)

4:30PM (157) *Classification of small Frattini Moufang loops.*
Tim Hsu, University of Michigan (922-20-133)

5:00PM (158) *Closed-like normal subgroups of finitary linear groups.*
Richard E. Phillips, Michigan State University (922-20-204)

Special Session on Recent Advances in Noncommutative Ring Theory, III

3:00 PM – 4:50 PM **Room 127, State Hall Building**

Organizers: **Peter Malcolmson**, Wayne State University
Frank Okoh, Wayne State University

3:00PM (159) *Non-standard quantum groups.* Preliminary report.
Timothy J. Hodges, University of Cincinnati (922-17-99)

3:30PM (160) *Quantum ruled surfaces.* Preliminary report.
David Patrick, Massachusetts Institute of Technology (922-16-12)

4:00PM (161) *The noncommutative algebraic geometry of some skew polynomial algebras.*
Irmgard T. Redman, Saginaw Valley State University, University Center, Michigan (922-16-57)

4:30PM (162) *Differential operators commuting with invariant functions.*
T. Levasseur, Universite de Poitiers, France, and **J. T. Stafford***, University of Michigan, Ann Arbor (922-17-62)

Special Session on Stochastic Processes in Finance and Control, III

3:00 PM – 5:40 PM **Room 115, State Hall Building**

Organizers: **Raoul LePage**, Michigan State University
Bert M. Schreiber, Wayne State University

3:00PM (163) *A limit theorem for stochastic processes which has applications to some problems of financial mathematics.*
Anatoli V. Skorokhod, Michigan State University (922-60-192)

3:50PM (164) *Prediction of stock prices through Onsager-Machlup function of generalized geometric Brownian motion.* Preliminary report.
Yaozhong Hu, University of California at Irvine (922-60-188)

4:20PM (165) *Reflected forward-backward SDE's and obstacle problems with boundary conditions.*
Jin Ma*, Purdue University, West Lafayette, and **Jaksa Cvitanic**, Columbia University (922-60-42)

4:50PM (166) *A deterministic approach to fractional Brownian motion.* Preliminary report.
Donna Mary Salopek, The Fields Institute (922-60-124)

5:20PM (167) *Recent results on risk sensitive portfolio selection and factor modeling of returns.*
Tomasz R. Bielecki*, Northeastern Illinois University, and **Stanley R. Pliska**, University of Illinois at Chicago (922-93-135)

Special Session on C-Algebras, III*

3:00 PM – 5:50 PM **Room 116, State Hall Building**

Organizers: **Jerry Kaminker**, Indiana University-Purdue University at Indianapolis
Claude L. Schochet, Wayne State University

3:00PM (168) *The groupoid analytic index as a KK-element.* Preliminary report.
Alan L.T. Paterson*, and **Jerry Kaminker**, IUPUI (922-46-24)

3:30PM (169) *Toeplitz algebras associated to isometric flows.*
Efton Park, Texas Christian University (922-58-43)

4:00PM (170) *Kasparov theory for Riemannian foliations.* Preliminary report.
James F. Glazebrook*, Eastern Illinois University and University of Illinois, **James L. Heitsch**, **Steven E. Hurder** and **Franz W. Kamber**, University of Illinois (922-58-14)

4:30PM (171) *Cyclic homology and crossed product C^*-algebras.*
Ronghui Ji, Indiana University-Purdue University (922-46-122)

5:00PM ▶ (172) *A_∞-structures in cyclic homology.* Preliminary report.
Masoud Khalkhali, University of Western Ontario (922-18-27)

5:30PM (173) *K-theory of compact quantum simple Lie groups.*
Gabriel Nagy, Kansas State University (922-47-205)

Special Session on VOA's Monstrous Moonshine and Related Topics, III

3:00 PM – 5:50 PM **Room 135, State Hall Building**

Organizers: **Robert L. Griess Jr.**, University of Michigan
Chongying Dong, University of California Santa Cruz

3:00PM (174) *Twisted modules for a Virasoro VOA: A preliminary report.* Preliminary report.
Julie S. Glass, California State University at Hayward (922-17-132)

3:30PM (175) *On $\mathcal{W}_{1+\infty}$ with a negative central charge.* Preliminary report.
Weiqiang Wang, Yale University, Gibbs Instructor (922-17-56)

4:00PM (176) *Axiomatic study of intertwining operator algebras.* Preliminary report.
Yi-Zhi Huang, Rutgers University (922-17-92)

4:30PM (177) *Famlies of representations of the Virasoro and $N = 1$ and $N = 2$Neveu-Schwarz algebras in terms of superderivations and implications.* Preliminary report.
Katrina Deane Barron, University of California, Santa Cruz (922-17-93)

5:00PM (178) *q-Vertex operators of twisted quantum affine algebras.*
Naihuan Jing, North Carolina State University (922-17-71)

5:30PM (179) *Bosonic realizations of $U_q(C_n^{(1)})$.*
Kailash C. Misra, North Carolina State University (922-17-77)

Special Session on Analysis and Geometry, III

3:00 PM – 4:50 PM **Room 113, State Hall Building**

Organizers: **Carlos E. Kenig**, University of Chicago
Tatiana Toro, University of Washington

3:00PM (180) *The Monge-Kantorovich problem and its applications to PDEs.*
Wilfrid D. Gangbo, Georgia Institute of Technology (922-42-157)

3:30PM (181) *Convex viscosity solutions of nonlocal geometric motion.*
Mikhail Feldman, University of California, Berkeley (922-35-84)

4:00PM (182) *Bilinear operators with nonsmooth symbols.* Preliminary report.
Andrea R. Nahmod, The University of Texas at Austin (922-42-267)

4:30PM (183) *Area integral estimates and nonsymmetric systems.* Preliminary report.
Gregory C. Verchota and **Andrew L. Vogel***, Syracuse University (922-35-222)

Special Session on Algebraic Combinatorics, III

3:00 PM – 5:50 PM **Room 137, State Hall Building**

Organizer: **Devadatta M. Kulkarni**, Oakland University

3:00PM (184) *Posets with a natural local action of the symmetric group on chains.*
David J. Grabiner, Mathematical Sciences Research Institute (922-05-226)

3:30PM (185) *Quotients of Coxeter groups under the weak order.* Preliminary report.
Debra J. Waugh, University of Michigan, Ann Arbor (922-05-23)

4:00PM (186) *Multiplying Schubert polynomials and chains in the Bruhat order.*
Frank Sottile, MSRI and the University of Toronto (922-05-208)

4:30PM ▸ (187) *Ladder determinantal ideals: A survey.* Preliminary report.
Devadatta M. Kulkarni, Oakland University (922-05-245)

5:00PM (188) *Enumerative aspects of Kazhdan-Lusztig polynomials.* Preliminary report.
Francesco Brenti*, MSRI and Univ. of Perugia, and **Rodica Simion**, MSRI and George Washington University (922-05-273)

5:30PM (189) *Standard monomial theory for Bott-Samelson varieties.*
Venkatramani Lakshmibai and **Peter M. Magyar***, Northeastern University (922-14-272)

Special Session on Optimization and Variational Analysis, III

3:00 PM – 5:20 PM **Room 117, State Hall Building**

Organizers: **Boris S. Mordukhovich**, Wayne State University
Jay S. Treiman, Western Michigan University
Qiji Zhu, Western Michigan University

3:00PM (190) *Conflicting and delayed controls as components of a joint control.*
Jack Warga, Northeastern University (922-49-38)

3:30PM (191) *Optimum problems with lower semicontinuous set-valued constraints.*
Vera Zeidan, Northeastern University (922-49-39)

4:00PM (192) *Semicontinuous and continuous blowup and minimal time functions.*
Wenxiong Liu, Loyola University (922-49-67)

4:30PM (193) *Discrete approximations and necessary optimality conditions for nonconvex differential inclusions with delay.*
Ruth Trubnik, Morris Brown Colllege (922-49-173)

5:00PM (194) *Optimality conditions for minimax control of state-constrained parabolic systems with uncertain disturbances and Dirichlet boundary controllers.*
Kaixia Zhang, Wayne State University (922-49-142)

Special Session on Wavelets and Applications, II

3:00 PM – 5:20 PM **Room 111, State Hall Building**

Organizers: **Gregory F. Bachelis**, Wayne State University
Grant Gerhart, Tardec, Tacom, Army
Tze-Chien Sun, Wayne State University

3:00PM (195) *MRA methods for homogenization of differential equations.*
A. C. Gilbert, Princeton University (922-42-103)

3:30PM (196) *A fast wavelet algorithm for computing Sturm-Liouville transforms.*
Michael Frazier, Michigan State University (922-42-59)

4:00PM (197) *Wavelet methods for estimating the intensity profiles of astronomical gamma-ray bursts.*
Eric D. Kolaczyk, University of Chicago (922-62-123)

4:30PM ▸ (198) *An adaptive wavelet based contrast enhancement method (AWCEM) for signature reduction applications.*
Sridhar Srinivasan*, LNK Corporation, Inc., **Rob Karlsen**, TARDEC, US Army TACOM, **Srini Raghavan**, Hughes STX, **Laveen Kanal**, LNK Corporation, Inc., and **Grant Gerhart**, TARDEC, USArmy TACOM (922-68-260)

5:00PM (199) *A wavelet representation of fractional Brownian motions.* Preliminary report.
T. C. Sun, Wayne State University (922-60-286)

Contributed Paper Session

3:00 PM – 4:10 PM **Room 112, State Hall Building**

3:00PM (200) *Countable partitions of reals into nonmeasurable subsets.*
Alexander Abian, Iowa State University (922-28-105)

3:15PM (201) *Search for a (120,35,10) difference set.* Preliminary report.
Paul E. Becker, Saginaw Valley State University (922-05-88)

3:30PM ▸ (202) *On the generalized thermodynamics of mime-matter interactions.* Preliminary report.
Dennis G. Collins (922-90-248)

3:45PM (203) *Ky Fan's best approximation theorems and applications.*
S. P. Singh, Memorial University of Newfoundland (922-47-78)

4:00PM (204) *Sampling theorem for solutions of the Dirichlet problem for the Schrödinger operator.* Preliminary report.
Alexander Kheyfits, Queensborough Community College/CUNY (922-42-11)

Sunday, May 4

Registration

8:00 AM – 11:00 AM **Lobby Area, State Hall Building**

AMS Exhibit and Book Sale

8:00 AM – 11:00 AM **Lobby Area, State Hall Building**

Invited Address

9:30 AM – 10:20 AM **Auditorium, Upper Deroy Building**

(205) *Singular integrals and multivariate stochastic processes: New problems and methods.*
Alexander L. Volberg, Michigan State University (922-42-03)

Special Session on Partial Differential Equations: Theories, Applications and Numerical Approaches, IV

10:30 AM – 1:20 PM **Room 114, State Hall Building**

Organizers: **Jennifer Zhao**, University of Michigan-Dearborn
Frank J. Massey III, University of Michigan-Dearborn
Daoqi Yang, Wayne State University

10:30AM (206) *A parallel algorithm for solving the implicit diffusion difference equations.*
Lei Li*, **Tadao Nakamura**, Aomori University, Aomori 030, Japan, and **Baolin Zhang**, Comput. Math., Beijing (922-35-196)

11:00AM (207) *Another fast algorithm for the heat conduction problems.*
R. C. Y. Chin, Purdue University at Indianaplis, and **S. Shao***, Cleveland State University (922-35-168)

11:30AM (208) *The role of charge separation in the response of electrochemical systems.*
Daniel R. Baker* and **Mark W. Verbrugge**, General Motors Research and Development Center (922-35-09)

NOON (209) *Analysis and computation of a cyclic plasticity model.*
Peter Shi, Oakland University, Rochester, Michigan (922-35-166)

12:30PM (210) *A new scheme for the incompressible Navier-Stokes equations employing alternating-direction operator splitting and domain decomposition.* Preliminary report.
John T. Spyropoulos, Purdue University, West Lafayette, Indiana (922-76-257)

1:00PM (211) *Dynamics of two coupled beams.*
Meir Shillor, **Xiulin Zou***, Oakland University, and **Noel Friedrick**, General Motors Corporation, Pontiac, Michigan 48309 (922-35-191)

Special Session on Differential Geometry and Its Applications, IV

10:30 AM – 12:20 PM **Room 123, State Hall Building**

Organizers: **Daniel S. Drucker**, Wayne State University
Chorng-Shi Houh, Wayne State University

10:30AM (212) *Lightlike hypersurfaces of Lorentz framed manifolds.*
Krishan L. Duggal, University of Windsor (922-53-63)

11:00AM (213) *Some basic facts about Lorentz surfaces.* Preliminary report.
Naomi L. Klarreich, Case Western Reserve University (922-53-199)

11:30AM (214) *Causality conditions on simply connected Lorentz surfaces.* Preliminary report.
Luke A. Higgins, Rutgers University (922-53-177)

NOON (215) *Symplectic connections and quasars.* Preliminary report.
Ivan C. Sterling* and **Geoffrey Martin**, University of Toledo (922-53-73)

Special Session on Algebraic Topology, IV

10:30 AM – 12:50 PM **Room 125, State Hall Building**

Organizers: **Robert R. Bruner**, Wayne State University
David Handel, Wayne State University

10:30AM (216) *Classical homotopy techniques and telescopes.*
Paul L. Shick, John Carroll University (922-55-213)

11:00AM (217) *Connective K-theory and the Chern character.* Preliminary report.
Jay A. Wood, Purdue University Calumet (922-55-18)

11:30AM (218) *Hit polynomials and conjugation in the dual Steenrod algebra.*
Judith H. Silverman, Indiana University–Purdue University at Columbus (922-55-224)

NOON (219) *Identification of infinite loop spaces arising from group theory.*
Kathryn Lesh, University of Toledo (922-55-238)

12:30PM (220) *A simplicial model category structure for the category of small categories CAT.* Preliminary report.
Wojciech Chacholski*, The Fields Institute, and **Jerome Scherer**, ETH, Zurich (922-55-237)

Special Session on Analysis and Geometry, IV

10:30 AM – 12:20 PM **Room 113, State Hall Building**

Organizers: **Carlos E. Kenig**, University of Chicago
Tatiana Toro, University of Washington

10:30AM (221) *Local Schauder estimate and its applications.* Preliminary report.
Qing Han, University of Notre Dame (922-35-160)

11:00AM (222) C^∞ *regularity of the free boundary of the porous medium equation.*
Panagiota Daskalopoulos, University of California, Irvine (922-35-275)

11:30AM (223) *Boundary regularity for free boundary problems with two phases.* Preliminary report.
Alex Gurevich, The University of Chicago (922-35-154)

NOON (224) *Parabolic PDE's in time-varying domains, or with time varying coefficients.*
Steve Hofmann*, University of Missouri, and **John L. Lewis**, University of Kentucky (922-42-156)

Special Session on Algebraic Combinatorics, IV

10:30 AM – 1:30 PM **Room 137, State Hall Building**

Organizer: **Devadatta M. Kulkarni**, Oakland University

10:30AM (225) *No feedback card guessing for dovetail shuffles.*
Mihai A. Ciucu, MSRI, Berkeley (922-05-138)

11:00AM ▶ (226) *A "Fourier transform" for multiplicative functions on non-crossing partitions.*
Alexandru M. Nica*, University of Michigan, Ann Arbor, and **Roland Speicher**, University of Heidelberg, Germany (922-05-33)

11:30AM (227) *Multivariable Lagrange inversion, Gessel-Viennot cancellation and the matrix tree theorem.*
Ian P. Goulden*, University of Waterloo, and **Datta M. Kulkarni**, Oakland University (922-05-241)

NOON (228) *Minimal transitive factorisations into pure cycles.* Preliminary report.
David M. Jackson, University of Waterloo (922-05-278)

12:30PM Problem Session

Special Session on Representation Theory of Finite Groups and Related Topics, IV

11:00 AM – 12:20 PM **Room 129, State Hall Building**

Organizer: **David Howard Gluck**, Wayne State University

11:00AM (229) *Calculating some Schur indices.* Preliminary report.
Alexandre Turull, University of Florida (922-20-64)

11:30AM (230) *Feit's conjecture on* p*-Steinberg characters.*
Pham Huu Tiep, Ohio State University, Columbus, OH 43210 (922-20-28)

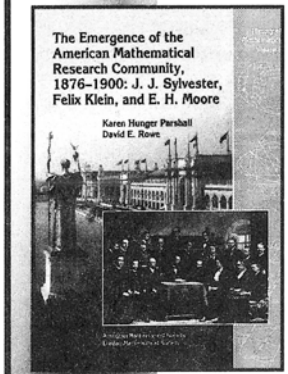
NOON (231) *The Mclaughlin finite simple group* Mc *and Dade's conjecture.*
John C. Murray, University of Illinois at Urbana-Champaign (922-20-85)

American Mathematical Society

ON SALE!

The Emergence of the American Mathematical Research Community, 1876–1900: J. J. Sylvester, Felix Klein, and E. H. Moore

Karen Hunger Parshall, *University of Virginia, Charlottesville,* and **David E. Rowe,** *University of Mainz, Germany*



... fine and extensive account of the growth of mathematics in the United States ... completed by a fine bibliography and index ... Professional research-level mathematics ... came late to the United States; however, once inaugurated ... it rose more like a liftoff than a takeoff. This book admirably records the countdown and launch.

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In an excellent way this book gives an incredible amount of details never losing sight of the whole. Thirteen tables and a subject index make information easy.... many photos, some of them being published for the first time.... a sound and high quality investigation.

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Special Session on C-Algebras, IV*

11:00 AM – 12:20 PM **Room 116, State Hall Building**

Organizers: **Jerry Kaminker**, Indiana University-Purdue University at Indianapolis
Claude L. Schochet, Wayne State University

11:00AM (232) *On the stable rank of simple C*-algebras.* Preliminary report.
Jesper Villadsen, The Fields Institute (922-47-266)

11:30AM (233) *Index map on compact contact manifolds.* Preliminary report.
Pradeep Alwis, The Fields Institute (922-46-206)

NOON (234) *K-Theory with R/Z coefficients and von Neumann algebras.*
Devraj Basu, Indiana University, Bloomington (922-46-163)

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Meetings and Conferences of the AMS

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The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Up-to-date meeting and conference information is available on the World Wide Web via the Internet at URL `http://www.ams.org/`.

Meetings:

1997

May 2–4	Detroit, Michigan	p. 626
June 26–28	Republic of South Africa	p. 627
September 26–28	Montreal, Canada	p. 628
October 4	Claremont, California	p. 629
**October 17-19	Atlanta, Georgia **New Dates	p. 629
October 24–26	Milwaukee, Wisconsin	p. 629
November 8-9	Albuquerque, New Mexico	p. 630
December 4–7	Oaxaca, Mexico	p. 630

1998

January 7-10	Baltimore, Maryland Annual Meeting	p. 631
March 20–21	Louisville, Kentucky	p. 631
March 27–28	Manhattan, Kansas	p. 632
April 4–5	Philadelphia, Pennsylvania	p. 632
April 25–26	Davis, California	p. 632
September 12–13	Chicago, Illinois	p. 633
November 14–15	Tucson, Arizona	p. 633

1999

January 13-16	San Antonio, Texas Annual Meeting	p. 633
April 10–11	Las Vegas, Nevada	p. 633
April 24–25	Buffalo, New York	p. 633

2000

January 19–22	Washington, DC Annual Meeting	p. 634

2001

January 10-13	New Orleans, LA Annual Meeting	p. 634

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 183 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.

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Conferences:

See `http://www.ams.org/meetings/` for the most up-to-date information on these conferences.

1997:

June 22–July 31: AMS-IMS-SIAM Joint Summer Research Conferences in the Mathematical Sciences, University of Washington, Seattle. See November 1996, p. 1448, for details.

June 29–July 19: Summer Research Institute, *Differential Geometry and Control*, University of Colorado at Boulder. See October 1996, p. 1304, for details.

1998:

January 11-16 : AMS-SIAM Summer Seminar in Applied Mathematics, *Neuroengineering and Dynamical Systems in the Neurosciences*, Arizona State University. See April 1997, p. 534, for details.


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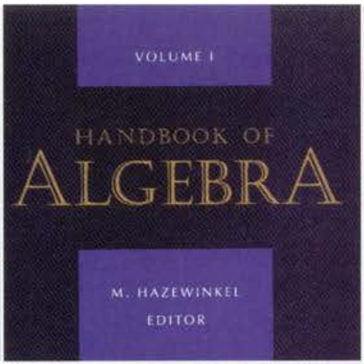
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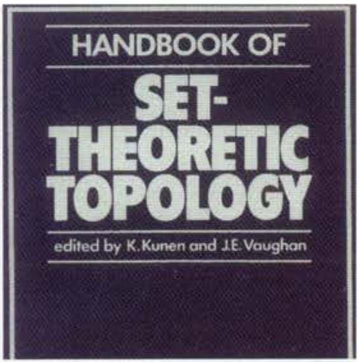
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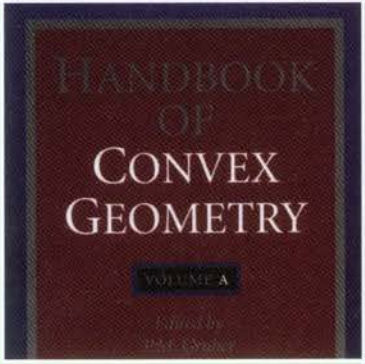
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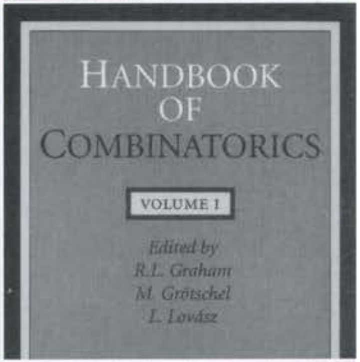
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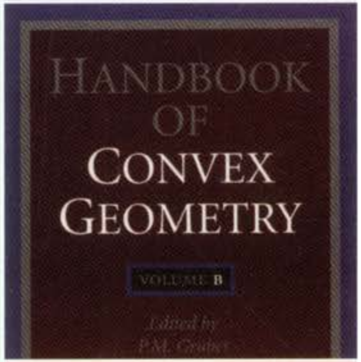
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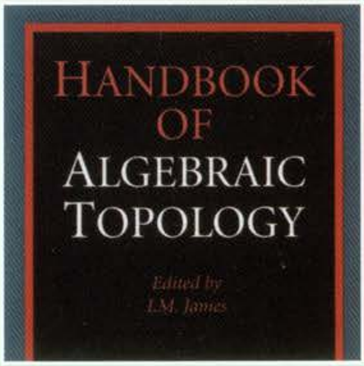
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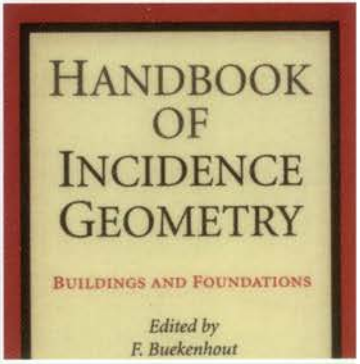
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