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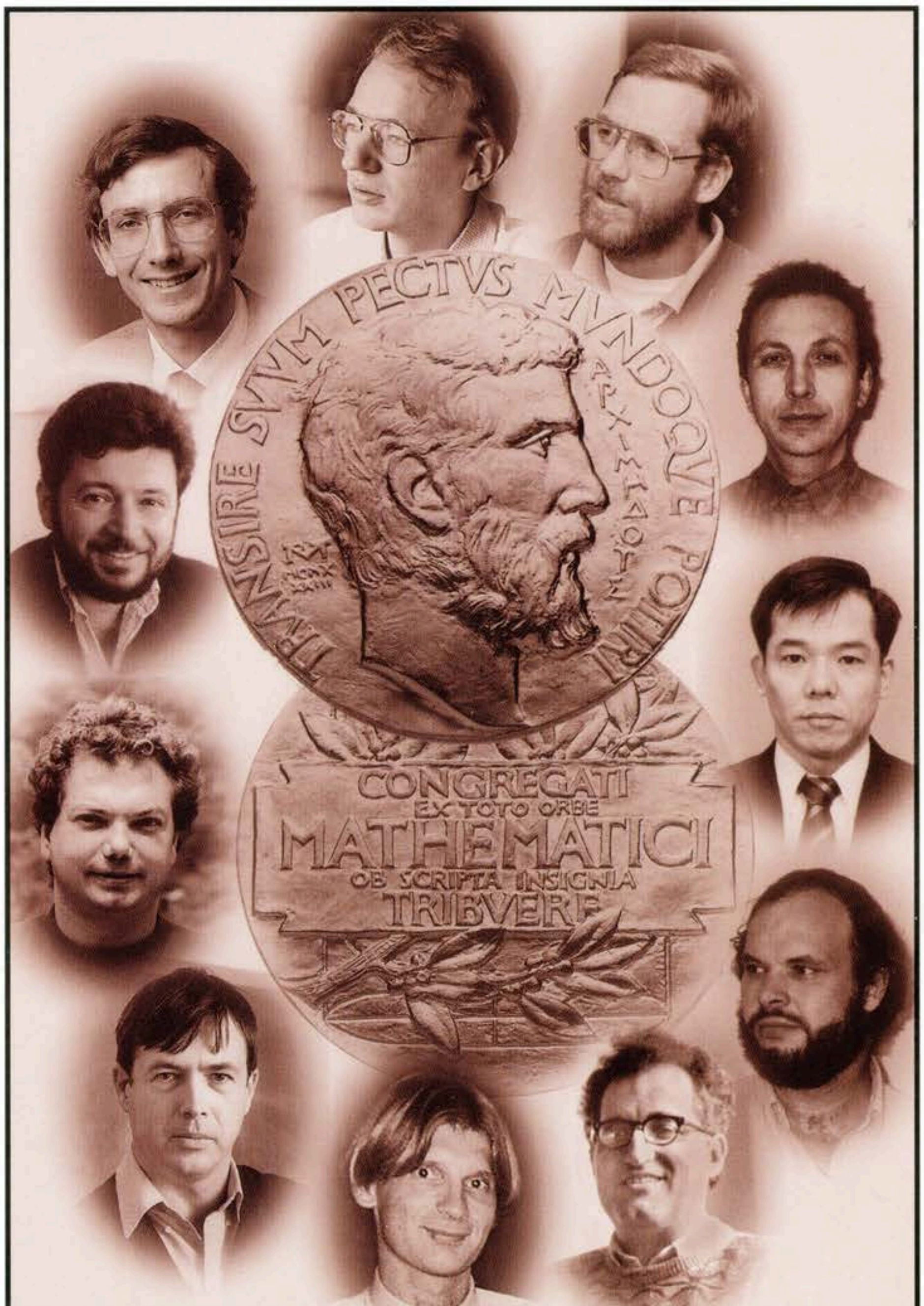
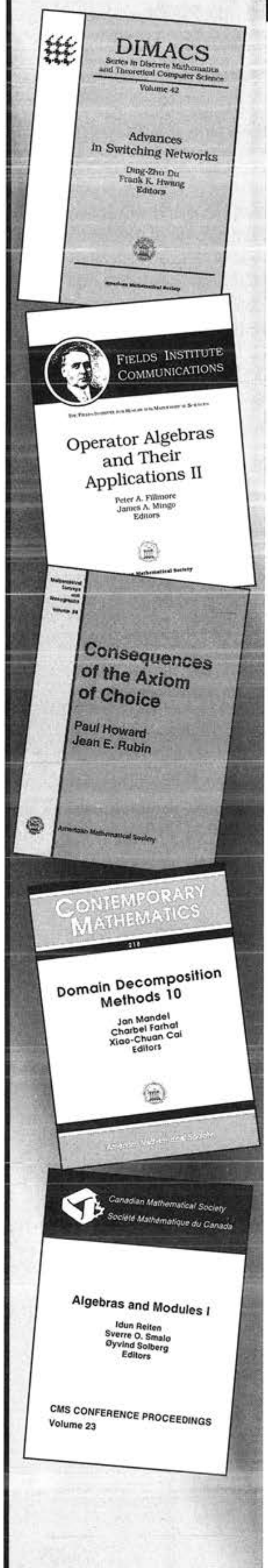


Fields Medalists, 1986, 1990, 1994 (See page 890)



AMERICAN MATHEMATICAL SOCIETY

New Titles from the AMS

Advances in Switching Networks

Ding-Zhu Du, *University of Minnesota, Minneapolis*, and **Frank K. Hwang**, *National Chiao Tung University, Hsinchu, Taiwan*, Editors

The articles collected in this book were presented at the DIMACS Workshop on Network Switching, held in July 1997 at Princeton University.

DIMACS: Series in Discrete Mathematics and Theoretical Computer Science, Volume 42; 1998; 333 pages; Hardcover; ISBN 0-8218-0831-1; List $70; Individual member $42; Order code DIMACS/42NT88

Operator Algebras and Their Applications II

Peter A. Fillmore, *Dalhousie University, Halifax, NS, Canada*, and **James A. Mingo**, *Queens University, Kingston, ON, Canada*, Editors

This volume is the second selection of papers that arose from the seminars and workshops of a year-long program, Operator Algebras and Applications, that took place at The Fields Institute. Topics covered include the classification of amenable C*-algebras, lifting theorems for completely positive maps, and automorphisms of von Neumann algebras of type III.

Fields Institute Communications, Volume 20; 1998; 170 pages; Hardcover; ISBN 0-8218-0908-3; List $46; Individual member $28; Order code FIC/20NT88

Consequences of the Axiom of Choice

Paul Howard, *Eastern Michigan University, Ypsilanti*, and **Jean E. Rubin**, *Purdue University, West Lafayette, IN*

This book is a comprehensive listing of statements that have been proved in the last 100 years using the axiom of choice.

Mathematical Surveys and Monographs, Volume 59; 1998; 432 pages; Hardcover; ISBN 0-8218-0977-6; List $89; Individual member $53; Order code SURV/59NT88

Domain Decomposition Methods 10

Jan Mandel, *University of Colorado, Denver*, and **Charbel Farhat** and **Xiao-Chuan Cai**, *University of Colorado, Boulder*, Editors

This volume contains the proceedings of the Tenth International Conference on Domain Decomposition Methods, which focused on the latest developments in realistic applications in structural mechanics, structural dynamics, computational fluid dynamics, and heat transfer.

The electronic version is available at no additional charge to purchasers of the print volume. Access instructions are provided in the book. There is also the option to purchase only the electronic version.

Contemporary Mathematics, Volume 218; 1998; 554 pages; Softcover; ISBN 0-8218-0988-1; *Print and electronic:* List $110; Individual member $66; Order code CONM/218NT88
ISBN 0-8218-1177-0, *Electronic only:* List $99; Individual member $59; Order code CONM/218.ENT88

Quasicrystals and Discrete Geometry

Jiří Patera, *Centre de Recherches Mathématiques, Université de Montréal, PQ, Canada*, Editor

The common topic of the eleven articles in this volume is ordered aperiodic systems realized either as point sets with the Delone property or as tilings of a Euclidean space. The volume brings together contributions by leading specialists. Important advances in understanding the foundations of this new field are presented.

Fields Institute Monographs, Volume 10; 1998; 289 pages; Hardcover; ISBN 0-8218-0682-3; List $79; Individual member $47; Order code FIM/10NT88

Algebras and Modules I

Idun Reiten, **Sverre O. Smalø**, and **Øyvind Solberg**, *Norwegian University of Science and Technology, Trondheim*, Editors

The invited contributions to this volume are based on lectures given by leading researchers in the field at the Workshop on Representations of Algebras and Related Topics, Trondheim, Norway, in 1996.

A general background in noncommutative algebra including rings, modules and homological algebra is required. Given that, parts of this volume would be suitable as a textbook for an advanced graduate course in algebra.

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

Conference Proceedings, Canadian Mathematical Society, Volume 23; 1998; 198 pages; Softcover; ISBN 0-8218-0850-8; List $39; Individual member $23; Order code CMSAMS/23NT88

Algebras and Modules II

Idun Reiten, **Sverre O. Smalø**, and **Øyvind Solberg**, *Norwegian University of Science and Technology, Trondheim*, Editors

This volume contains 43 research papers based on results presented at the Eighth International Conference on Representations of Algebras (ICRA VIII) held in Geiranger, Norway, in 1996. The papers, written by experts in the field, cover the most recent developments in the representation theory of artin algebras and related topics.

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

Conference Proceedings, Canadian Mathematical Society, Volume 24; 1998; 569 pages; Softcover; ISBN 0-8218-1076-6; List $99; Individual member $59; Order code CMSAMS/24NT88

Selected Works of Maurice Auslander

Idun Reiten, **Sverre O. Smalø**, and **Øyvind Solberg**, *Norwegian University of Science and Technology, Trondheim*, Editors

This book features a broad selection of the core of Auslander's work, including commutative algebra, singularity theory, the theory of orders, and the representation theory of artin algebras.

This book is of interest for the historical development of algebra over a 40-year period and for the use of homological methods in algebra.

Collected Works, Volume 10; 1998; ***Part 1***: 895 pages; Hardcover; ISBN 0-8218-0998-9; List $165; Individual member $99; Order code CWORKS/10.1NT88; ***Part 2***: 743 pages; Hardcover; ISBN 0-8218-1000-6; List $155; Individual member $93; Order code CWORKS/10.2NT88; ***Set***: 1638 pages; Hardcover; ISBN 0-8218-0679-3; List $299; Individual member $179; Order code CWORKS/10NT88

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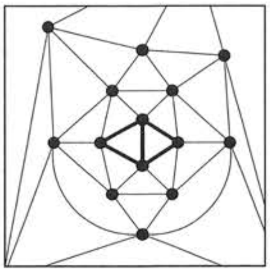

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Editorial

Opinion in the *Notices*

Starting with the February issue this year, opinion columns by associate editors, which formerly had occupied the *Notices* editorial column, began to appear on the op-ed page under a heading "In My Opinion" or "In Our Opinion". Though mathematicians can largely agree on what is a proof, much is controversial about the field: what the proper balance is between research and education, whether some areas are more important than others, at what stage the Four-Color Theorem is truly proved, to what extent calculus needs reform, whether the universities of one country should give preference in mathematics employment to the residents of that country.

The associate editors are often in a position to know some of the current issues of interest to large groups of *Notices* readers. These editors may or may not have the answers we all seek, but their writing about these issues from particular points of view has been a way of sparking discussion.

This month the *Notices* is expanding this activity by opening the op-ed page to submissions from all its readers. The first column of this kind is by Greg Kuperberg, David Morrison, and Richard Palais. As is the case with the associate editors, these people are expressing their own opinions, not necessarily those of the AMS. They make reference to a column by Steven Krantz in the September 1997 issue, and that too was a column expressing the opinion of the author and not necessarily of the AMS.

Columns of this new kind will appear under the heading "Another Opinion". According to the current plan, there will be at most one per issue, and it will occupy the full op-ed page.

The *Notices* invites submissions of "Another Opinion", which may be sent to the usual address listed in the masthead. Electronic submissions are preferred. The intention is that such a column start discussion of a mathematics-related issue that ought to be of current interest to many mathematicians. Standards may be expected to be high. Not only must the writing be of high quality, but also the topic must be an important one appropriate for much of the AMS membership. The word limit is fairly strict—800 to 850 words. Footnotes and sidebars are permitted, but not a bibliography.

In the case of columns about large educational issues, let us heed Secretary of Education Riley's call for an "end to shortsighted, politicized, and harmful bickering over the teaching and learning of mathematics." Toward this goal, columns about large educational issues are expected to meet certain conditions: (1) Sarcasm and hyperbole have no place in this kind of writing. (2) The context of the column must be made clear to the reader, indicating the writer's affiliations and possible conflicts of interest and also revealing, more broadly, where the writer is coming from. (3) Educational jargon must be used only in acceptable ways that are understandable to the reader.

Similar principles apply to other controversial topics.

With this change the *Notices* hopes to broaden the scope of significant issues that are brought to the attention of the readers. Associate editors will continue to have occasional "In My Opinion" columns, and all of us should gain by the addition.

—Anthony W. Knapp

In This Issue

Return of the "Forum"

The "Forum" returns this month to the *Notices* after an absence of several months. Mikhael Gromov gives his view of "Possible Trends in Mathematics in the Coming Decades". This writing is adapted from an appendix to an assessment report by the National Science Foundation on U.S. mathematics, and Allyn Jackson writes about the full report elsewhere in this issue.

—A. W. K.

Commentary

Another Opinion

Mathematics Journals Should Be Electronic and Free(ly Accessible)

Except for one word, that was the title of Steven Krantz's editorial column in the September 1997 *Notices*. Krantz's column began: "Of course *I* don't believe what the title says. But I got your attention." He then lists problems he sees with free electronic journals. Three of these objections deserve a response by those of us who *do* agree with the title. The three objections are: (1) electronic media are perishable, (2) electronic formats change frequently, and (3) electronic journals still have major costs.

Below is a description of an important new initiative—the LANL Mathematics E-print Archive—for the storage and distribution of electronic research articles. We expect that over the next several years it will become the home of a substantial fraction of the entire primary mathematical literature.

Numerous benefits will accrue from having a carefully managed, uniform database of nearly the entire mathematical literature. Here we comment only on how it can help provide solutions to the above three problems.

1) The LANL e-print archive is mirrored in sixteen countries. No credible catastrophe could simultaneously destroy all these independent repositories.

2) Only rarely used or poorly maintained databases are at risk when electronic formats change. Large, widely used databases, such as the LANL archive, can be and have been translated to new formats with mininal cost and effort.

3) Using a model referred to as an "overlay" journal, the LANL e-print archive will enable publishers to produce electronic journals at minimum cost and with minimum fees. An overlay journal evaluates papers in the time-honored manner, but authors submit papers by first contributing them to the LANL math archive and then providing the paper's ID number to the journal. Accepted papers constitute the journal; they are available from the journal's Web site, but they continue to be directly accessible from the LANL archive.

Other electronic journals will choose to go beyond this bare-bones approach, adding value in various ways (for example, by copyediting authors' manuscripts). This will incur added expense, but by avoiding the costs of printing, binding, and mailing, these electronic journals too will be considerably less expensive to produce than traditional paper journals.

The cost savings of "going electronic" can contribute substantially to the most essential goal of publication: keeping the entire mathematical primary literature freely available to scholars everywhere. And insofar as we mathematicians leave our papers on the LANL e-print archive, no one will be prevented from accessing them.

—Greg Kuperberg, David Morrison, and Richard Palais
(for the LANL Mathematics E-print Archive Steering Committee)

The LANL Mathematics E-print Archive

A new service has been established that could have significant consequences for research in mathematics and for the mathematical community—the LANL Mathematics E-print Archive. The Steering Committee* invites you to explore this archive on the Web, at either the UC Davis front end (http://front.math.ucdavis.edu/) or directly at Los Alamos (http://xxx.lanl.gov/).

The LANL physics archive has more than 70,000 e-prints, accruing at a rate of over 20,000 per year. Maintained by a full-time staff and funded by the DOE and the NSF, it offers many technical conveniences, including an automatic TeX compilation system with next-day distribution, e-mail notification, search facilities, and a network of mirror sites in sixteen countries. The mathematics archive was formed at the beginning of 1998 from various subject-based e-print archives on the Internet; although new, it already has over 5,000 e-prints and is increasing by over 150 each month. The Steering Committee is a group of mathematicians formed to direct this expansion in coordination with the LANL archive staff at Los Alamos.

Fundamental changes in scholarly communication in mathematics are on the horizon, and we believe that mathematicians need to intervene now to ensure that the system that emerges meets our needs. Historically, the mathematical literature has been maintained by an array of publishers, and universal indexing (provided by *Math Reviews* and *Zentralblatt*) has only come afterwards. With the Internet it is possible, and in our view important and desirable, for the mathematical community to establish a free, universal, primary database of e-prints that will allow rapid access to the literature from anywhere in the world.

We invite each of you to submit at least one research article in mathematics to LANL to learn the system. (Instructions are available at http://front.math.ucdavis.edu/submissions.html or at http://xxx.lanl.gov/help/submit/.) Anything you contribute will give your work immediate and significant visibility, since thousands of mathematicians regularly browse the archive. More importantly, your presence will encourage your closest colleagues to contribute also; it will help establish the use of LANL e-prints in your research areas.

*The Steering Committee for the LANL Mathematics E-print Archive is composed of Gilbert Baumslag, Robert Bryant, Bill Casselman, Joe Christy, Paul Ginsparg (ex officio), Greg Kuperberg, Robert Lazarsfeld, Elliott Lieb, Dave Morrison (committee chair), Andy Odlyzko, Dick Palais, Jim Stasheff, Mark Steinberger, and Bill Thurston.

Forum

Possible Trends in Mathematics in the Coming Decades

Mikhael Gromov

Here are a few brief remarks on possible trends in mathematics for the coming decades.

1. Classical mathematics is a quest for structural harmony. It began with the realization by ancient Greek geometers that our 3-dimensional continuum possessed a remarkable (rotational and translational) symmetry (groups $O(3)$ and $\mathbb{R}^3$) which permeates the essential properties of the physical world. (We stay intellectually blind to this symmetry no matter how often we encounter and use it in everyday life while generating or experiencing mechanical motion, e.g., walking. This is partly due to noncommutability of $O(3)$, which is hard to grasp.) Then deeper (noncommutative) symmetries were discovered: Lorentz and Poincaré in relativity, gauge groups for elementary particles, Galois symmetry in the algebraic geometry and number theory, etc. And similar mathematics appears once again on a less fundamental level, e.g., in crystals and quasicrystals, in self-similarity for fractals, dynamical systems and statistical mechanics, in monodromies for differential equations, etc.

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Article adapted from Appendix 3 of the "Report of the Senior Assessment Panel of the International Assessment of the U.S. Mathematical Sciences", National Science Foundation, March 1998.

The search for symmetries and regularities in the structure of the world will stay at the core of the pure mathematics (and physics). Occasionally (and often unexpectedly) some symmetric patterns discovered by mathematicians will have practical as well as theoretical applications. We saw this happening many times in the past; for example, integral geometry lies at the base of the x-ray tomography (CAT scan), the arithmetic over prime numbers leads to generation of perfect codes, and infinite-dimensional representations of groups suggests a design of large economically efficient networks of a high connectivity.

2. As the body of mathematics grew, it became itself subject to a logical and mathematical analysis. This has led to the creation of mathematical logic and then of the theoretical computer science. The latter is now coming of age. It absorbs ideas from the classical mathematics and benefits from the technological progress in the computer hardware which leads to a practical implementation of theoretically devised algorithms. (Fast Fourier transform and fast multipole algorithm are striking examples of the impact of pure mathematics on numerical methods used every day by engineers.) And the logical computational ideas interact with other fields, such as the quantum computer project, DNA-based molecular design, pattern formation in biology, the dynamics of the brain, etc. One expects that in several decades computer science will develop ideas on even deeper mathematical levels which will be followed by radical progress in the industrial application of computers, e.g., a (long overdue) breakthrough in artificial intelligence and robotics.

3. There is a wide class of problems, typically coming from experimental science (biology, chemistry, geophysics, medical science, etc.), where one has to deal with huge amounts of loosely structured data. Traditional mathematics, probability theory, and mathematical statistics work pretty well when the structure in question is essentially absent. (Paradoxically, the lack of structural organization and of correlations on the local level lead to a high

degree of overall symmetry. Thus the Gauss law emerges in the sums of random variables.) But often we have to encounter structured data where classical probability does not apply. For example, mineralogical formations or microscopic images of living tissues harbor (unknown) correlations which have to be taken into account. (What we ordinarily "see" is not the "true image" but the result of the scattering of some wave: light, x-ray, ultrasound, seismic wave, etc.) More theoretical examples appear in percolation theory, in self-avoiding random walk (modelling long molecular chains in solvents), etc. Such problems, stretching between clean symmetry and pure chaos, await the emergence of a new brand of mathematics. To make progress one needs radical theoretical ideas, as well as new ways of doing mathematics with computers and closer collaboration with scientists in order to match mathematical theories with available experimental data. (The wavelet analysis of signals and images, context-dependent inverse scattering techniques, geometric scale analysis, and x-ray diffraction analysis of large molecules in crystallized form indicate certain possibilities.)

We shall need ... the creation of a new breed of mathematical professionals able to mediate between pure mathematics and applied science. The cross-fertilization of ideas is crucial for the health of the science and mathematics.

Both the theoretical and industrial impacts of this development will be enormous. For example, an efficient inverse scattering algorithm would revolutionize medical diagnostics, making ultrasonic devices at least as efficient as current x-ray analysis.

4. As the power of computers approaches the theoretical limit and as we turn to more realistic (and thus more complicated) problems, we face the "curse of dimension", which stands in the way of successful implementations of numerics in science and engineering. Here one needs a much higher level of mathematical sophistication in computer architecture as well as in computer programming, along with the ideas indicated above in (2) and (3). Successes here may provide theoretical means for performing computations with high power growing arrays of data.

5. We must do a better job of educating and communicating ideas. The volume, depth, and structural complexity of the present body of mathematics make it imperative to find new approaches for communicating mathematical discoveries from one domain to another and drastically improving the accessibility of mathematical ideas to nonmathematicians. As matters stand now, we mathematicians often have little idea of what is going on in science and engineering, while experimental scientists and engineers are in many cases unaware of opportunities offered by progress in pure mathematics. This dangerous imbalance must be restored by bringing more science to the education of mathematicians and by exposing future scientists and engineers to core mathematics. This will require new curricula and a great effort on the part of mathematicians to bring fundamental mathematical techniques and ideas (especially those developed in the last decades) to a broader audience. We shall need for this the creation of a new breed of mathematical professionals able to mediate between pure mathematics and applied science. The cross-fertilization of ideas is crucial for the health of the science and mathematics.

6. We must strengthen financing of mathematical research. As we use more computer power and tighten collaboration with science and industry, we need more resources to support the dynamic state of mathematics. Even so, we shall need significantly less than other branches of science, so that the ratio of return/investment remains highest for mathematics, especially if we make a significant effort to popularize and apply our ideas. So it is important for us to make society well aware of the full potential of mathematical research and of the crucial role of mathematics in near- and long-term industrial development.

An Update on the Four-Color Theorem

Robin Thomas

Every planar map of connected countries can be colored using four colors in such a way that countries with a common boundary segment (not just a point) receive different colors. It is amazing that such a simply stated result resisted proof for one and a quarter centuries, and even today it is not yet fully understood. In this article I concentrate on recent developments: equivalent formulations, a new proof, and progress on some generalizations.

Brief History

The Four-Color Problem dates back to 1852 when Francis Guthrie, while trying to color the map of the counties of England, noticed that four colors sufficed. He asked his brother Frederick if it was true that *any* map can be colored using four colors in such a way that adjacent regions (i.e., those sharing a common boundary segment, not just a point) receive different colors. Frederick Guthrie then communicated the conjecture to DeMorgan. The first printed reference is by Cayley in 1878.

A year later the first "proof" by Kempe appeared; its incorrectness was pointed out by Heawood eleven years later. Another failed proof was published by Tait in 1880; a gap in the argument was pointed out by Petersen in 1891. Both failed proofs did have some value, though. Kempe proved the five-color theorem (Theorem 2 below) and discovered what became known as Kempe chains, and Tait found an equivalent formulation of the Four-Color Theorem in terms of edge 3-coloring, stated here as Theorem 3.

The next major contribution came in 1913 from G. D. Birkhoff, whose work allowed Franklin to prove in 1922 that the four-color conjecture is true for maps with at most twenty-five regions. The same method was used by other mathematicians to make progress on the four-color problem. Important here is the work by Heesch, who developed the two main ingredients needed for the ultimate proof—"reducibility" and "discharging". While the concept of reducibility was studied by other researchers as well, the idea of discharging, crucial for the unavoidability part of the proof, is due to Heesch, and he also conjectured that a suitable development of this method would solve the Four-Color Problem. This was confirmed by Appel and Haken (abbreviated A&H) when they published their proof of the Four-Color Theorem in two 1977 papers, the second one joint with Koch. An expanded version of the proof was later reprinted in [1].

Let me state the result precisely. Rather than trying to define maps, countries, and their boundaries, it is easier to restate Guthrie's 1852 conjecture using planar duality. For each country we select a capital (an arbitrary point inside that country) and join the capitals of every pair of neighboring countries. Thus we arrive at the notion of a plane graph, which is formally defined as follows.

A *graph* G consists of a finite set $V(G)$, the set of *vertices* of G, a finite set $E(G)$, the set of *edges*

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of G, and an incidence relation between vertices and edges such that every edge is incident with two distinct vertices, called its *ends*. (Thus I permit parallel edges, but do not allow edges that are loops.) A *plane graph* is a graph G such that $V(G)$ is a subset of the plane, each edge e of G with ends u and v is a polygonal arc in the plane with end-points u and v and otherwise disjoint from $V(G)$, and every two distinct edges are disjoint except possibly for their ends. A *region* of G is an arcwise-connected component of the complement of G. A graph is *planar* if it is isomorphic to a plane graph. (Equivalently, one can replace "polygonal" in the above definition by "continuous image of [0, 1]" or, by Fáry's theorem, by "straight line segment", and the class of planar graphs remains the same.) For an integer k, a k*-coloring* of a graph G is a mapping $\phi : V(G) \to \{1, \dots, k\}$ such that $\phi(u) \neq \phi(v)$ for every edge of G with ends u and v. An example of a plane graph with a 4-coloring is given in the left half of Figure 1. The Four-Color Theorem (abbreviated 4CT) now can be stated as follows.

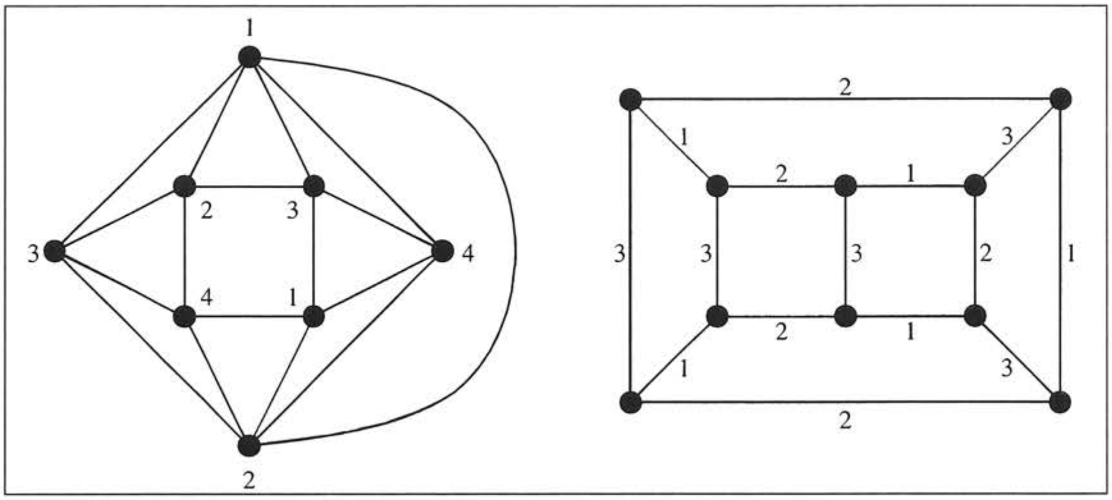

Figure 1. A 4-coloring and an edge 3-coloring.

Theorem 1. Every plane graph has a 4-coloring.

While Theorem 1 presented a major challenge for several generations of mathematicians, the corresponding statement for five colors is fairly easy to see. Let us state and prove that result now.

Theorem 2. Every plane graph has a 5-coloring.

Proof. Let G be a plane graph, and let R be the number of regions of G. We proceed by induction on $|V(G)|$. We may assume that G is connected, has no parallel edges, and has at least three vertices. By Euler's formula $|V(G)| + R = |E(G)| + 2$. Since every edge is incident with at most two regions and the boundary of every region has length at least three, we have $2|E(G)| \geq 3R$. Thus $|E(G)| \leq 3|V(G)| - 6$. The *degree* of a vertex is the number of edges incident with it. Since the sum of the degrees of all vertices of a graph equals twice the number of edges, we see that G has a vertex v of degree at most five.

If v has degree at most four, we consider the graph $G\backslash v$ obtained from G by deleting v (and all edges incident with v). The graph $G\backslash v$ has a 5-coloring by the induction hypothesis, and since v is adjacent to at most four vertices, this 5-coloring may be extended to a 5-coloring of G. Thus we may assume that v has degree five. I claim that J, the subgraph of G induced by the neighbors of v, has two distinct vertices that are not adjacent to each other. Indeed, otherwise J has $\binom{5}{2} = 10$ edges, and yet $|E(J)| \leq 3|V(J)| - 6 = 9$ by the inequality of the previous paragraph. Thus there exist two distinct neighbors v_1 and v_2 of v that are not adjacent to each other in J, and hence in G. Let H be the graph obtained from $G\backslash v$ by identifying v_1 and v_2; it is clear that H is a graph (it has no loops) and that it may be regarded as a plane graph. By the induction hypothesis the graph H has a 5-coloring. This 5-coloring gives rise to a 5-coloring ϕ of $G\backslash v$ such that $\phi(v_1) = \phi(v_2)$. Thus the neighbors of v are colored using at most four colors, and hence ϕ can be extended to a 5-coloring of G, as desired. □

For future reference it will be useful to sketch another proof of Theorem 2. The initial part proceeds in the same manner until we reach the one and only nontrivial step, namely, when we have a vertex v of degree five and a 5-coloring ϕ of $G\backslash v$, giving the neighbors of v distinct colors. Let the neighbors of v be $v_1, v_2, \dots, v_5$, listed in the order in which they appear around v; we may assume that $\phi(v_i) = i$. Let J_{13} be the subgraph of $G\backslash v$ induced by vertices u with $\phi(u) \in \{1, 3\}$. Let ϕ' be the 5-coloring of $G\backslash v$ obtained from ϕ by swapping the colors 1 and 3 on the component of J_{13} containing v_1. If v_3 does not belong to this component, then ϕ' can be extended to a coloring of G by setting $\phi'(v) = 1$. We may therefore assume that v_3 belongs to said component and hence there exists a path P_{13} in $G\backslash v$ with ends v_1 and v_3 such that $\phi(u) \in \{1, 3\}$ for every vertex u of P_{13}. Now let J_{24} be defined analogously, and by arguing in the same manner we conclude that we may assume that there exists a path P_{24} in $G\backslash v$ with ends v_2 and v_4 such that $\phi(u) \in \{2, 4\}$ for every vertex u of P_{24}. Thus P_{13} and P_{24} are vertex-disjoint, contrary to the Jordan curve theorem.

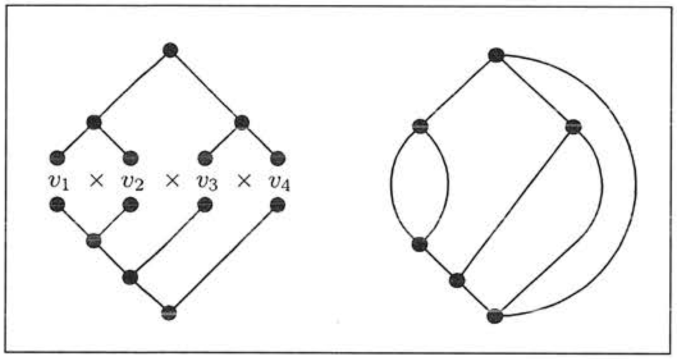

Figure 2.

Equivalent Formulations

Another attractive feature of the 4CT, apart from the simplicity of its formulation, is that it has many equivalent formulations using the languages of several different branches of mathematics. Indeed, in a 1993 article Kauffman and Saleur write: "While it has sometimes been said that the four-color problem is an isolated problem in mathematics, we have found that just the opposite is the case. The four-color problem and the generalization discussed here is central to the intersection of algebra, topology, and statistical mechanics."

Saaty [10] presents twenty-nine equivalent formulations of the 4CT. In this article let me repeat the most classical reformulation and then mention three new ones. A graph is *cubic* if every vertex has degree three, that is, is incident with precisely three edges. An *edge 3-coloring* of a graph G is a mapping $\psi : E(G) \to \{1, 2, 3\}$ such that $\psi(e) \neq \psi(f)$ for every two edges e and f of G that have a common end. Examples of a cubic graph and an edge 3-coloring are given in the right half of Figure 1. A *cut-edge* of a graph G is an edge e such that the graph $G\backslash e$ obtained from G by deleting e has more connected components than G. It is easy to see that if a cubic graph has an edge 3-coloring, then it has no cut-edge. Tait (see also [3] or [4]) showed in 1880 that the 4CT is equivalent to the following.

Theorem 3. Every cubic plane graph with no cut-edge has an edge 3-coloring.

The equivalence of Theorems 1 and 3 is not hard to see and can be found in most texts on graph theory. To illustrate where the equivalence comes from, let us see that Theorem 1 implies Theorem 3. Let G be a cubic plane graph with no cut-edge; we may assume that G is connected. The 4CT implies that the regions of G can be colored using four colors in such a way that the two regions incident with the same edge receive different colors (those two regions are distinct, because G has no cut-edge). Let us use the colors $(0, 0)$, $(1, 0)$, $(0, 1)$, and $(1, 1)$ instead of $1, 2, 3, 4$. Given such a 4-coloring, give an edge of G the color that is the sum of the colors of the two regions incident with it, the sum taken in $\mathbf{Z}_2 \times \mathbf{Z}_2$. Since the two regions incident with an edge are distinct, only the colors $(1, 0)$, $(0, 1)$, and $(1, 1)$ will be used to color the edges of G, giving rise to an edge 3-coloring of G, as desired.

Let me now describe three striking reformulations of the 4CT. The first is similar but deeper than a result found by Whitney and discussed in [10]. Let $\times$ denote the vector cross product in $\mathbf{R}^3$. The vector cross product is not associative, and hence the expression

$$v_1 \times v_2 \times \cdots \times v_k$$

is not well defined, unless $k \leq 2$. In order to make the expression well defined, one needs to insert parentheses to indicate the order of evaluation. By an *association* we mean an expression obtained by inserting $k - 2$ pairs of parentheses so that the order of evaluation is determined. Thus

$$(v_1 \times v_2) \times (v_3 \times v_4) \quad \text{and} \quad ((v_1 \times v_2) \times v_3) \times v_4$$

are two examples of associations. One can ask whether given two associations of $v_1 \times v_2 \times \cdots \times v_k$ there exists some choice of vectors such that the evaluations of the two associations are equal. This is easy to do by choosing $v_1 = v_2 = \cdots = v_k$. But how about making the two evaluations equal and *nonzero*? Kauffman [5] has shown the following.

Theorem 4. Let $\mathbf{i}, \mathbf{j}, \mathbf{k}$ be the usual unit vector basis of $\mathbf{R}^3$. If two associations of $v_1 \times v_2 \times \ldots \times v_k$ are given, there exists an assignment of $\mathbf{i}, \mathbf{j}, \mathbf{k}$ to $v_1, v_2, \ldots, v_k$ such that the evaluations of the two associations are equal and nonzero.

At this point interested readers might try to prove Theorem 4 before reading further. After all, it is only a statement about the vector cross product in a 3-dimensional space, and so it cannot be too hard. Or can it? Kauffman [5] has also shown:

Theorem 5. Theorem 4 is equivalent to the Four-Color Theorem.

Let me clarify that Kauffman proves Theorem 4 by reducing it to the Four-Color Theorem, and so despite Theorem 5 he did not obtain a new proof of the 4CT.

Where does Theorem 5 come from? To understand it, we should think of an association as a rooted tree in the natural sense. Given two associations A_1 and A_2 of $v_1 \times v_2 \times \cdots \times v_k$, let us grow the corresponding trees T_1 and T_2 vertically in opposite directions, as in the left half of Figure 2. Let us join the roots of T_1 and T_2 by an edge, identify the leaves corresponding to the same variable, and suppress the resulting vertices of degree two, forming a cubic plane graph H. This process is illustrated in the right half of Figure 2. It is easy to see that H has no cut-edge and hence has an edge 3-coloring by the 4CT. Let us use the colors $\mathbf{i}, \mathbf{j}, \mathbf{k}$ instead of $1, 2, 3$. Noticing that each variable v_i corresponds to an edge of H, we see that this edge 3-coloring gives an assignment of $\mathbf{i}, \mathbf{j}, \mathbf{k}$ to the variables $v_1, v_2, \dots, v_k$, and it follows from the construction that for this assignment the absolute values of the evaluations of A_1 and A_2 are equal to the color assigned to the edge of H that joins the roots of T_1 and T_2. Thus we have shown that the 4CT gives an assignment such that the corresponding evaluations are nonzero and either they are equal or one equals the negative of the other. It can in fact be shown that the evaluations are indeed equal, but we shall not prove that here.

This explains why the 4CT implies Theorem 4. To prove the converse, one must show that it suffices to prove Theorem 3 for cubic graphs H that arise in the above manner. That follows from a deep theorem of Whitney on hamiltonian circuits in planar triangulations.

For the next reformulation let L denote the Lie algebra $sl(N)$, that is, the vector space of all real $N \times N$ matrices with trace zero and with the product $[A, B]$ defined by $[A, B] = AB - BA$. Let $\{A_i\}$ be a vector space basis of L. The *metric tensor* t_{ij} is defined by $t_{ij} = tr(A_i A_j)$, where tr denotes the trace of a matrix. Let t^{ij} denote the inverse of the metric tensor, and let f_{ijk} be the *structure constants* of L, defined by $f_{ijk} = tr(A_i[A_j, A_k])$. Now let G be a cubic graph, and let us choose, for every vertex $v \in V(G)$, a cyclic permutation of the edges of G incident with v. Our objective is to define an invariant $W_L(G)$. To this end, let us break every edge of G into two half-edges and label all the half-edges by indices from $\{1, 2, \dots, \dim L\}$. With each such labelling λ we associate the product

$$\pi(\lambda) = \prod_{v \in V(G)} f_v \prod_{e \in E(G)} t^e,$$

where $t^e = t^{ij}$ if the two half-edges of e have labels i and j (notice that $t^{ij} = t^{ji}$) and $f_v = f_{ijk}$ if the three half-edges incident with v have labels i, j, k and occur around v in the cyclic order listed (notice that $f_{ijk} = f_{jki} = f_{kij}$). Finally, we define $W_L(G)$ as the absolute value of the sum of $\pi(\lambda)$ taken over all labellings λ of the half-edges of G by elements of $\{1, 2, \dots, \dim L\}$. It follows that $W_L(G)$ does not depend on the choice of the cyclic permutations. It can also be shown that $W_L(G)$ does not depend on the choice of basis, but for our purposes it suffices to stick to one fixed basis. Further, it can be shown that $W_L(G)$ is a polynomial in N of degree at most $k = \frac{1}{2}|V(G)| + 2$, and so we can define $W_L^{top}(G)$ to be the coefficient of N^k in $W_L(G)$. The next result, due to Bar-Natan [2], is best introduced by a quote from his paper: "For us who grew up thinking that all there is to learn about $sl(N)$ is already in $sl(2)$, this is not a big surprise."

Theorem 6. For a connected cubic graph G, $W_{sl(2)}(G) = 0$ implies $W_{sl(N)}^{top}(G) = 0$.

However, the following theorem of Bar-Natan *is* surprising, regardless of what one grew up thinking about the relationship of $sl(2)$ and $sl(N)$.

Theorem 7. Theorem 6 is equivalent to the Four-Color Theorem.

Like Theorem 4, Theorem 6 is deduced from the Four-Color Theorem, and hence Theorem 7 does not yield a new proof of the 4CT.

There is an easy hint as to why Theorem 7 holds. Penrose has shown that $W_{sl(2)}(G)$ is a nonzero constant multiple of the number of edge 3-colorings of G. Bar-Natan has shown that if G is a connected cubic graph, then $W_{sl(N)}^{top}(G)$ is 0 if G has a cut-edge and is equal to the number of embeddings of G in the sphere otherwise. The two results combined with Theorem 3 immediately establish Theorems 6 and 7. The details may be found in [2].

The last reformulation, in terms of divisibility, is due to Matiyasevich [6].

Theorem 8. There exist linear functions A_k, B_k, C_k, and D_k ($k = 1, 2, \dots, 986$) of twenty-one variables such that the Four-Color Theorem is equivalent to the statement that for every two positive integers n, m there exist nonnegative integers $c_1, c_2, \dots, c_{20}$ such that

$$\prod_{k=1}^{986} \binom{A_k(m, c_1, c_2, \dots, c_{20}) + 7^n B_k(m, c_1, c_2, \dots, c_{20})}{C_k(m, c_1, c_2, \dots, c_{20}) + 7^n D_k(m, c_1, c_2, \dots, c_{20})}$$

is not divisible by 7.

In fact, Matiyasevich found the functions A_k, B_k, C_k, and D_k explicitly, and he conjectures that a more general statement holds.

Let us try to understand where this theorem comes from. Let $\mathbf{N}$ denote the set of nonnegative integers. For a positive integer n let S_n denote the infinite graph with vertex-set $\mathbf{N}$ in which vertices i and j are adjacent if $|i - j| = 1$ or $|i - j| = n$. A *discrete map* is a pair (n, μ), where $n \in \mathbf{N}$ and $\mu : \mathbf{N} \to \mathbf{N}$ is a mapping such that $\mu(i) = 0$ for all but finitely many $i \in \mathbf{N}$. A discrete map (n, μ) gives rise to a graph as follows. Let H' be the subgraph of S_n induced by all vertices i with $\mu(i) \neq 0$, and let H be obtained from H' by contracting all edges with ends i, j, where $\mu(i) = \mu(j)$. Then H is indeed a graph (it is loopless), and μ is a coloring of H. We say that two discrete maps (n, μ) and (n', μ') are *equivalent* if

- $n = n'$,
- $\mu(i) = 0$ if and only if $\mu'(i) = 0$,
- $\mu(i) = \mu(i + 1)$ if and only if $\mu'(i) = \mu'(i + 1)$, and
- $\mu(i) = \mu(i + n)$ if and only if $\mu'(i) = \mu'(i + n)$.

It is not too difficult to show that every planar graph arises as the planar graph H above for some discrete map and hence the 4CT is equivalent to

Theorem 9. For every discrete map (n, μ) there exists an equivalent discrete map (n, λ) such that $\lambda(i) \in \{0, 1, 2, 3, 4\}$ for all $i \in \mathbf{N}$.

By Theorem 2 we can in the above theorem confine ourselves to discrete maps (n, μ) such that $\mu(i) \in \{0, 1, 2, 3, 4, 5\}$ for all $i \in \mathbf{N}$. Each such function μ can be encoded as an integer $m = \sum_{i=0}^{\infty} \mu(i)7^i$. Thus the phrase "for every two integers n, m" in Theorem 8 plays the role of "for every plane graph". Similarly, the function λ can be encoded as an integer, but we prefer to encode it using the twenty integers $c_1, c_2, \dots, c_{20}$ defined for $i = 0, 1, \dots, 4$ and $j = 1, 2, 3, 4$ by

$$c_{4i+j} = \sum(7^k : \mu(k) = i + 1, \lambda(k) = j).$$

Now there are conditions the integers $c_1, c_2, \dots, c_{20}$ have to satisfy in order to represent a valid discrete map (n, λ) as in Theorem 9, but each such condition can be expressed in the form "7 does not divide $\binom{A+7^n B}{C+7^n D}$", where A, B, C, D are linear functions of $m, c_1, c_2, \dots, c_{20}$. The reader may find more details in [6].

An Outline

The work of Appel and Haken undoubtedly represents a major breakthrough in mathematics, but, unfortunately, there remains some skepticism regarding the validity of their proof. To illustrate the nature of those concerns, let me quote from a 1986 article by Appel and Haken themselves: "This leaves the reader to face 50 pages containing text and diagrams, 85 pages filled with almost 2500 additional diagrams, and 400 microfiche pages that contain further diagrams and thousands of individual verifications of claims made in the 24 lemmas in the main sections of text. In addition, the reader is told that certain facts have been verified with the use of about twelve hundred hours of computer time and would be extremely time-consuming to verify by hand. The papers are somewhat intimidating due to their style and length and few mathematicians have read them in any detail."

A discussion of errors, their correction, and other potential problems may be found in the above article, in [1], and in F. Bernhart's review of [1]. For the purpose of this survey, let me telescope the difficulties with the A&H proof into two points:

(1) part of the proof uses a computer and cannot be verified by hand, and
(2) even the part that is supposedly hand-checkable has not, as far as I know, been independently verified in its entirety.

To my knowledge, the most comprehensive effort to verify the A&H proof was undertaken by Schmidt. According to [1], during the one-year limitation imposed on his master's thesis Schmidt was able to verify about 40 percent of part I of the A&H proof.

Neil Robertson, Daniel P. Sanders, Paul Seymour, and I tried to verify the Appel-Haken proof, but soon gave up and decided that it would be more profitable to work out our own proof. So we did and came up with the proof that is outlined below. We were not able to eliminate reason (1), but we managed to make progress toward (2).

The basic idea of our proof is the same as Appel and Haken's. We exhibit a set of 633 "configurations" and prove each of them is "reducible". This is a technical concept that implies that no configuration with this property can "appear" in a minimal counterexample to the Four-Color Theorem. It can also be used in an algorithm, for if a reducible configuration appears in a sufficiently connected planar graph G, then one can construct in constant time a smaller planar graph G' such that any 4-coloring of G' can be converted to a 4-coloring of G in linear time.

Birkhoff showed in 1913 that every minimal counterexample to the Four-Color Theorem is an "internally 6-connected" triangulation. In the second part of the proof we prove that at least one of our 633 configurations appears in every internally 6-connected planar triangulation (not necessarily a minimal counterexample to the 4CT). This is called proving unavoidability and uses the "discharging method" first suggested by Heesch. Here our method differs from that of Appel and Haken.

The main aspects of our proof are as follows. We confirm a conjecture of Heesch that in proving unavoidability a reducible configuration can be found in the second neighborhood of an "overcharged" vertex; this is how we avoid "immersion" problems that were a major source of complication for Appel and Haken. Our unavoidable set has size 633 as opposed to the 1,476-member set of Appel and Haken; our discharging method uses only 32 discharging rules instead of the 487 of Appel and Haken; and we obtain a quadratic algorithm to 4-color planar graphs, an improvement over the quartic algorithm of Appel and Haken. Our proof, including the computer part, has been independently verified, and the ideas have been and are being used to prove more general results. Finally, the main steps of our proof are easier to present, as I will attempt to demonstrate below.

Before I turn to a more detailed discussion of configurations, reducibility, and discharging, let me say a few words about the use of computers in our proof. The theoretical part is completely described in [7], but it relies on two results that are stated as having been proven by a computer. The rest of [7] consists of traditional (computer-free) mathematical arguments. There is nothing extraordinary about the theoretical arguments, and so the main burden of verification lies in those two computer proofs. How is one supposed to be convinced of their validity? There are basically two ways. The reader can either write his or her own computer programs to check those results (they are easily seen to be finite problems), or he or she can download our programs along with their supporting documentation and verify that those programs do what we claim they do.

The reducibility part is easier to believe, because we are doing almost the same thing as many authors before us (including Appel and Haken) have done, and so it is possible to compare certain numerical invariants obtained during the computation to gain faith in the results. This is not possible in the unavoidability part, because our approach to it is new. To facilitate checking, we have written this part of the computer proof in a formal language so that it will be machine verifiable. Every line of the proof can be read and checked by a human, and so can (at least theoretically) the whole argument. However, the entire argument occupies about 13,000 lines, and each line takes some thought to verify. Therefore, verifying all of this without a computer would require an amount of persistence and determination my coauthors and I do not possess. The computer data, programs, and documentation are available by anonymous ftp[1] and can also be conveniently accessed on the World Wide Web.[2]

Two of my students independently verified the computer work. Tom Fowler verified the reducibility part (and in fact extended it to obtain a more general result—see later), and Christopher Carl Heckman wrote an independent version of the unavoidability part using a different programming language. Bojan Mohar also informed us that his student Gašper Fijavž wrote independent programs and was able to confirm both parts of the computer proof. The computer verification can be carried out in a matter of several hours on standard commercially available equipment.

I should mention that both our programs use only integer arithmetic, and so we need not be concerned with round-off errors and similar dangers of floating point arithmetic. However, an argument can be made that our "proof" is not a proof in the traditional sense, because it contains steps that most likely can never be verified by humans. In particular, we have not proven the correctness of the compiler on which we compiled our programs, nor have we proven the infallibility of the hardware on which we ran our programs. These have to be taken on faith and are conceivably a source of error. However, from a practical point of view, the chance of a computer error that appears consistently in exactly the same way on all runs of our programs on all the compilers under all the operating systems that our programs run on is infinitesimally small compared to the likelihood of a human error during the same amount of case-checking. Apart from this hypothetical possibility of a computer consistently giving an incorrect answer, the rest of our proof, including the programs, can be checked in the same way as traditional mathematical proofs. My coauthors and I concede, however, that checking a computer program is much more difficult than verifying a mathematical proof of the same length.

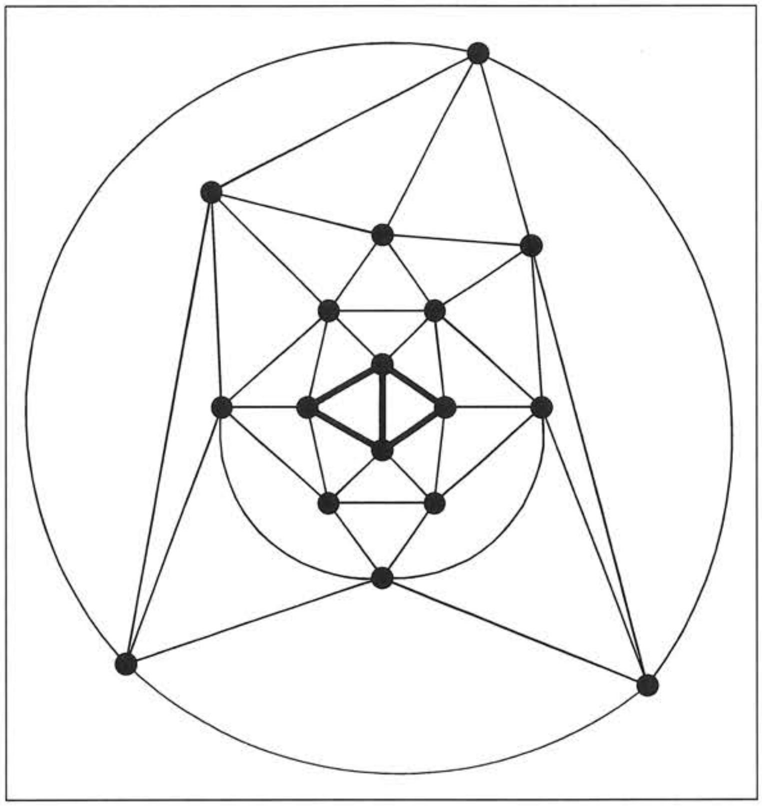

Figure 3. A configuration appearing in an internally 6-connected triangulation.

Configurations

First we need a result of Birkhoff about connectivity of minimal counterexamples. Let G be a plane graph. A *triangle* is a region of G bounded by precisely three edges of G. A plane graph G is a *triangulation* if every region of G (including the unbounded region) is a triangle. See Figure 3 for an example. A graph G is *internally* 6*-connected* if for every set X of at most five vertices, either the graph $G \setminus X$ obtained from G by deleting X is connected, or $|X| = 5$ and $G \setminus X$ has exactly two connected components, one of which consists of a single vertex. Thus every vertex of an internally 6-connected graph has degree at least five. For example, the triangulation in Figure 3 is internally 6-connected. Let me formally state the result of Birkhoff mentioned earlier. A proof can be obtained by

[1] ftp://ftp.math.gatech.edu/pub/users/thomas/four

[2] http://www.math.gatech.edu/~thomas/FC/ftpinfo.html

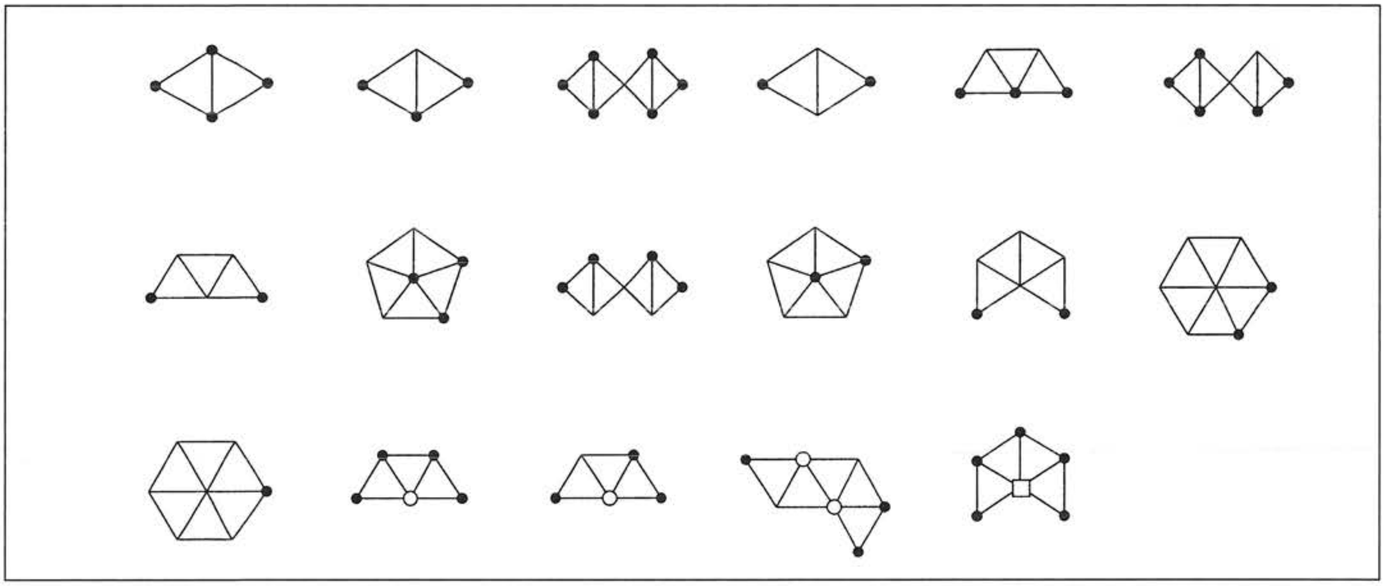

Figure 4. A set of configurations.

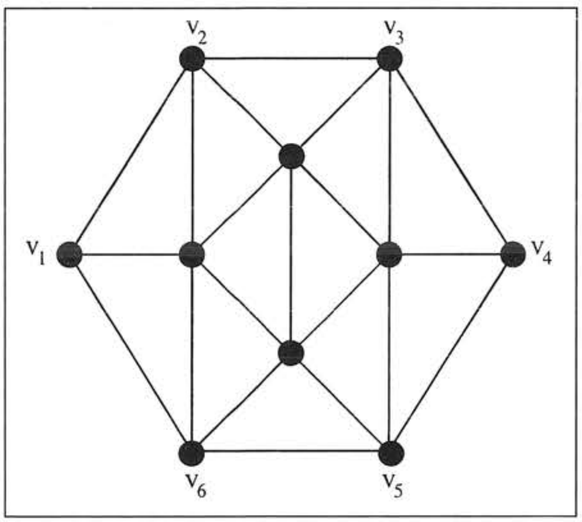

Figure 5. The free completion *S* of *K*.

pushing the arguments presented in the two proofs of Theorem 2.

Theorem 10. Every minimal counterexample to the Four-Color Theorem is an internally 6-connected triangulation.

Next we need to introduce the concept of a configuration, which is central to the rest of the proof. Configurations are technical devices that permit us to capture the structure of a small part of a larger triangulation. A graph G is an *induced subgraph* of a graph T if G is a subgraph of T and every edge of T with both ends in $V(G)$ belongs to G. If (G, γ) is a configuration, one should think of G as an induced subgraph of an internally 6-connected triangulation T, with $\gamma(v)$ being the degree of v in T. This notion can be traced back to Birkhoff's 1913 paper and has been used in various forms by many researchers since then. Here is the formal definition of the version that we use.

A *near-triangulation* is a nonnull connected plane graph with one region designated as *special* such that every region, except possibly the special region, is a triangle. A *configuration* K is a pair (G, γ), where G is a near-triangulation and γ is a mapping from $V(G)$ to the integers with the following properties:

1. for every vertex v of G, if v is not incident with the special region of G, then $\gamma(v)$ equals $\deg(v)$, the degree of v, and otherwise $\gamma(v) > \deg(v)$, and in either case $\gamma(v) \geq 5$;
2. for every vertex v of G, $G \backslash v$ has at most two components, and if there are two, then the degree of v in G is $\gamma(v) - 2$;
3. K has ring-size at least 2, where the *ring-size* of K is defined to be $\sum(\gamma(v) - \deg(v) - 1)$, summed over all vertices v incident with the special region of G such that $G \backslash v$ is connected.

The significance of condition (1) will become clearer from the definition of "appears" below; conditions (2) and (3) are needed for the definition of the "free completion", discussed in the next section.

When drawing pictures of configurations, one possibility is to draw the underlying graph and write the value of γ next to each vertex. There is a more convenient way, introduced by Heesch. The special region is the unbounded region, and the shapes of vertices indicate the value of $\gamma(v)$ as follows: A solid black circle means $\gamma(v) = 5$, a dot (or what appears in the picture as no symbol at all) means $\gamma(v) = 6$, a hollow circle means $\gamma(v) = 7$, a hollow square means $\gamma(v) = 8$, a triangle means $\gamma(v) = 9$, and a pentagon means $\gamma(v) = 10$. In Figure 4, seventeen of our 633 reducible configurations are displayed using the indicated convention. The whole set can be found in [7] and can be viewed electronically.[3]

Isomorphism of configurations is defined in the natural way. Any configuration isomorphic to one of the 633 configurations exhibited in [7] is

[3] `ftp://ftp.math.gatech.edu/pub/users/thomas/fcdir/unavoidable.ps.gz`

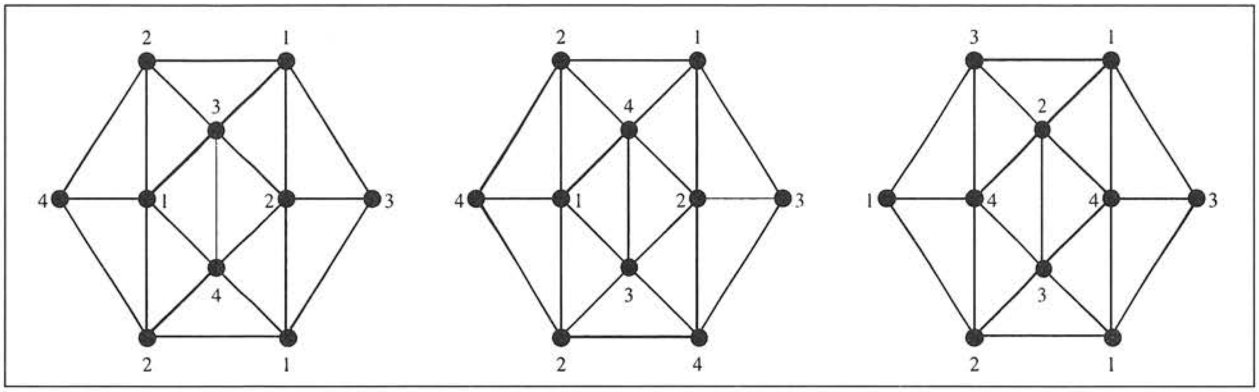

Figure 6. Three colorings of *R* that extend into *S*.

called a *good* configuration. Let T be a triangulation. A configuration (G, γ) *appears* in T if G is an induced subgraph of T, every region of G except possibly the special region is a region of T, and $\gamma(v)$ equals the degree of v in T for every vertex v of G. See Figure 3 for an example of a configuration isomorphic to the first configuration in Figure 4 appearing in an internally 6-connected triangulation. We prove the following two statements.

Theorem 11. If T is a minimal counterexample to the Four-Color Theorem, then no good configuration appears in T.

Theorem 12. For every internally 6-connected triangulation T, some good configuration appears in T.

For example, the good configuration in the upper left corner of Figure 4 appears in the center of Figure 3.

From Theorems 10, 11, and 12 it follows that no minimal counterexample exists, and so the 4CT is true. I will discuss the proofs of the latter two theorems in the next two sections.

Reducibility

Reducibility is a technique for proving statements such as Theorem 11. Qualitatively it can be described by saying that it is obtained by pushing to the limit the arguments used in the two proofs of Theorem 2. It was developed from Kempe's failed attempt at proving the 4CT by Birkhoff, Bernhart, Heesch, Allaire, Swart, Appel and Haken, and others.

I will explain the idea of reducibility by giving an example; interested readers may find the precise definition in [7]. Let us consider the first configuration in Figure 4, and let us call it $K = (G, \gamma)$. Suppose for a contradiction that K appears in a minimal counterexample T to the 4CT. Given that $\gamma(v)$ is equal to the degree in T of the vertex v of G, we can deduce what T looks like in a small "neighborhood" of G. In fact, since T is internally 6-connected by Theorem 10, it follows that the graph S pictured in Figure 5 is isomorphic to a subgraph of T, and so we may assume that S is actually a subgraph of T. Notice that G is a subgraph of S, that $R = S\setminus V(G)$ is a (simple) circuit with vertex-set $\{v_1, v_2, \dots, v_6\}$, and that the length of R is equal to the ring-size of K. We call S the *free completion of K*.

(Here we were lucky—for larger configurations it does not follow that the free completion is a subgraph of T. However, the most that can happen, given that G is an *induced* subgraph of T, is that for some distinct vertices of R the corresponding vertices of T are equal. On the other hand, this does not matter for the forthcoming argument, and so for the purpose of this article let me ignore this possibility.)

Now let us consider $T' = T\setminus V(G)$. Let $\mathcal{K}$ be the set of all 4-colorings of R, and let $C' \subseteq \mathcal{K}$ be the set of all those 4-colorings of R that extend to a 4-coloring of T'. Since T is a minimal counterexample, T' has a 4-coloring, and hence $C' \neq \emptyset$. To obtain a contradiction, let me prove that $C' = \emptyset$. Let C be the set of all 4-colorings of R that extend to a 4-coloring of S. Notice that C can be computed from the knowledge of the configuration K. Since T is a counterexample to the 4CT, $C' \subseteq \mathcal{K} - C$ (otherwise a 4-coloring of R that extends to both S and T' extends to a 4-coloring of T). We need a method that would allow us to show that a 4-coloring $\phi \in \mathcal{K} - C$ does not belong to C'. As an example let us consider the 4-coloring ϕ of R defined by $(\phi(v_1), \phi(v_2), \dots, \phi(v_6)) = (1, 2, 1, 3, 1, 2)$, where $v_1, v_2, \dots, v_6$ are the vertices of R, numbered as in Figure 5. To simplify the notation, I shall write $\phi = 121312$ and similarly for other colorings. Suppose for a contradiction that $\phi \in C'$, and let κ be a 4-coloring of T' extending ϕ. Let T_{14} be the subgraph of T' induced by the vertices $v \in V(T')$ with $\kappa(v) \in \{1, 4\}$, and let L be the component of T_{14} containing the vertex v_1. Let κ' be obtained from κ by exchanging colors 1 and 4 on vertices of L, and let ϕ' be the restriction of κ' to R. Thus $\phi' \in C'$. If $v_3, v_5 \notin V(L)$, then $\phi' = 421312$, and if $v_3 \notin V(L)$, $v_5 \in V(L)$, then $\phi' = 421342$. In either case $\phi' \in C$ (see Figure 6), a contradiction. Thus $v_3 \in V(L)$, and hence there exists a path P in T' with ends v_1 and v_3 such that $\kappa(v) \in \{1, 4\}$ for every $v \in V(P)$. Let T_{23} be defined analogously, and let J be the component of

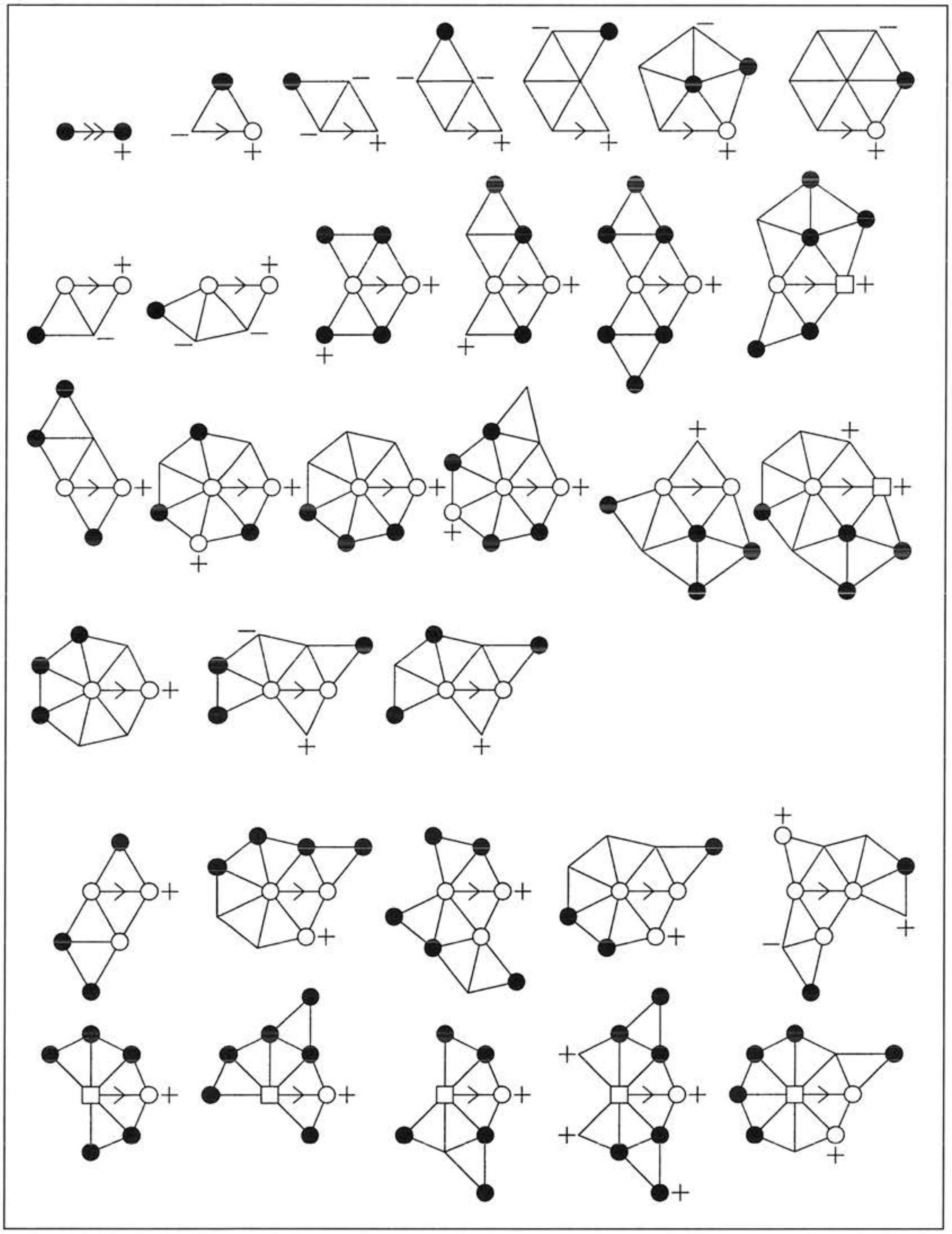

Figure 7. Discharging rules.

T_{23} containing v_2. Since $V(J) \cap V(P) = \emptyset$ we deduce from the Jordan curve theorem that $v_4, v_6 \notin V(J)$. Let κ'' be obtained from κ by exchanging colors 2 and 3 on vertices of J, and let ϕ'' be the restriction of κ'' to R. Then $\phi'' = 131312$, and hence $\phi'' \in C$ (see Figure 6), and yet $\phi'' \in C'$, a contradiction. Thus $\phi \notin C'$, as required. The arguments for other colorings in $\mathcal{K} - C$ proceed similarly. The order in which colorings are handled is important here, because for some colorings it is necessary to use the previously established fact that other colorings in $\mathcal{K} - C$ do not belong to C'.

The above argument is called D-*reducibility* in the literature. Notice the way in which we used the fact that T is a minimal counterexample—we used it to deduce that T' has a 4-coloring. This may seem wasteful, for rather than deleting G, we could replace it by a smaller graph G'. Doing so yields a more powerful method, called C-*reducibility*. In our proof of the 4CT we use a special case of C-reducibility, where G' is obtained from G by contracting at most four edges. C-reducibility is dangerous in general, because it requires checking that the new graph obtained by substituting G' for G is loopless, which can be rather tedious. By limiting ourselves to graphs obtained by contracting at most four edges, we were able to eliminate these difficulties.

D- and C-reducibility can be automated and carried out on a computer. In fact, they must be carried out on a computer, because we need to test configurations with ring-size as large as 14, in which case there are almost 200,000 colorings to be checked. At the present time there is little hope of doing this part of the proof by hand. Even writing down the proof in a formal language, as we did for the discharging part, does not seem practical because of the length of the argument.

Discharging

Discharging is a clever and effective use of Euler's formula, first suggested by Heesch and later used by Appel and Haken and many others since then. In fact, discharging has become a standard tool in graph theory. In what follows I will refer to Figure

7, which some readers may find overwhelming at the first sight. I recommend focusing attention on the first row and thinking of the rest as being of secondary importance. The first row has a geometric interpretation, discussed below. Also, we will make use of Heesch's notational convention introduced two paragraphs prior to Theorem 11.

Let T be an internally 6-connected triangulation. Initially, every vertex v is assigned a *charge* of $10(6 - \deg(v))$. It follows from Euler's formula that the sum of the charges of all vertices is 120; in particular, it is positive. We now redistribute the charges according to the following rules. Whenever T has a subgraph isomorphic to one of the graphs in Figure 7 satisfying the degree specifications (for a vertex v of one of those graphs with a minus sign next to v, this means that the degree of the corresponding vertex of T is at most the value specified by the shape of v, and analogously for vertices with a plus sign next to them; equality is required for vertices with no sign next to them), a charge of one (two in case of the first graph) is to be sent along the edge marked with an arrow.

This procedure defines a new set of charges with the same total sum. For instance, if T is the triangulation depicted in Figure 3, then only the rule corresponding to the first graph in Figure 7 applies, and it causes a charge of two to be sent along each edge in either direction. Hence the net effect of all the rules is zero, and so every vertex ends up with a final charge of 10.

Since the total sum of the new charges is positive, there is a vertex v in T whose new charge is positive. We show that a good configuration appears in the second neighborhood of v (that is, the subgraph induced by vertices at distance at most two from v). If the degree of v is at most six or at least twelve, then this can be seen fairly easily by a direct argument. (See [7] for details; for this argument the configurations of Figure 4 suffice. In fact, when v has degree at most six, this follows immediately from the geometric interpretation of the first row of Figure 7 given at the end of this section.) For the remaining cases, however, the proofs are much more complicated. Since the amount of charge a vertex of T receives depends only on its second neighborhood (and not on the rest of T), it suffices to examine all possible second neighborhoods of vertices of degree 7, 8, 9, 10, and 11. It is easy to see that this reduces to a finite problem. Strictly speaking, there are infinitely many such second neighborhoods, but for vertices of degree at least twelve the actual degree affects neither the amount of charge nor the presence of reducible configurations. Thus all possible second neighborhoods can be divided into finitely many classes, where for every two second neighborhoods in the same class, the same good configurations appear and the central vertex has the same charge. Therefore, it suffices to examine all these equivalence classes. As mentioned earlier, this part of the proof has actually been written down in a formal language.

The rules corresponding to the first row in Figure 7 were derived from an elegant method of Mayer and have the following geometric interpretation. Let $v \in V(T)$ have degree five, and assume, as we may in the proof of Theorem 12, that no good configuration appears in the second neighborhood of v. The vertex v is originally assigned a charge of ten. The rules in the first row are designed to send this charge from v to vertices of degree at least seven. Let e be an edge incident with v, let u be the other end of e, and let x be a common neighbor of u and v. Since T is internally 6-connected, there are exactly ten such pairs (e, x). For each such pair a charge of one will be sent away from v into a suitable vertex, found as follows. If the degree of u is at least seven, the unit of charge will be deposited into u. Otherwise, if x has degree at least seven, the unit of charge will be deposited into x. Finally, if both u and x have degree at most six, let $z_1 = v$, $z_2 = u$, $z_3, z_4, \ldots$ be the neighbors of x listed in the order in which they appear around x. Since no good configuration appears in the second neighborhood of v, one of these vertices has degree at least seven, as is easily seen. Thus we may take the smallest integer $i \geq 2$ such that z_i has degree at least seven, and the unit of charge corresponding to (e, x) will be deposited into z_i.

While this redistribution of charges seems natural, unfortunately it is not true that a reducible configuration appears in the second neighborhood of every vertex of positive charge. Therefore, we had to introduce additional rules to make small changes to this distribution to take care of second neighborhoods of vertices with positive charge in which no reducible configuration appeared. The additional rules were obtained by trial and error; there is a lot of flexibility in their choice, but they were not designed with any geometric intuition behind them.

Beyond the Four-Color Theorem

The new proof of the 4CT gives hope that other more general conjectures that are known to imply the 4CT could be settled by an appropriate adaptation of the same methods. Let me start by discussing a result of my student Tom Fowler on unique colorability. A graph G is uniquely 4-colorable if it has a 4-coloring and every two 4-colorings differ only by a permutation of colors. Here is a construction. Start with the complete graph on four vertices. Given a plane graph G constructed thus far, pick a triangle in G, and add a new vertex adjacent to all vertices incident with the triangle. It is easy to see that every graph constructed in this fashion is uniquely 4-colorable. Fiorini and Wilson conjectured in 1977 that every uniquely 4-

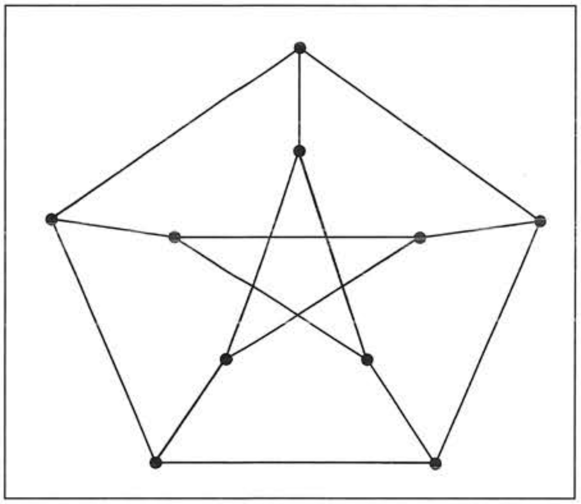

Figure 8. The Petersen graph.

colorable plane graph on at least four vertices can be obtained this way. Fowler in his Ph.D. thesis extended our proof of the 4CT to prove this conjecture. More precisely, he has shown

Theorem 13. Every internally 6-connected triangulation has at least two different 4-colorings.

By Theorem 10 this generalizes the Four-Color Theorem, and it implies the Fiorini-Wilson conjecture by a result of Goldwasser and Zhang, who have shown that a minimal counterexample is internally 6-connected. (The proof of the latter is analogous to that of Theorem 10.)

While the 4CT becomes false very quickly once we leave the world of planar graphs, Tutte noticed that Theorem 3 remains true for a reasonably large class of nonplanar graphs. The smallest cubic graph with no cut-edge and no edge 3-coloring is the famous Petersen graph depicted in Figure 8. We say that a graph G has an H minor if a graph isomorphic to H can be obtained from a subgraph of G by contracting edges. Tutte conjectured the following.

Conjecture 14. Every cubic graph with no cut-edge and no edge 3-coloring has a Petersen minor.

Tutte's conjecture implies the 4CT by Theorem 3 (because the Petersen graph is not planar, and contraction preserves planarity), but it seems to be much stronger. However, it now appears that there is a good chance that Tutte's conjecture can be proven. Indeed, Robertson, Seymour, and I have reduced the problem to the following two classes of graphs. We say that a graph G is *apex* if $G\backslash v$ is planar for some vertex v of G, and we say that a graph is *doublecross* if it can be drawn in the plane with two crossings in such a way that the two crossings belong to the same region (see Figure 9). Robertson, Seymour, and I [9] have shown the following.

Theorem 15. Let G be a counterexample to conjecture 14 with $|V(G)|$ minimum. Then G is apex or doublecross.

Thus, in order to prove Conjecture 14 it suffices to prove it for apex and doublecross graphs, two classes of graphs that are "almost" planar. In fact, my recent work with Sanders suggests that it might be possible to adapt our proof of the 4CT to show that no apex graph is a counterexample to Tutte's conjecture. There is an indication that the doublecross case will be easier, but we cannot confirm that yet.

There is a way to generalize the 4CT along the lines of (vertex) 4-coloring. Hadwiger conjectured the following.

Conjecture 16. For every positive integer t, if a graph has no K_{t+1} minor, then it has a t-coloring.

This is trivial for $t \leq 2$, and for $t = 3$ it was shown by Hadwiger and Dirac (this case is also reasonably easy). However, for every $t \geq 4$, Hadwiger's conjecture implies the 4CT. To see this, take a plane graph G, and construct a graph H by adding $t - 4$ vertices adjacent to each other and to every vertex of G. Then H has no K_{t+1} minor (because no plane graph has a K_5 minor) and hence has a t-coloring by the assumed truth of Hadwiger's conjecture. In this t-coloring, vertices of G are colored using at most four colors, as required. Thus there is a rather sharp increase in the level of difficulty of Hadwiger's conjecture between $t = 3$ and $t = 4$. On the other hand, Wagner showed in 1937 that Hadwiger's conjecture for $t = 4$ is in

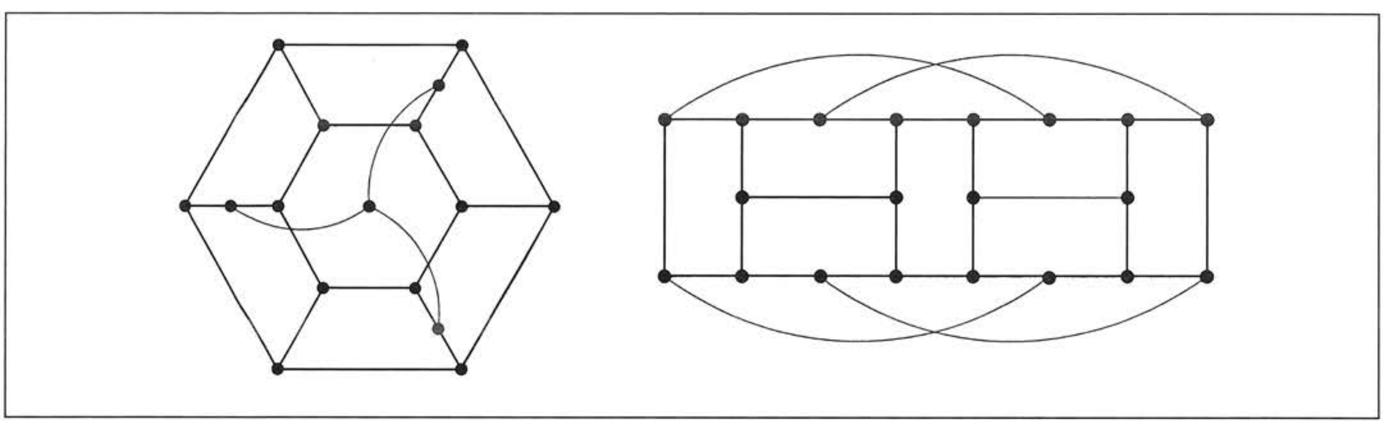

Figure 9. An apex and a doublecross graph.

fact equivalent to the 4CT. (Notice that this result preceded the proof of the 4CT by four decades and, in fact, inspired Hadwiger's conjecture.) Recently, Robertson, Seymour, and I were able to show that the next case is also equivalent to the 4CT [8]. More precisely, we managed to prove (without using the 4CT) the following.

Theorem 17. Let G be a counterexample to Hadwiger's conjecture for $t = 5$ with the minimum number of vertices. Then G is apex.

By the 4CT every apex graph has a 5-coloring, and so Hadwiger's conjecture for $t = 5$ follows. The cases $t \geq 6$ are still open.

Acknowledgments

I am indebted to Reinhard Diestel, Christopher Carl Heckman, Petr Hliněný, Tommy Jensen, and Anthony Knapp for carefully reading earlier versions of this article and for providing many valuable suggestions.

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Interview with Shiing Shen Chern

This article is based on an interview with Shiing Shen Chern conducted on March 4, 1998, by Allyn Jackson, with mathematical help from Dieter Kotschick.

Shiing Shen Chern is one of the greatest living geometers. He was born on October 28, 1911, in Jia Xin, China. His father had a degree in law and worked for the government. When Chern was a youngster, China was just starting to establish Western-style colleges and universities. He entered Nankai University at the age of fifteen and was drawn to physics but, finding himself clumsy with experimental work, eventually settled on mathematics. In 1930 he entered the graduate school of Tsinghua University, where there were a number of Chinese mathematicians who had obtained Ph.D.s in the West. Among these was Guangyuan Sun (Dan Sun), who had been a student of E. P. Lane at the University of Chicago. Some twenty years later, Chern became Lane's successor at Chicago. In 1932 Wilhelm Blaschke, a mathematician from the University of Hamburg, visited Tsinghua, and his lectures had a great influence on Chern.

Notices: *After your studies in China, you decided to get a doctorate in the West.*

Chern: I was given a fellowship to come to the West by Tsinghua University in 1934, after one year of assistantship and three years in the graduate school. I decided Europe was a better place than the United States. The normal thing to do was to come to the United States, but I was not interested in Princeton or Harvard.

Notices: *Why not?*

Chern: Not so good. I wanted to be a geometer. The United States did not have the type of geometry I wanted to work on, so I went to Europe. At that time, I think I had the advantage that although I was a beginning student, I had some ideas about what I wanted, about the mathematical situation in the world, who are the good mathematicians, where are the best centers. My evaluation could have been wrong, but I had my ideas. And I decided to go to Hamburg. In fact, it was a very good choice. At the end of the nineteenth century the center of science was Germany, including mathematics. And the center of mathematics in Germany was Göttingen, with Berlin and Munich not far behind. And Paris, of course, was always a center.

I graduated from Tsinghua graduate school in 1934. In 1933 Hitler took power in Germany, and there was great movement in German universities. The Jewish professors were removed, and so on, and Göttingen collapsed. And Hamburg became a very good place. Hamburg was a new university founded after the First World War. It was not so distinguished, but the math department was excellent. So I went there at the right time.

It was in Hamburg that Chern first came into contact with the work of Elie Cartan, which had a profound influence on Chern's approach to mathematics. At that time, Erich Kähler, a Privatdozent at Hamburg, was one of the main proponents of Cartan's ideas. Kähler had just written a book, the main theorem of which is now known as the Cartan-Kähler theorem, and he organized a seminar in Hamburg. On the first day of the seminar all of the full professors—Blaschke, Emil Artin, and Erich Hecke—attended.

Chern: [The seminar] looked like a kind of celebration. The classroom was filled, and the book had just come out. Kähler came in with a pile of the books and gave everybody a copy. But the subject was difficult, so after a number of times, peo-

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ple didn't come anymore. I think I was essentially the only one who stayed till the end. I think I stayed till the end because I followed the subject. Not only that, I was writing a thesis applying the methods to another problem, so the seminar was of great importance to me. I even came to see Herr Kähler after the seminar. A lot of times we had lunch together. There was a restaurant near the institute, and we had lunch together and talked about all kinds of things. My German was very limited, and Herr Kähler did not speak English at that time. Anyway, we got along. So, as a result, I finished my thesis very quickly.

Everybody knew that Elie Cartan was the greatest differential geometer. But his writings were very difficult. One reason is that he uses the so-called exterior differential calculus. And in our subject of differential geometry, where you talk about manifolds, one difficulty is that the geometry is described by coordinates, but the coordinates do not have meaning. They are allowed to undergo transformation. And in order to handle this kind of situation, an important tool is the so-called tensor analysis, or Ricci calculus, which was new to mathematicians. In mathematics you have a function, you write down the function, you calculate, or you add, or you multiply, or you can differentiate. You have something very concrete. In geometry the geometric situation is described by numbers, but you can change your numbers arbitrarily. So to handle this, you need the Ricci calculus.

Chern had a three-year fellowship, but finished his degree after only two years. For the third year, Blaschke arranged for Chern to go to Paris to work with Cartan. Chern did not understand much French, and Cartan spoke only French. On their first meeting, Cartan gave Chern two problems to do. After some time they happened to meet on the stairs at the Institut Henri Poincaré, and Chern told Cartan he had been unable to do the problems. Cartan asked Chern to come to his office to discuss them. Chern thereafter came regularly to Cartan's office hours, which often attracted a large number of visitors who wanted to meet with the famous mathematician. After a few months, Cartan invited Chern to meet with him at his home.

Chern: Usually the day after [meeting with Cartan] I would get a letter from him. He would say, "After you left, I thought more about your questions..."—he had some results, and some more questions, and so on. He knew all these papers on simple Lie groups, Lie algebras, all by heart. When you saw him on the street, when a certain issue would come up, he would pull out some old envelope and write something and give you the answer. And sometimes it took me hours or even days to get the same answer. I saw him about once every two weeks, and clearly I had to work very hard. This lasted for a year, till 1937, and then I went back to China.

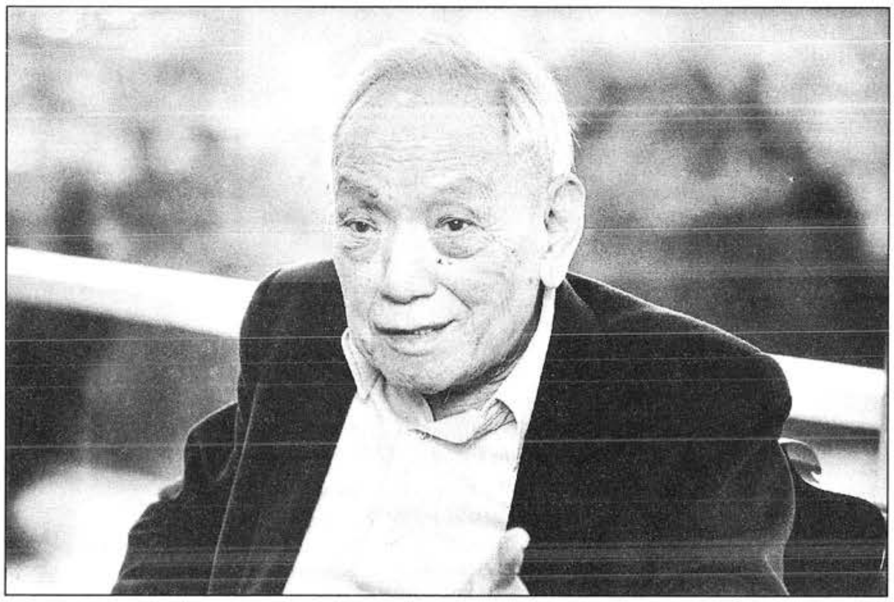
Photography by Peg Skorpinski.

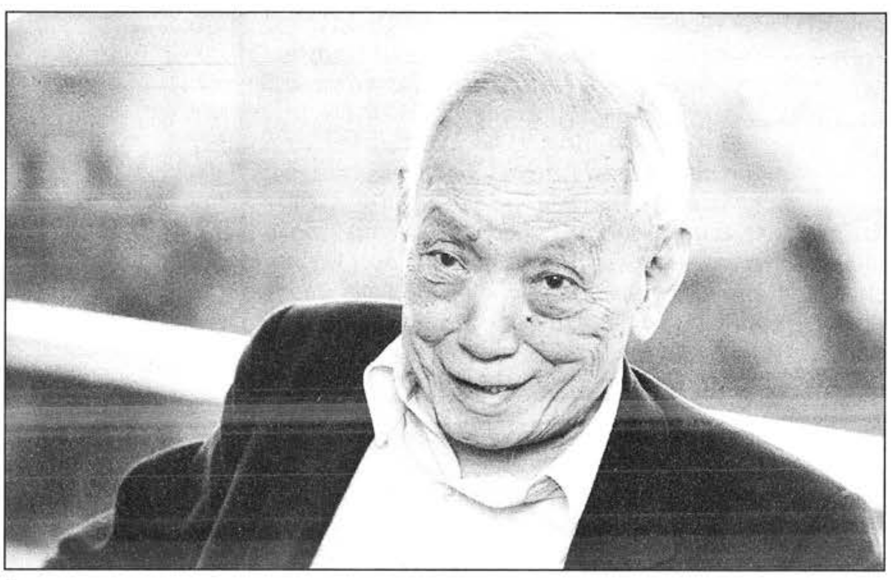
Shiing Shen Chern

When he returned to China, Chern became a professor of mathematics at Tsinghua, but the Sino-Japanese War severely limited his contact with mathematicians outside China. He wrote to Cartan about his situation, and Cartan sent a box of his reprints, including some old papers. Chern spent a great deal of time reading and thinking about them. Despite his isolation Chern continued to publish, and his papers attracted international attention. In 1943 he received an invitation from Oswald Veblen to come to the Institute for Advanced Study in Princeton. Because of the war it took Chern a week to reach the United States by military aircraft. During his two years at the Institute, Chern completed his proof of the generalized Gauss-Bonnet Theorem, which expresses the Euler characteristic of a closed Riemannian manifold of arbitrary dimension as a certain integral of curvature terms over the manifold. The theorem's marriage of the local geometry to global topological invariants represents a deep theme in much of Chern's work.

Notices: *What among your mathematical works do you consider the most important?*

Chern: I think the differential geometry of fiber spaces. You see, mathematics goes in two different directions. One is the general theory. For instance, everybody has to study point set topology,





everybody has to study some algebra, so they get a general foundation, a general theory that covers almost all mathematics. And then there are certain topics which are special, but they play such an important role in application of mathematics that you have to know them very well, such as the general linear group, or even the unitary group. They come out everywhere, whether you do physics or do number theory. So there is the general theory, which contains certain beautiful things. And the fiber space is one of these. You have a space whose fibers are very simple, are classical spaces, but they are put together in a certain way. And that is a really fundamental concept. Now, in fiber spaces the notion of a connection becomes important, and that's where my work comes in. Usually the best mathematical work combines some theory with some very special problems. The special problems call for development in the general theory. And I used this idea to give the first proof of the Gauss-Bonnet formula.

The Gauss-Bonnet formula is one of the important, fundamental formulas, not only in differential geometry, but in the whole of mathematics. Before I came to Princeton [in 1943] I had thought about it, so the development in Princeton was in a sense very natural. I came to Princeton and I met André Weil. He had just published his paper with Allendoerfer[1]. Weil and I became good friends, so we naturally discussed the Gauss-Bonnet formula. And then I got my proof. I think this is one of my best works, because it solved an important, a fundamental, classical problem, and the ideas were very new. And to carry out the ideas you need some technical ingenuity. It's not trivial. It's not something where once you have the ideas you can carry it out. It's subtle. So I think it's a very good piece of work.

Notices: *One of your other most important works was the development of characteristic classes.*

Chern: The characteristic classes—they are not that impressive. Characteristic classes are very important, because these are the fundamental invariants of fiber spaces. Fiber spaces are very important;

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[1] *This paper presented a proof of Gauss-Bonnet that was less desirable than Chern's in that it relied on the fact that a Reimannian manifold can be locally isometrically embedded in a Euclidean space. Chern's proof used only intrinsic properties of the manifold.*

therefore, the characteristic classes come up. But it did not take me that much thought. They come up often, even the characteristic class c_1 comes up, because in electricity and magnetism you need the notion of complex line bundles. And the complex line bundles lead to c_1, which comes up in Dirac's paper on quantum electrodynamics. Of course, Dirac did not call it c_1. When c_1 is not zero, that's related to the so-called monopole. So characteristic classes are important in the sense that they come up naturally in concrete problems, fundamental problems.

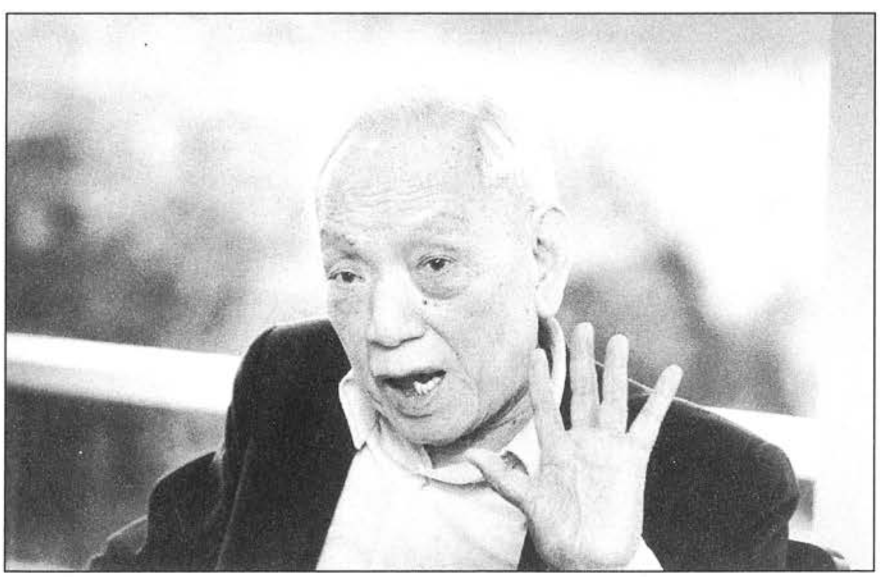
Notices: *When you first developed the theory of Chern classes in the 1940s, were you aware of Pontryagin's work and the fact that the Pontryagin classes of a real bundle could be recovered from the Chern classes of its complexification?*

Chern: My main idea is that you should do topology or global geometry in the complex case. The complex case has more structure and is in many ways simpler than the real case. So I introduced the complex Chern classes. I read the Pontryagin papers, but the real case is much more complicated. I didn't see his full papers, but I think he made some kind of announcement in *Doklady* in English. I learned from Hirzebruch the relations between Chern classes and Pontryagin classes.

Chern classes can be expressed in terms of the curvature, in terms of the local invariant. I was mainly interested in the relations between local properties and global properties. When you study spaces, what you can measure are the local properties. It's very remarkable that some local properties are related to the global properties. The simplest case of the Gauss-Bonnet formula is that the sum of angles of a triangle is 180 degrees. It shows up already in very simple cases.

Notices: *You are seen as one of the main exponents of global differential geometry. Like Cartan you have worked with differential forms and connections and so on. But the German school, of which Wilhelm P. A. Klingenberg is one of the exponents, does global geometry in a different way. They don't like to use differential forms, they argue with geodesics and comparison theorems, and so on. How do you see this difference?*

Chern: There is no essential difference. It's a historical development. In order to do, say, geometry on manifolds, the standard technique was Ricci calculus. The



Bay Laurels: Endowed Professorship Honors Chern

S. S. Chern is the recipient of many international honors, including six honorary doctorates, the U.S. National Medal of Science, Israel's Wolf Prize, and membership in learned academies around the world. He has also received a more homegrown honor, the dream-turned-reality of an appreciative student of 30 years ago, who grew up in the Bay Area.

When Robert Uomini would buy his 10 tickets for the California State Lottery, he had an unusual "what if I win?" fantasy: He wanted to endow a professorship to honor S. S. Chern. While an undergraduate at U.C. Berkeley in the 1960s, Uomini was greatly inspired by a differential geometry course he took from Chern. With Chern's support and encouragement, Uomini entered graduate school at Berkeley and received his Ph.D. in mathematics in 1976. Twenty years later, while working as a consultant to Sun Microsystems in Palo Alto, Uomini won $22 million in the state lottery. He could then realize his dream of expressing his gratitude in a concrete way.

Uomini and his wife set up the Robert G. Uomini and Louise B. Bidwell Foundation to support an extended visit of an outstanding mathematician to the U.C. Berkeley campus. There have been three Chern Visiting Professors so far: Sir Michael Atiyah of the University of Cambridge (1996), Richard Stanley of the Massachusetts Institute of Technology (1997), and Friedrich Hirzebruch of the Max Planck Institute for Mathematics in Bonn (1998). Jean-Pierre Serre of the Collège de France will be the Chern Visiting Professor for 1999.

The foundation also helps to support the Chern Symposium, a yearly one-day event held in Berkeley during the period when the Chern Visiting Professor is in residence. The March 1998 Symposium was co-sponsored by the Mathematical Sciences Research Institute and was expanded to run for three days, featuring a dozen speakers.

—A. J.

fundamental problem was the form problem, which was solved by Lipschitz and Christoffel, particularly Christoffel. And the Christoffel idea went to Ricci, and Ricci has his book on the Ricci calculus. So all these people, including Hermann Weyl, learned mathematics through the Ricci calculus. Tensor analysis had such an important role, so everybody learned it. That's how everybody started in differential geometry, with tensor analysis. But somehow in certain aspects, the differential forms should come in. I usually like to say that vector fields is like a man, and differential forms is like a woman. Society must have two sexes. If you only have one, it's not enough.

After spending 1943–45 at the Institute in Princeton, Chern returned to China for two years, where he helped to build the Institute of Mathematics at the Academia Sinica. In 1949 he became a professor of mathematics at the University of Chicago and in 1960 moved to the University of California, Berkeley. After his retirement in 1979 he continued to be active, and in particular helped launch the Mathematical Sciences Research Institute in Berkeley, serving as its first director from 1981 to 1984. Chern has had forty-one Ph.D. students. This number does not count the many students he has had contact with on his frequent visits to China. Because of the Cultural Revolution in China, the country lost many talented mathematicians and the tradition of mathematical research almost died out. Chern did much to regenerate this tradition. In particular, he was instrumental in starting the Nankai Institute for Mathematics in Tianjin, China, in 1985.

Notices: *How often do you get back to China?*

Chern: In recent years I go back every year, usually staying one month or longer. I started the institute at Nankai, and the most important thing is to get some good young people who will stay in China. In this respect we have been successful. Our new faculty includes Yimin Long (dynamical systems), William Chen (discrete mathematics), Weiping Zhang (index theory), and Fuquan Fong (differential topology). There are other very good young people. I think the main obstruction to the progress of mathematics in China is the low pay. By the way, the International Mathematical Union has chosen Beijing for the next International Congress of Mathematicians.

Notices: *Do you think that will be a big boost for mathematics in China?*

Chern: Oh, yes. But I think what I am worried about is that there will be too many mathematicians in China.

Notices: *It's a large country; maybe they need a lot of mathematicians.*

Chern: I think they don't need too many mathematicians. China is a large country, so naturally it has a lot of talent, particularly in the smaller places. For instance, there's the International Mathematical Olympiad for the high school students, and China generally does very well. In order to achieve well in competitions like this, the students need training, and as a result other topics could be ignored. Now the parents in China want their children to know more English, go into business, and make more money. And these exams don't give money. One year I think they just did less of this training, and China immediately dropped. What do you do for a country with 1.2 billion people? It means that the standard of living cannot be very high, if you have any social justice.

In 1934, when Chern chose to go to Germany for graduate study, geometry was a peripheral subject in the United States. By the time of his retirement in 1979, geometry counted as one of the most vibrant specialties on the U.S. mathematical scene. Much of the credit for this transformation goes to Chern. Still, he is modest about his achievements.

Chern: I don't think I have big views. I only have small problems. In mathematics a lot of concepts and new ideas come in, and you just ask some questions, you try to get some simple answer, and you want to give some proofs.

Notices: That's how you get your ideas, just observing things?

Chern: Yes, in most cases you don't have an idea. And in even more cases your ideas don't work.

Notices: You're describing yourself as a problem solver, rather than somebody who builds a theory.

Chern: I think the difference is small. Every good mathematician has to be a problem solver. If you are not a problem solver, you only have vague ideas, how can you make a good contribution? You solve some problems, you use some concepts, and the merit of mathematical contributions, you probably have to wait. You can only see it in the future.

It is very difficult to evaluate a mathematician or a part of mathematics. Like the concept of differentiability. Some time ago, twenty or thirty years ago, a lot of people just didn't like differentiability. I heard a lot of people who told me personally, "I'm not interested in any mathematics with a notion of differentiability." These are the people who tried to make mathematics simple. If you exclude notions involving differentiability you could exclude a lot of mathematics. But it's not enough. Newton and Leibniz, they should play a role. But it's interesting because there are ideas in mathematics which are controversial.

Notices: Can you give some examples of controversial ideas in mathematics?

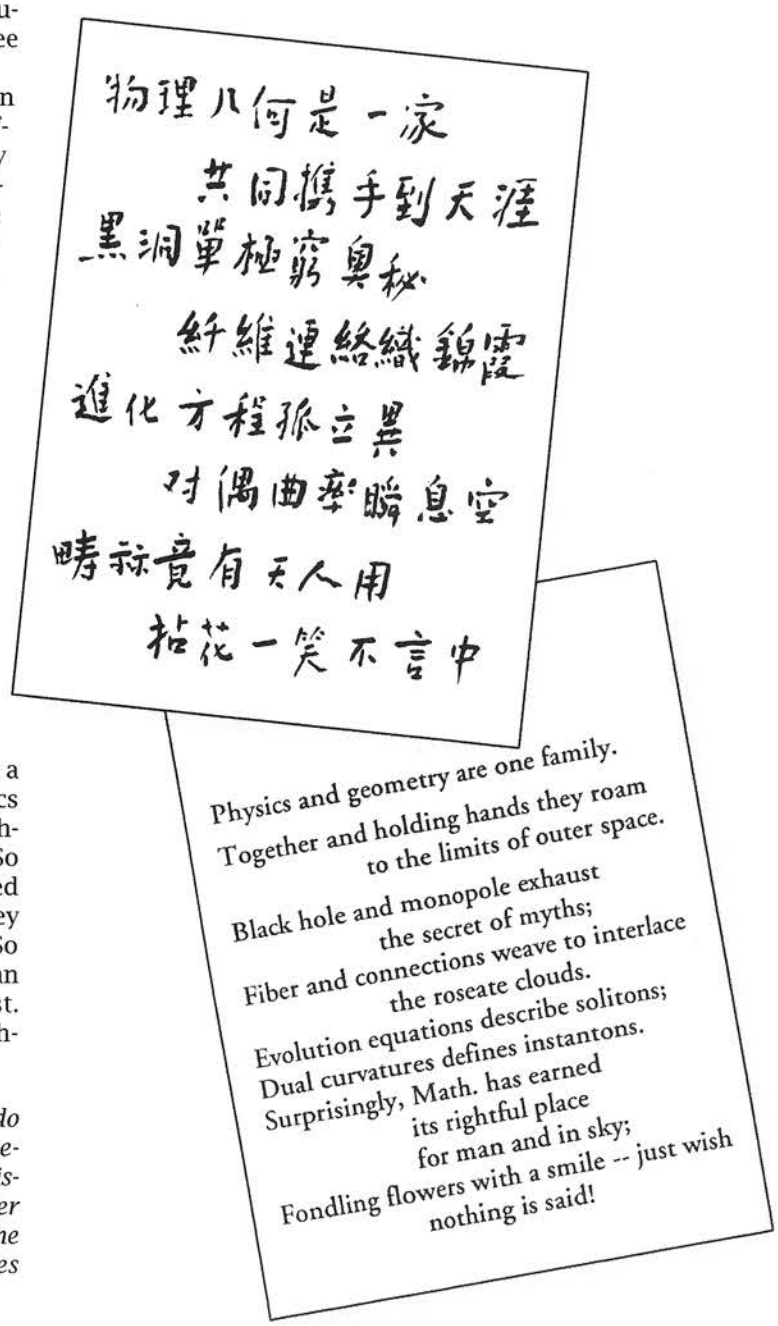
Chern: One thing is that some of the papers nowadays are too long. Like the classification of finite simple groups. Who is going to read 1,000 pages of proof? Or even the proof of the 4-color problem. I think people have to make mathematics interesting.

I think mathematics won't die soon. It will be around for some time, because there are a lot of beautiful things to be done. And mathematics is individual. I don't believe you can do mathematics with a group. Basically, it's individual. So it's easy to carry on. Mathematics does not need much equipment. It's not like other sciences. They need more material support than mathematics. So our subject will last for some time. Now, human civilization, I don't know how long it will last. That's a very much bigger problem. But mathematics itself, we will get along for some time.

At the age of eighty-six Chern continues to do mathematics. In recent years he has been especially interested in Finsler geometry, which he discussed in a Notices *article two years ago ("Finsler geometry is just Riemannian geometry without the quadratic restriction", September 1996, pages 959–963).*

Chern: Finsler geometry is much broader than Riemannian geometry and can be treated in an elegant way. It will be the subject of the basic course on differential geometry within the next ten years in many universities.

I have no difficulty in mathematics, so when I do mathematics, I enjoy it. And therefore I'm always doing mathematics, because the other things I cannot do. Like now, I am retired for many years, and people ask me if I still do mathematics. And I think my answer is, it's the only thing I can do. There is nothing else I can do. And this has been true throughout my life.



A poem written by Chern. Provided courtesy of T. Y. Lam.

Mina Spiegel Rees (1902–1997)

Judy Green, Jeanne LaDuke, Saunders Mac Lane, and Uta C. Merzbach

Judy Green and Jeanne LaDuke

Mina S. Rees died in New York City on 25 October 1997. Although she was probably best known in the mathematical community for her work with the Applied Mathematics Panel of the National Defense Research Committee during World War II and with the Office of Naval Research after the war, her influence on mathematics and science extended far beyond her years with the federal government. She was also known as a scholar and remarkably effective administrator, and she was extensively recognized for her farsighted contributions to the formulation of policies concerning mathematical research, federal support of science, and graduate education.

Mina Spiegel Rees was born 2 August 1902 in Cleveland, Ohio, and grew up in New York City, where she attended Hunter College, then a women's college. After her graduation summa cum laude in 1923, Rees became an assistant teacher at Hunter College High School and a full-time graduate student at Columbia. She recalled later, "When I had taken four of their six-credit graduate courses in mathematics and was beginning to think about a thesis, the word was conveyed to me—no official ever told me this, but I learned—that the Columbia mathematics department was really not interested in having women candidates for Ph.D.'s. This was a very unpleasant shock. Of course, this is certainly not at all true of the mathematics department at Columbia now. I decided to switch to Teacher's College and take the remaining courses necessary for an M.A. there."[1]

Rees received her M.A. in 1925 and was hired as instructor of mathematics at Hunter College in 1926. Having had an interest in associative algebras since her work at Columbia and realizing that she wanted to get a Ph.D. in that area, Rees decided to go to the University of Chicago so that she could study with Leonard Eugene Dickson, a leader in the field whose work she knew. However, when she arrived at Chicago in 1929 with a leave of absence from Hunter College, Dickson's attention had turned to number theory. Even so, he asked Rees to be his student, and she completed her dissertation in associative algebras under his supervision. The dissertation was published in 1932 in the *American Journal of Mathematics* [7].

After receiving her degree in 1931 Rees returned to Hunter College as an instructor. She was assistant professor 1932–40 and associate professor 1940–50, although with the advent of World War II her interests and talents were refocused, and she took an extended leave of absence from Hunter in 1943 to contribute to the war effort. Her publications during these first years at Hunter consist mainly of book reviews published in *Scripta Mathematica*.[2]

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This segment of the article is adapted with permission from the AWM Newsletter, *January-February 1998, pp. 10–12,*

[1] *Interview with Rosamond Dana and Peter J. Hilton in [1], p. 258.*

[2] *An extensive list of her other publications, along with material about her life and work, is found in: Phyllis Fox,* Mina Rees, *Women of Mathematics: A Biobibliographic Sourcebook, edited by Louise S. Grinstein and Paul J. Campbell, Greenwood Press, 1987, Westport, CT, pp. 175–181.*

In 1942 the National Defense Research Committee (NDRC) was established as a part of the Office of Scientific Research and Development. The Applied Mathematics Panel (AMP) was set up as a part of the NDRC the following year, and Warren Weaver, chief of the AMP, asked Rees to become a technical aide and his executive assistant. In that position and as secretary to the panel, Rees was in a central position with respect to the problems that were posed by the various military constituents, efforts to extract the mathematical essence of the problems, and the task of finding mathematicians to solve them. Rees represented the government in contracting the problems to various universities throughout the country. She described the activities of the panel in a 1980 article [11] in the *American Mathematical Monthly.* Shortly after the end of the war, Rees received the President's Certificate of Merit in this country and the King's Medal for Service in the Cause of Freedom awarded by the British government in recognition of wartime civilian services by foreign nationals.

In 1946 Rees went to Washington, DC, as head of the mathematics branch of the Office of Naval Research (ONR). Subsequently she was director of the mathematical sciences division, 1949-52, and then deputy science director, 1952-53. In a 1948 article [8] Rees noted that the ONR was committed "primarily to the support of fundamental research in the sciences, as contrasted with development, or with applications of known scientific results—the types of activity in which scientists were largely engaged during the war." The article goes on to describe activities in pure mathematics and in applied mathematics, including especially mathematical statistics and computer theory and development. The significance of Rees's role at the ONR was recognized in a resolution adopted by the Council of the AMS at its annual meeting in December 1953 and in a similar resolution adopted by the Institute of Mathematical Statistics. The former reads in part:[3]

> Under her guidance, basic research in general, and especially in mathematics, received the most intelligent and wholehearted support. No greater wisdom and foresight could have been displayed and the whole postwar development of mathematical research in the United States owes an immeasurable debt to the pioneering work of the Office of Naval Research and to the alert, vigorous and farsighted policy conducted by Miss Rees.

[3]*Bull. Amer. Math. Soc.* ***60*** *(1954), 134.*

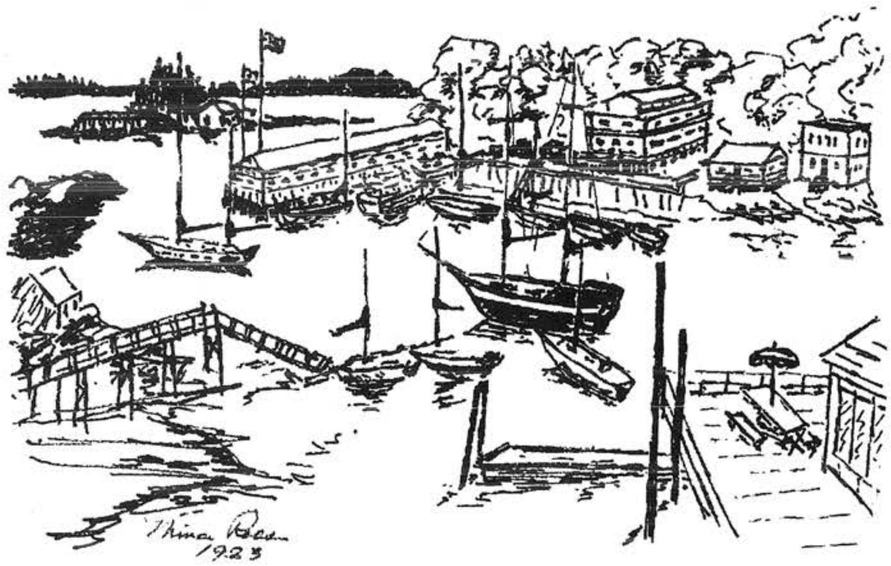
Mina Rees

In the 1950s Rees wrote a number of articles that convey a sense of the wide range of her interests at that time. Among these is a remarkably comprehensive one [9] on the federal computer program that appeared in *Science* in 1950, having first been delivered as an invited address to the then recently founded Association for Computing Machinery. In 1952 she published a research article [2] with Richard Courant and Eugene Isaacson in *Communications on Pure and Applied Mathematics.* She wrote several other articles, especially on computers and computing and on expanding roles for mathematicians.[4] Thirty years later Rees contributed more to the history of that period. An important survey [12] of the computing program at the ONR first appeared in 1982. Rees was also a member of the MAA committee on World War II history and contributed financial support for the preparation of a history of the Institute for Numerical Analysis at UCLA that had been commissioned by the National Bureau of Standards and the ONR.

Rees returned to Hunter College as professor of mathematics and dean of the faculty in 1953 and remained in those positions until 1961. In 1955 she married Leopold Brahdy, a physician who died in November 1977. During her tenure as an admin-

[4]*See, for example,* Digital computers—their nature and use, *American Scientist* ***40*** *(1952), 328-335, and* Mathematicians in the market place, *Amer. Math. Monthly* ***65*** *(1958), 332-343.*

Sketches of scenes from Maine by Mina Rees, courtesy of Saunders Mac Lane.



Pleasure Boats at Anchor, Booth Bay, Harbor, Maine. 1923

istrator at the college, Rees was appointed to numerous boards and committees by the National Research Council, the National Bureau of Standards, and the National Science Foundation, among others. For example, she served as consultant to the Bureau of the Census to prepare for machine handling of the 1960 census data. Details about many of these positions can be found in the citation accompanying the MAA's first Award for Distinguished Service to Mathematics, which she received in January 1962.[5] Two years later the United States Senate confirmed her appointment to a six-year term on the National Science Board.

In 1961, when the City University of New York was established, Rees was appointed professor and dean of graduate studies. At that time the university consisted of three community colleges and four senior colleges: City, Hunter, Brooklyn, and Queens. Rees was instrumental in developing and shaping graduate studies at CUNY. She was provost of the graduate division 1968–69 and was appointed as the first president of the Graduate School in 1969. In 1970 a colleague described Rees in [13] as "a person of engaging warmth and liveliness, of boundless energy, and—foremost—of an extraordinary directness and clarity in interpretation, giving sight to imagination." She retired as president emeritus in 1972.

As the 1965 American Association of University Women Achievement Award Winner, Rees was described as the only woman dean of a graduate school in a coeducational institution. Rees [10] noted at the time:

> It may be because the Graduate Dean is a woman, or it may be for completely objective reasons, that ours is proving an ideal university to draw into advanced graduate work the most obvious source of unused talent in a society that desperately needs additional numbers of persons with training through the doctorate, namely, women.

Among attractions to women offered by the Graduate School, she added, "we have welcomed qualified women who have applied even to the extent of considering the need for a babysitter a proper reason for providing financial assistance." In a similar vein, Rees was a supporter of the Association for Women in Mathematics. Her 1990 letter accompanying a generous contribution to AWM's Schafer Prize Fund[6] reads in part, "I was …thrilled at the clear indications that we shall be producing truly distinguished women mathematicians in the immediate future who will carry on the trend that is well on its way."

Mina Rees held policymaking positions in a number of professional societies: she served as a trustee of the AMS, on the board of directors of the Society for Industrial and Applied Mathematics, and as chair of the Council of Graduate Schools in the U.S., among others. In 1970, shortly before her retirement and after many years of service within the association, Rees became president-elect of the American Association for the Advancement of Science (AAAS). The following year she served as president, the first woman in this position since the founding of AAAS in 1848. Furthermore, she is the last of the eight mathematicians who have held this position to date.[7]

In 1983 Rees was awarded the Public Welfare Medal by the Council of the National Academy of Sciences. The citation accompanying the award,

[5]Award for Distinguished Service to Mathematics, *Amer. Math. Monthly* **69** *(1962), 185–187.*

[6]*The Schafer Prize is awarded annually to an undergraduate woman in recognition of excellence in mathematics.*

[7]*Presidents of AAAS who can be considered mathematicians are Benjamin Peirce (1852 and 1853), Simon Newcomb (1877), H. A. Newton (1885), R. S. Woodward (1900), E. H. Moore (1921), G. D. Birkhoff (1937), Warren Weaver (1954), and Mina Rees (1971). We thank Mary Beth Ruskai for pointing out the paucity of mathematicians among presidents of AAAS.*

described by NAS as "one of the most prestigious of the National Academy honors,"[8] reads:

> for her contributions to the scientific enterprise, especially in mathematics, astronomy and computer science, from wartime through the transition from war to peace and continuing today.

Rees later commented that the award was "intended to focus on the benefit to the country of the development of science and its application." She also explained that "it gives you all the privileges of the academy except electing members."[9]

Among many honors not yet noted are at least eighteen honorary degrees from U.S. colleges and universities. Finally, as a lasting tribute to her academic and professional excellence, the library at the Graduate School and University Center of CUNY was dedicated in 1985 as the Mina Rees Library.

Saunders Mac Lane

About 1928 Mina Rees enrolled as a graduate student of mathematics at the University of Chicago. She later told me that previously, in her studies in New York, she had learned of the research of Professor Dickson at Chicago on associative algebras, and she hoped to prepare a thesis in this field. When she arrived at Chicago, she found that he was no longer active in this field, but had turned his attention to Waring's problem and his students were now working on that. Nevertheless, she succeeded in getting him to direct her thesis in algebra. This thesis is now in the Eckhart Library in Chicago.

I graduated from Yale in 1930. President Hutchins had arranged for me to have a good fellowship at Chicago. I was an aggressive student there; I met Mina and many others. Someone even suggested that she should consult me about her review for the Ph.D. exam; this of course did not happen. She and I at one point played tennis on one of the university courts. She passed her exams with no trouble. Julia Bower, a fellow graduate student of Mina's at Chicago, said the following of her.[10]

> You and I knew Mina Rees during our first year at Chicago.... Vibrant would be a word to describe her. She was happily and totally interested in the people around her and in all the events taking place. I sat next to her in one of Professor Lane's classes. While most of us were busily taking notes, she sat there concentrating every fiber of her mind on what was being said, only occasionally writing something or making an intelligent remark or asking an intelligent question. I had the feeling that she was so thoroughly absorbing the important points that she would not need to do any further studying at all.
>
> I believe that all of her life she went directly to the heart of a problem and dealt with it efficiently. Yet she had patience with those who were not so bright. She really liked people and enjoyed being with them.

At that time, the University had many—maybe fifty or more—graduate students in mathematics, chiefly hoping to get a Ph.D., for which a research thesis was required. However, the chairman, Gilbert A. Bliss, was realistic. He guessed that many of them would not continue in research; in fact, he at one point said that the thesis research was there to have the students learn what research was like so as to give background for their subsequent teaching. So some, but by no means all, went on to do research—for example, Adrian Albert, a student of Dickson in algebra, obtained his Ph.D. in 1928; E. J. McShane in 1930; and Magnus Hestenes, about 1933.

At that time the three leading mathematics departments were Harvard, Princeton, and Chicago. A number of other universities had groups of mathematicians active in research; examples include Yale, Michigan, and Wisconsin.

Jobs for the new Ph.D.s were arranged by the old boys' network. Bliss knew all the department chairmen and chose which students to recommend where. There were a considerable number of women among them (none at Princeton, few at Harvard). Often the Chicago women Ph.D.s were sent to teach at women's colleges; at that time, only Bryn Mawr among the women's colleges was active in research in mathematics. Mina went back to Hunter College in 1931.

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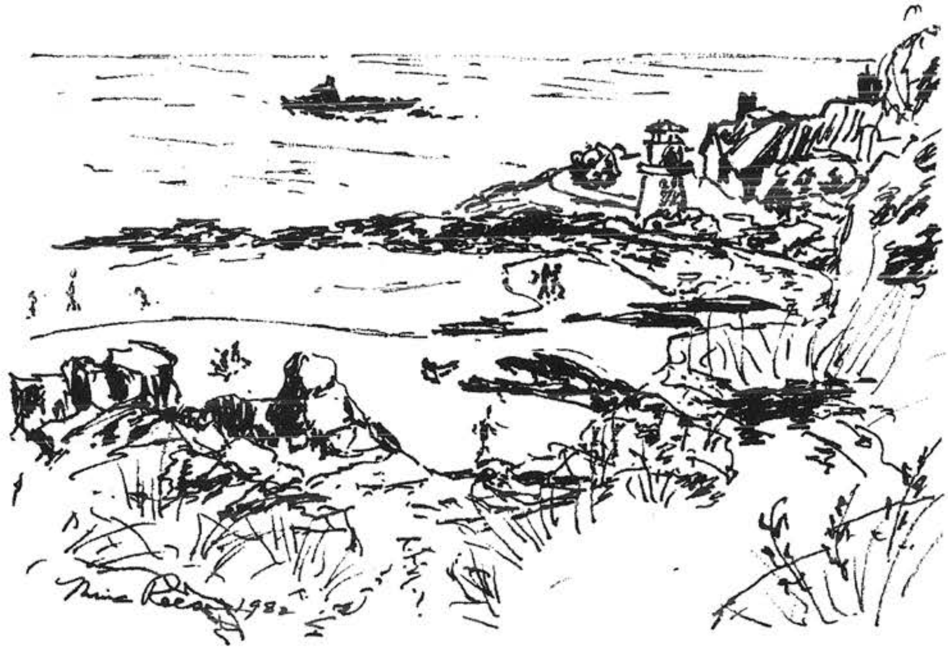
[8]Rees Awarded Medal, *AWM Newsletter* ***13**, no. 3 (May-June 1983), 9.*

[9]*Interview with Rosamond Dana and Peter J. Hilton in [1], p. 263.*

[10]*Excerpt from a letter to Saunders Mac Lane in April 1998 from Julia W. Bower.*

Saunders Mac Lane is Max Mason Distinguished Service Professor, Emeritus, at the University of Chicago. This segment is adapted from a statement made at a memorial service December 8, 1997, at the Graduate School and University Center, CUNY.



Bathing Beach on the Marginal Way Ogunquit, Maine. 1982

Mina's 1931 Ph.D. thesis was published in the *American Journal of Mathematics* as "Division algebras associated with an equation whose group has four generators" [7]. It dealt with the construction of certain associative algebras by highly computational methods. Those methods had been developed at Chicago by Dickson, who had written a book about them, *Algebras and Their Arithmetics* [3].

Mina's return to Hunter in 1931 represents a missed opportunity for mathematics. In fact, Mina Rees's graduate study came at exactly the time when there was an ongoing great revolution in algebra: "modern algebra" was developed in Göttingen by Emmy Noether and was supported by Emil Artin, Helmut Hasse, and B. L. van der Waerden. Van der Waerden's splendidly influential book *Modern Algebra* did not appear until 1930–31 and did not at once attract attention in this country. I had the good luck to learn of Noether's work in 1929 at Yale from Professor Oystein Ore and from a Noether-influenced (but pedantic) text by Otto Haupt.

When I arrived for graduate study at Chicago in the fall of 1930, I was surprised to find there little or no knowledge of Noether's work. I did not understand that it could be applied to the Chicago specialty of linear associative algebras. Consequently I did not discuss it with Mina, even in connection with her thesis. I learned that Adrian Albert had recently written a Chicago thesis on linear algebras and had won a National Research Council Fellowship for postdoctoral study (at Princeton). For my part, I wrote an M.A. thesis reflecting some ideas in abstract algebra, and in June shook the dust of Chicago from my feet to go study in Göttingen; I somehow knew that there was real logic and algebra there.

On my arrival, Professor Hermann Weyl told me that Fraulein Noether was the leading algebraist—his equal. So I listened to Noether's (sometimes confusing) lectures on hypercomplex systems. I was startled to find that she often cited an influential German translation *Algebren und Ihre Zahlentheorie* of Dickson's book—though I had not heard Dickson talk about his book in his course in number theory. I heard from Noether about the use of factor sets, but did not then understand them. Much later I did. They made Mina's thesis obsolete. The idea used by German group theorists in the 1920s is simple: Try to describe a group G in terms of a given normal subgroup N and the corresponding factor group Γ. The group consists of cosets Nu_σ, one for each σ in Γ. The group law for G follows from knowing how to multiply u_σ and u_τ. Write $u_\sigma u_\tau = f(\sigma, \tau)u_{\sigma\tau}$ with $f(\sigma, \tau)$ in N. Then write the associative law as an equation in f's. This f is a *factor set.* Factor sets provide a startling simplification of the cumbersome verification of the associative law for linear algebras as then done in the Chicago school. They work for algebras: For example, to get the quaternions, start with the complex numbers $\mathbb{C}$ and their Galois group over the reals, which is cyclic of order 2 with generator j. The action of j on $\mathbb{C}$ is given by $jc = \bar{c}j$, and the formula for the factor set comes down to $jj = -1$. Dickson's cyclic algebras had carried out this construction for arbitrary cyclic groups. Noether's lectures in Göttingen in 1929–30 first used factor sets for arbitrary finite groups to define associative algebras as crossed products. I personally did not understand factor sets well at the time of Noether's lectures, but later Eilenberg and I used factor sets to invent the cohomology of groups, as is explained in [4]. They still involve heavy computation.

The late Adrian Albert once told me that his own study of Dickson's construction of cyclic algebras led him to invent factor sets on his own. He showed them to Professor Dickson, who dismissed them as too much formality. Dickson had shifted his interests back from algebra to number theory (as I know from his 1930–31 course). His real motto was "One subject at a time".

Now for a missed opportunity for mathematics in connection with Mina. Mina's thesis was finished in the spring of 1931. Professor Dickson might then have recommended her for an NRC postdoctoral fellowship. If she had won one, and if she had heard of Noether, she could have gone to Göttingen, where she would surely have attended Noether's lectures on hypercomplex systems and factor sets. From Mina's subsequent accomplishments we know that she would have understood these notions and made use of them to simplify her earlier proof. We know that Emmy Noether took care of her associates and students, both men and women. We also know about Mina and so can imagine many splendid research results. But it was not to be.

Yes, I understand. A fellowship for a woman was not the way the mathematical world usually worked then. At that time I would not have dared to talk back to Professor Dickson, a towering figure in American mathematics.

The work of the Germans essentially made Mina's thesis obsolete. It would then have been very hard for her to do further effective research—quite aside from the situation that women mathematicians at that time were not expected to do research. Indeed, she did not publish any further research in the next decade.

War research from 1941 in physics and such subjects was active in Chicago, but there was little use of mathematicians, to the disgust of leaders such as Marston Morse and Marshall Stone. Warren Weaver, an applied mathematician from Wisconsin, then an assistant director at the Rockefeller Foundation, was active in the NRDC and the OSRD. Early in 1943, in a shift, an "applied mathematics panel" was established. This panel established "applied mathematics groups" at Columbia, Princeton, and later NYU and Northwestern. These groups had government contracts and hired mathematicians and other scientists to do war research on problems proposed by the Government Applied Math Panel. To oversee this work, Weaver had several so-called "Technical Aides". I believe they were government appointees. Mina Rees was one of these. Richard Courant had recommended her to Weaver.

The Rocks at Ocean Point, Maine, 1983

From April 1943 to September 1945, with one gap, I was a member of the "Applied Math Group, Columbia (AMG-C)" and was its director for the last year. In this connection I knew of Mina's work for AMP. I do not recall any detailed connection of her work with AMG-C; we had a different Technical Aide, to whom I paid little attention. I negotiated directly with Weaver and often disagreed with him. Mina admired him. Many years later she wrote a biographical memoir on Weaver for the National Academy of Sciences.

The planned National Science Foundation was not set up directly at the end of the war, but the government support of scientific research was considered important and was then carried out by the defense agencies, especially by the Office of Naval Research (ONR). Alan Waterman (later the first director of the NSF) headed the ONR, and Mina was the program director for mathematics there. The work was successful. Mina once told me that it was then easy to get "peer review" for the projects proposed; she knew all the leading mathematicians and called them up for advice about projects.

After this stint Mina returned to Hunter College. I saw her from time to time, though I never met her husband. For many years she and I exchanged Christmas cards; in particular one such included her sketches of scenes from Maine.

In 1983 Mina was awarded the Public Welfare Medal of the National Academy of Sciences. This is a medal awarded once a year to a person who has made important contributions to science, but not of the nature of research. The other mathematician to have received the medal was Warren Weaver, who received it in 1957.

Mina was a member of the National Science Board from 1964 to 1970. R. H. Bing, a mathematician from Wisconsin and Texas, was also a member for an overlapping period. He told me that the interaction of two mathematicians helped greatly. Since then there have never again been two mathematicians on the National Science Board at the same time.

Uta C. Merzbach

When the National Academy of Sciences chose to honor Mina Rees with its Public Welfare Medal, she received an award described by the original proponent[11] as "a medal for eminence in the application of science to the public welfare." When the mathematical community chooses to honor Mina Rees's contributions, it is for eminence in the application of public policy to the welfare of mathematics.

Certain personal characteristics enabled Mina Rees to promote basic research so effectively and to establish a solid foundation for sustained public support of mathematics.

Mina Rees was eminently rational. Her devotion to reason helped her formulate goals clearly and allocate resources judiciously in accordance with these goals. This applied to decisions concerning her career as much as it did to dispensation of public funds. In neither area did it always meet with approval or understanding. She could be a tough contract administrator. There were engineers who never forgave the woman whom they regarded as the epitome of the autocratic Washington administrator with little understanding for cost overruns. At the same time there were mathematicians who never forgot to praise this colleague, whom they saw as their support for unfashionable causes such as the revitalization of research in numerical analysis.

Mina Rees was eminently intelligent. She comprehended quickly, communicated effectively, and thought creatively. Her ability to attach realizable pieces of basic research to mission-oriented applications of mathematics did much to develop a broadened base of support for mathematicians' work.

Mina Rees was eminently civilized. Her diplomatic skills were considerable; her conversational technique bespoke her broad knowledge base as well as her wide interest in mathematical and nonmathematical topics. Experience and reflection led her to a balanced outlook on teaching and research, the arts and the sciences, long-range and short-range planning, and the obligations of the professional and the private life.

In recalling meetings and conversations with Mina Rees, another, less well-known, characteristic comes to mind. It pertains to her interest in the history of her time. My acquaintance with her dates back to the 1960s. She had taken charge of the graduate program at CUNY; I was interested in learning more about her activities at the Applied Mathematics Panel and with ONR. We had stimulating conversations, but when I requested that she provide the Smithsonian's Computer History Project with some formal taped interviews, she initially demurred, explaining that that part of her life was over and that she could probably provide little information. Although she did agree to the interviews, I was puzzled by her reluctance. Neither her memory nor her self-assurance seemed to be impaired. Was it a disregard for history, a feeling that she had more important things to do? More than a decade and more conversations passed before I realized that just the opposite was true. She had a keen sense for the difference between anecdotal and documented statements. She shared the concern of her contemporaries Bailey Price, Barkley Rosser, and others that the contributions of American mathematicians in the critical years of World War II and the immediate postwar era be properly documented and revealed. Her autobiographical publications of the 1980s were largely the result of the realization that neither she nor her contemporaries would live to see the day when a qualified scholar had written the history of that period. In making her own contribution toward that day, she was meticulous in checking her sources, cross-checking her memory and that of her colleagues, and ensuring that she followed proper stylistic protocol. I know no graduate student more concerned than Mina Rees when she telephoned to ensure that she had used a proper citation style for a bibliographic reference.

Above all, Mina Rees was a mathematician who loved mathematics and believed in supporting those who are capable of contributing to its growth and propagation. She persuaded relevant members of the mathematical and governmental power structures that mathematicians can provide important public service and that such service to the public sector is most fruitfully balanced between theory and applications. With this singular accomplishment she provided the framework after World War II that enabled mathematicians to ben-

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[11] *George F. Becker in 1909, quoted in the interview with Rosamond Dana and Peter J. Hilton in [1], p. 262.*

efit from public support and to multiply their institutional foci.

We are memorializing Mina Rees at a time when the interest of young Americans in mathematical research is at a low point. In 1948 she wrote an article [8] in the *Bulletin* intended to acquaint the American mathematical community with the work of her division at the Office of Naval Research. The piece is of interest for the clear formulation of goals, the diplomatic approach in enlisting support, and the understanding of the narrow base of mathematical research in the United States at the end of World War II. A half century later her motivational call is still pertinent:

> It is hoped that the impact of this program on the mathematical life of the United States will be in the direction of stimulating significant mathematical research, and of enabling the faculties of universities in all parts of the country to encourage the interest in mathematical research of their most promising students. It is expected that this activity will contribute toward the production of a gradually increasing corps of able and experienced mathematical research workers.
>
> In its broad outline, the ONR program reflects the Navy's recognition that intensive research in certain fields of applied mathematics may be counted upon to yield specific results directly applicable to engineering and other scientific problems and therefore of use to industry and research laboratories as well as to Naval establishments; but it reflects also the recognition that a lively activity in mathematical research and a sustained growth in the number of mathematically trained personnel are necessary to enhance the scientific life of this country and to maintain the position of the United States relative to scientific progress abroad.

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Book Review

Impostures intellectuelles

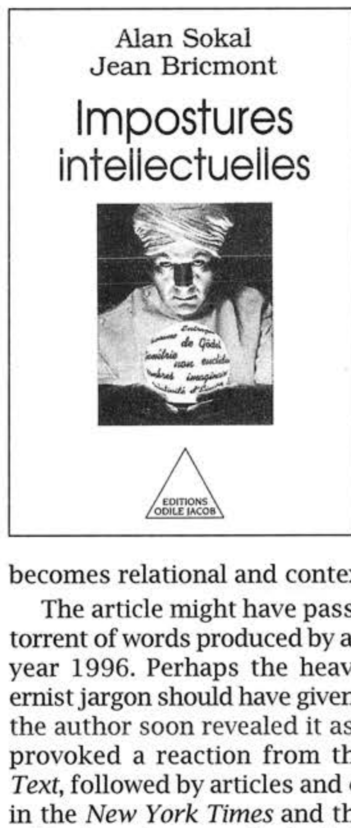
Reviewed by William G. Faris

Impostures intellectuelles
Alan Sokal and Jean Bricmont
Éditions Odile Jacob, Paris, 1997
Softcover 140 Francs (ISBN 2-7381-0503-3)

Quantized Relativity

In 1996 the mathematical physicist Alan Sokal published an article [S1] in the cultural studies journal *Social Text*. He argued that "deep conceptual shifts within twentieth-century science have undermined [the] Cartesian-Newtonian metaphysics... It has thus become increasingly apparent that physical 'reality', no less than social 'reality', is at bottom a social and linguistic construct...the truth claims of science are inherently theory-laden and self-referential; and consequently, that the discourse of the scientific community, for all its undeniable value, cannot assert a privileged epistemological status with respect to counter-hegemonic narratives emanating from dissident or marginalized communities."

Sokal's professed aim was "to carry these deep analyses one step farther, by taking account of recent developments in quantum gravity: the emerging branch of physics in which Heisenberg's quantum mechanics and Einstein's general relativity are at once synthesized and superseded." Space-time no longer exists as an objective physical reality. "When even the gravitational field—geometry incarnate—becomes a noncommuting (and hence nonlinear) operator, how can the classical interpretation of $G_{\mu\nu}$ as a geometric entity be sustained? Now not only the observer, but the very concept of geometry, becomes relational and contextual."



The article might have passed unnoticed in the torrent of words produced by academics during the year 1996. Perhaps the heavy use of postmodernist jargon should have given it away. In any case, the author soon revealed it as a parody [S2]. This provoked a reaction from the editors of *Social Text*, followed by articles and exchanges of letters in the *New York Times* and the *New York Review of Books* and eventually in *Le Monde*. The dispute also generated new texts in the ultimate postmodern format, the Web page.

A scientifically alert reader might notice immediately that the article is not serious. For instance, in quantum mechanics the fundamental structure is a noncommutative algebra of operators, but Sokal's casual equation of noncommutative and nonlinear is ludicrous to a quantum physi-

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Editor's Note: *The topic of the book under review was also explored in "A mathematician reads* Social Text*", by Michael C. Sullivan, and "A report from the front of the 'Science Wars'", by Evans M. Harrell, both of which appeared in the October 1996 issue of the* Notices.

cist. One of the strangest features of quantum mechanics is that it is an entirely linear theory.

Relativistic Science

The book by Sokal and Bricmont—mathematical physicists who know the difference between noncommutative and nonlinear—continues the attack, implicit in the Sokal parody, on postmodernist views of science. It argues that relativistic views of science are both prevalent and wrong. It proceeds on two fronts. The first is criticism of authors said to use scientific language and metaphors in a misleading way. Those who merit chapter headings are Jacques Lacan, Julia Kristeva, Luce Irigaray, Bruno Latour, Jean Baudrillard, Gilles Deleuze, Félix Guattari, and Paul Virilio. These are French writers whom Sokal and Bricmont consider to be influential on postmodern thought in the United States.

Some of these writers produce quite extravagant prose. One author (Virilio) claims that "it seems necessary to reconsider the importance of the notion of ACCELERATION and DECELERATION (positive and negative velocities according to physicists)." (The capitals are in the original text.) Another (Baudrillard) suggests that "one should perhaps consider history itself as a chaotic formation where acceleration puts an end to linearity." After reading a number of these extracts, it is a pleasure to encounter a quoted paragraph that presents a clear and eloquent explanation of the principle of relativity; Galileo wrote it in 1632.

Sokal and Bricmont's other front is a more general attack on relativism in the philosophy and sociology of science. This is the notion that the validity of a scientific assertion is relative to an individual or to a social group. Sokal and Bricmont begin by a dismissal of radical skepticism, the doctrine that our sensations are not adequate to give us access to reality. They consider this to be a general philosophical position that applies to all forms of knowledge equally. They do not claim to refute it, but instead argue that a skepticism this universal cannot be relevant to the discussion of the reliability of particular forms of knowledge.

The real question is the degree to which scientific practice has a rational basis. Sokal and Bricmont insist on the continuity of scientific rationality with rationality in other areas of human knowledge and in everyday life. They admit that there is no definitive and complete codification of scientific practice, and they present the example of a police investigation as an analog of scientific research. In both cases principles of good practice arise through experience.

They also discuss a movement sometimes known as the "strong program" in the sociology of science [BBH]. This is a sociological explanation of the conditions that give rise to scientific beliefs. Some proponents maintain that the particular beliefs a person prefers to hold will generally coincide with those of other persons in the same community, and the words "true" and "false" are the language in which the preferences are expressed. Sokal and Bricmont consider this position ambiguous: either it falls into radical skepticism (there is no reality beyond our inadequate perceptions), or it itself relies on the external reliability of science. When Sokal believes that he has taken his morning coffee, then that is not the expression of a preference, but an attempt to record a fact. He might have broken his pattern and taken morning tea. If he forgot this switch to tea, then his belief is wrong. The tea bag may remain as evidence, if it has not gone out with the garbage.

Scientific Truth

Who could doubt such conclusions of common sense? Even a postmodernist might agree with the fact that Sokal took his morning coffee, or tea. Perhaps language is in some circumstances an innocent tool for describing a world of subjects and objects. But is this so common? The use of language in many spheres of life is as much instrumental as descriptive. An advertiser wants Sokal to change to another brand of coffee. A neighbor offers tea and conversation simply to affirm friendship. An activist (cited in the Sokal parody) has a political purpose: "to develop *strategic* theories—not true theories, not false theories, but strategic theories."

The concept that there are multiple uses of language is quite acceptable in philosophy of science provided that there is some way to insulate the truth-telling function of language from its other uses. However, this is difficult, precisely for the reasons that Sokal and Bricmont describe. In their view, "historians, detectives, and plumbers—in fact, all humans—use the same methods of induction, deduction, and evaluation of facts that physicists and biochemists use." Modern science is only more systematic and precise. Furthermore, they agree with Feyerabend when he claims that "the idea that science can and should be organized according to fixed and universal rules is at the same time utopian and pernicious."

If one judges the epistemological basis of science by the standards of physical science and mathematics, then the lack of fixed and universal rules is troubling. Can there not be a decent general theory of truth in science? The idea is not absurd. The logical positivists made an attempt to find such a theory; the fact that it failed does not say that it was not worth the effort.

Truth in mathematics is a somewhat different story. The logician Tarski gave a precise definition of truth for sentences in a formalized language interpreted in a universe of mathematical objects. However, Tarski then proved that the criterion for truth in a language cannot be formalized in the language itself. (See Smullyan's book [Sm] for an elementary but precise treatment.) This seems un-promising for a general theory of truth, even though there have been attempts to supersede the Tarski analysis [BE]. Of course, a theorem about truth in formalized mathematical languages is not directly relevant to other areas of discourse, and linguists debate the extent to which the semantics of natural languages resembles that of mathematical logic [H]. In any case, if it is difficult to characterize truth in the limited context of mathematics, then it may be even more difficult in empirical sciences. What if only some principle of pragmatic functioning is attainable? Is this enough to ward off relativism? Could there be but one universal truth: universal rules are impossible?

Mathematical practice does not require a complete characterization of mathematical truth. The notions of axiom system and mathematical proof already provide a rich and useful system. However, even here the foundations are obscure. In the *Social Text* article [S1] Sokal says, with humorous intent, that mathematicians "are often content to work in the hegemonic framework of Zermelo-Fraenkel set theory—but this framework is notoriously insufficient for a mathematics of liberation." Indeed, this framework is arbitrary, and some mathematicians have proposed both serious critiques and alternatives. To cite only one example, there are category theorists who do not regard the category of sets as privileged; it is only one category among many. In particular, certain categories of "variable sets" provide new settings for constructions of analysis and geometry [MR]. A recent text [LS] promotes the categorical point of view at the level of the general reader or beginning student.

Truth in Quantization

The major gap in the Sokal-Bricmont book is that it avoids dealing with the status of quantum mechanics. If Sokal had chosen a different area of physics, would he have been able to pull off the hoax? Though there are numerous scientific absurdities in the *Social Text* article, its heart is the confusion over the foundations of quantum mechanics. This confusion is a major weak point in modern physical science. Numerous popular writings about science exploit this obscurity, but the book does not address this issue. Writers who confuse velocity and acceleration are comparatively easy targets.

When Sokal and Bricmont briefly mention quantum mechanics, they recommend the recent book of Albert [A] as an introduction to nonspecialists. This is an excellent book, but the ideas are hardly comforting to Sokal and Bricmont's view that modern science is an extrapolation of common sense. Albert concludes his book with an interpretation of quantum mechanics due to Bohm and with another interpretation that he calls the "many-minds" theory. According to Albert, "what a 'many-minds' theory takes physics to be ultimately about is *what observers think*; and it entails that there will be frequently not even *matters of fact* about *where things go*." (The italics are in the original.) The Bohm theory and the many-minds theory are incommensurable. Thus, again according to Albert, "questions about the structure of space and time, and questions about whether the world is deterministic (which were supposed to be the two central questions of the physics of this century, and which both happen to be questions on which these two theories radically disagree with one another), are the kinds of questions which there can't ever be scientific answers to. Period." Is this an extrapolation of common sense? No, it is scientific authority in full retreat. What kind of hegemony is that?

Clearly quantum mechanics is one of the greatest successes of science. Yet something remains to be said before the full truth is known. (See Wick's recent book [W] for a fuller account of the quantum quandary.) One can take Sokal [S1] entirely seriously when he says that "images of the future mathematics must remain but the haziest glimmer: for, alongside these...young branches in the tree of science, there will arise new trunks and branches—entire new theoretical frameworks—of which we, with our present ideological blinders, cannot yet even conceive."

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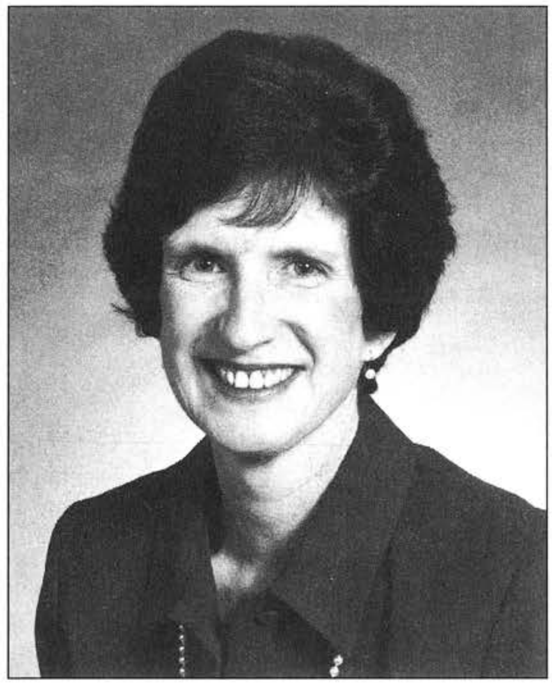
Jane Kister Appointed Executive Editor of *Mathematical Reviews*

"I don't come from a mathematical family," says Jane Kister. "At least, not until recently." Her father was a lawyer and then a judge until he retired at the age of seventy-five. At that point he took up mathematics and began working his way through an undergraduate degree in the subject at the Open University in the United Kingdom. He is now eighty-one. "He hopes to graduate in a couple of years when he has enough credits," says Kister. "I'm extremely proud of him."

And no doubt he is proud of his daughter. In July of this year Kister moved into the top post at *Mathematical Reviews*, that of executive editor. Beloved by the staff of MR's Ann Arbor office—and by many in the AMS Providence headquarters as well—Kister brings to this position experience and expertise that are hard to beat. Having worked at MR for nearly twenty years, she has shown her father's dedication and perseverance in mastering all facets of the MR operation. She succeeds R. Keith Dennis, who finished his term in July and will return to Cornell University in the fall.

Kister received her Ph.D. in mathematical logic from Oxford University in 1972 (she was a student of Robin Gandy, which makes her a mathematical granddaughter of Alan Turing). In 1978, known by her maiden name, Jane Bridge, she held a tenured faculty position at Oxford University and had no intention of leaving until she met and married University of Michigan topologist James Kister. As with many women mathematicians, her personal circumstances influenced her career path, and in 1979 she became an associate editor at MR. In 1984 she moved up to the position of associate executive editor.



Jane Kister

When Kister first came to MR, it had been publishing around 30,000 reviews per year and was only just starting to develop means of electronic delivery. Today she oversees an operation that will process at least 65,000 items in 1998 and makes reviews available through several different media, including the World Wide Web product MathSciNet. "MathSciNet has revolutionized the way people use the MR database," says Kister. "In part because they have access at their own desks, more people are accessing MR, and they are doing so more often than they did when only paper was available." One question that arises is whether the availability of MathSciNet is causing people to use the MR database in new ways. Kister plans to investigate this question through a survey and to use the survey results to assess what enhancements might be the most useful. Changes in how people use the MR data might also argue for changes in editorial procedures. For example, a great deal of effort has been put into making the reviews grammatically as well as mathematically correct. However, because MathSciNet includes links between reviews and is starting to include links from reviews to original articles that are available on the Web, it may be more important to make sure the references are appropriate and, of course, 100 percent accurate. "We will try to do both," she says.

The electronic delivery of MR has come a long way, but the production and acquisition process remains tied to paper. "The production pipeline has been honed over the last almost sixty years," says Kister. "It works extremely well, but it is based on paper: paper copies of original items and paper review manuscripts." Even reviews that arrive electronically are printed out for processing, for this is the simplest way to fit them into the current production scheme. Kister says that one of the main priorities for MR over the next few years is to develop a production pipeline that allows for electronic processing and editing. The lack of good online editing tools—whereby changes can be indicated by one person, checked by another, and implemented by a third—has been an obstacle. In addition, MR would like to develop a system whereby reviewers of papers that appear in electronic journals can obtain papers electronically, either on the Web or in e-mail.

Today she oversees an operation that will process at least 65,000 items in 1998 and make reviews available through several different media, including the World Wide Web product MathSciNet.

Another task for the AMS is to improve the onscreen appearance of MathSciNet. Currently, mathematical symbols and formulas are initially displayed in raw TeX coding, so that, for example, instead of seeing the symbol π, one would see `$\pi$`. Reviews may be retrieved in DVI format, and this summer, the AMS hopes also to offer PDF viewing capability on MathSciNet. However, both PDF and DVI are temporary measures. What is really needed is a genuine language for the efficient display of mathematical symbols and formulas in Web documents. Math Markup Language (currently under development by a committee that includes MR associate editor Patrick Ion) will provide exactly that. Says Kister, "I've great hopes that Math ML will become the standard way to display math on the Web."

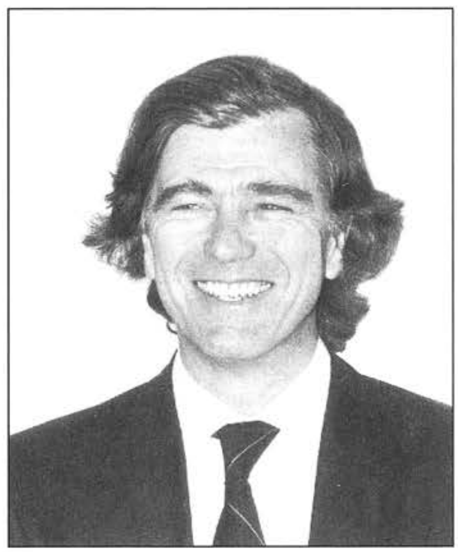
Although MathSciNet has been very successful, it has not meant a financial windfall for MR. The way MR products are priced permits support but not expansion of the operation. What this means is that MR continues to operate with a cap of about 50,000 reviews per year, despite an unexpected increase in the last few years in the amount of mathematical literature. "It had been more or less constant, and we were lulled into a false sense of security," Kister notes. In 1991 *Current Mathematical Publications* (which indexes mathematical literature with bibliographic information, no reviews) carried about 55,400 entries; this number grew to 62,000 last year, and estimates for 1998 are running at 65,000 to 67,000. The increase seems to be due to a combination of factors, including a rise in the number of mathematics journals. "Because of pressure on library budgets, we need to find ways to continue comprehensive coverage without significantly increasing our expenses," Kister says. "We will be looking at ways to cut production costs as we redesign the production stream, but we may want to make some editorial changes as well."

The explosion of electronic publishing technology means that MR has a promising if somewhat unpredictable future. Amid all the changes Jane Kister does not intend to lose sight of MR's core mission. She says, "My first priority is to make sure that MR goes on doing what it has done so well: producing a high-quality database of reviews and listings providing comprehensive coverage of the mathematical research literature."

—*Allyn Jackson*

Nesterenko and Pisier Share Ostrowski Prize

Yuri V. Nesterenko



Gilles I. Pisier

Photographs courtesy of Math. Inst., University of Basel, Switzerland.

YURI V. NESTERENKO of Moscow State University and GILLES I. PISIER of University Paris VI, France, shared the 1997 Ostrowski Prize. The prize carries a monetary award of 100,000 Swiss francs (approximately $66,000) and a Fellowship of 50,000 Swiss francs.

Nesterenko received the Ostrowski Prize for establishing the algebraic independence of $a = \pi$ and $b = exp(\pi)$. This means that there is no relation $P(a, b) = 0$ for any nonzero polynomial $P(x, y)$ with rational or even algebraic coefficients. Actually, the result appears as a trivial corollary to the algebraic independence of the three numbers a, b, and the value c of Euler's gamma function at 1/4. It is surprising that the proof uses modular functions. The proof is based on a result of Barré-Sirieix, Diaz, Gramain, and Philibert on transcendence of modular function values, an algebraic independence criterion of P. Philippon, and a new "zero estimate" for modular functions by Nesterenko himself. Nesterenko has derived various zero estimates in the past twenty years, and these have been applied by him and others to obtain other results on algebraic independence, a very sharp estimate for linear forms in logarithms, and sharp bounds in the Hilbert Nullstellensatz.

Pisier has obtained many fundamental results in various parts of analysis. In recent years he concentrated his efforts on the area of operator spaces. He transformed this area into a deep research area. In the framework of his research on this area Pisier solved in the last three years two extremely long-standing open problems. In C^* theory he solved, jointly with Junge, the problem of uniqueness of C^* norms on the tensor product of two copies of $B(H)$, the algebra of all bounded operators on Hilbert space. Pisier and Junge were able to produce two such tensor norms that are nonequivalent. In operator theory Pisier solved (again negatively) the problem of whether an operator which satisfies the von Neumann inequality (with a constant) is similar to a contraction. Both results are based on elegant constructions, and the verifications of the examples are ingenious. Both of these results had a considerable impact and have already led to important further research.

The Ostrowski Foundation was created by Alexander M. Ostrowski, for many years a professor at the University of Basel. He left his entire estate to the foundation and stipulated that the income should provide a prize for outstanding recent achievements in pure mathematics and the foundations of numerical mathematics. The prize is awarded every other year. Previous recipients of the Ostrowski Prize are Louis de Branges, Jean Bourgain, Miklós Laczkovich, Marina Ratner, and Andrew Wiles. The jury of the prize consists of representatives from the universities of Basel, Jerusalem, and Waterloo, and from the academies of Denmark and the Netherlands.

The 1997 prize was awarded April 25, 1998, at the University of Leiden.

—from Ostrowski Foundation news release

Reports Assess U.S. Standing in Mathematics

Within the past year, two major reports have been issued that attempt to assess the international standing of U.S. mathematical sciences research. The reports are part of an effort by the federal government to plan more coherently and more strategically its support of scientific research.

The first report, "International Benchmarking of U.S. Mathematics Research", was issued in October 1997 by the Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academy of Sciences (NAS). It comes in response to the 1993 COSEPUP report, "Science, Technology, and the Federal Government: National Goals for a New Era", which outlined a methodology for making decisions about federal spending on research. The first step in the methodology is to assess where the U.S. stands in comparison to its international peers in various scientific areas. Mathematics was the first field for which such a comparison was done; an NAS benchmarking report of materials science was released in April.

The second mathematics report, issued by the National Science Foundation (NSF), is called "Report of the Senior Assessment Panel of the International Assessment of the U.S. Mathematical Sciences". The NSF purposely chose as panelists individuals who had not recently received funding from the Foundation. Issued in March 1998, the report was produced in compliance with the Government Performance and Results Act (GPRA), which requires federal agencies to set strategic goals and evaluate their progress toward those goals. The NSF's goals call for upholding the U.S. position of world leadership in research, promoting the use of science in service to society, and achieving excellence in education.

While the two reports have many similarities, they are strikingly different in tone and outlook. In fact, the NSF report does not even mention the NAS report even though the latter had been out for six months by the time the NSF report was completed. Bland and dry, as most Academy publications are, the NAS report may have suffered from the fact that the panel producing it was instructed not to make any recommendations. The NSF panel, by contrast, was charged with making specific recommendations to the Foundation. Consequently, the NSF report is more opinionated and forceful, as well as longer and more detailed.

Both reports conclude that the U.S. is the world leader in mathematical sciences research. Among the evidence offered for this conclusion is the fact that U.S.-based mathematicians write about 40 percent of all research articles in the subject and claim a healthy share of international honors, such as prizes and invitations to speak at major meetings like the International Congress of Mathematicians. Despite these signs of success, the NSF report says that mathematicians in the U.S. suffer from a sense of "low morale" not found among their counterparts in Western Europe and the Pacific Rim. When it comes to promoting the use of mathematics outside the field, the U.S. is not doing much better than its peers: The NSF report states bluntly, "Communication between mathematical scientists and other scientists is poor the world over." In mathematics education, the reports say that the U.S. is clearly the leader at the Ph.D. level, attracting talented students from all over the world.

Both reports say that mathematics in the U.S. is strong, but warn that this strength is "fragile".

One of the reasons given for this fragility is the decline in federal support for mathematics; ironically, the NAS report counts good federal support in the past as one of the factors that has made mathematics in the U.S. so strong. One of the main themes of the NSF report is that federal support for graduate students and young researchers in mathematics is far below that for their counterparts in the physical and biological sciences. The emphasis on federal support is secondary in the NAS report, which says that the predominant factor contributing to the strength of U.S. mathematics has been the support of private and public universities. In fact, in its closing sentences the NAS report states: "The most important safeguard of U.S. preeminence in mathematical research—and in all the sciences—is the flourishing of both private and state research universities."

The NSF report suggests that the low level of federal support for young people in mathematics has induced talented undergraduates to enter other fields, leading to an overall decline in recent years in enrollments in U.S. Ph.D. programs in mathematics. The NAS report presents data showing that U.S. mathematics Ph.D.s have lower median salaries than those in other sciences and engineering. Also contributing to the lack of appeal of mathematics is the anemic academic job market, coupled with the perception that a career in academia is the only path open to a mathematics Ph.D. According to the NSF report, this is a misperception: "With a reorientation of curriculum and of employment expectations, possibilities for a career outside academia are very bright for mathematically talented and well-trained individuals."

The NSF report hammers away at the notion that mathematics must be open to taking on mathematical problems that arise in other fields of science, in industry, and in society. Academic mathematicians come in for some criticism for being "insufficiently connected" to users of mathematics, though the division of universities into departments, the rigidity of funding agencies, and lack of support from industry also take some of the blame. In its recommendations the report states that the NSF's objective should be to build an academic mathematical sciences community "that is both intellectually distinguished and relevant to society," noting that the inclusion of societal relevance is an "important shift in emphasis" for the Foundation. More specifically, the report recommends that the NSF "promote interactions between university-based mathematical scientists and users of mathematics in industry, government, and universities." The report makes it clear that the NSF has the clout to influence mathematics in the directions recommended. After presenting a graph that shows that the NSF holds the purse strings on

Report of the Senior Assessment Panel of the International Assessment of the U.S. Mathematical Sciences, National Science Foundation, March 1998.

Available on the World Wide Web at: `http://www.nsf.gov/cgi-bin/getpub?nsf9895/` and `http://www.nsf.gov/pubs/1998/nsf9895/nsf9895.htm`.

Available upon request from: Division of Mathematical Sciences, National Science Foundation, Room 1025, 4201 Wilson Boulevard, Arlington, VA 22230; telephone 703-306-1870.

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International Benchmarking of U.S. Mathematical Research, Committee on Science, Engineering, and Public Policy, National Academy of Sciences, 1997.

Available on the World Wide Web at: `http://www2.nas.edu/cosepup/`.

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Rudolph A. Marcus
California Institute of Technology, USA

Gary C. McDonald
GM Research and Development Center, USA

Cathleen S. Morawetz
Courant Institute of Mathematical Sciences, USA

Peter Sarnak
Princeton University, USA

I. M. Singer
Massachusetts Institute of Technology, USA

Margaret H. Wright
Bell Laboratories, Lucent Technologies, USA

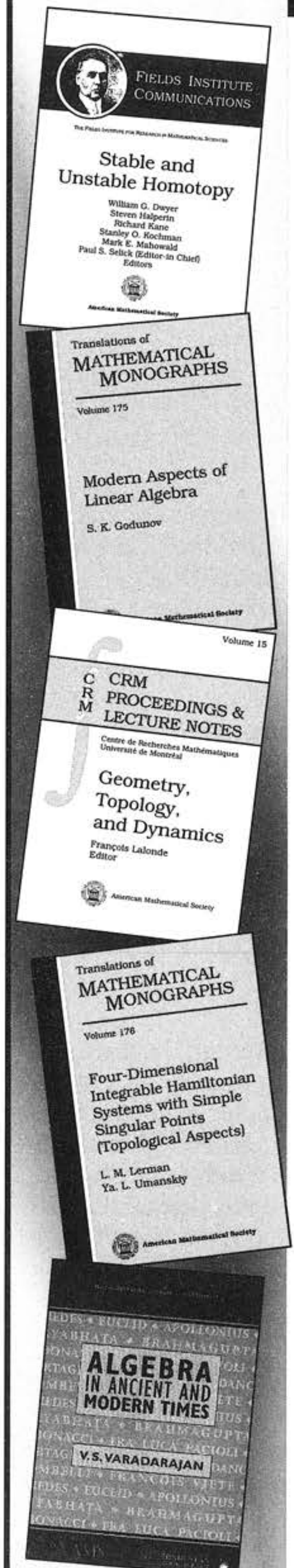
about 60 percent of all federal funds for mathematics research (with the remainder scattered among six other agencies with varying missions), the report notes that the Foundation has "high leverage in enforcing change."

Some of the most intriguing material in the NSF report appears in the appendices. One is a piece called "Possible Trends in the Coming Decades", by Mikhael Gromov; it is reproduced in the "Forum" column of this issue of the *Notices*. Another appendix contains an assessment of U.S. standing in various subfields of mathematics. For example, the assessment of algebraic geometry and number theory states that leadership in algebraic geometry is shared by the U.S., Japan, and Western Europe, "with the United States having the most active researchers." It comments that in the U.S., computational algebraic geometry "lacks depth, and leadership is held by the Europeans." It also notes that number theory is dominated by several "grand challenges," among them the Riemann Hypothesis (RH). "There is renewed activity in RH," the appendix says, "but probably not at the depth needed." There are similar evaluations of eight other subfields: foundations, algebra and combinatorics, topology and geometric analysis, analysis, probability, applied mathematics, computational mathematics, and statistics.

—*Allyn Jackson*

AMERICAN MATHEMATICAL SOCIETY

Recently Published Titles from the AMS



Stable and Unstable Homotopy

William G. Dwyer, *University of Notre Dame, South Bend, IN*, **Steven Halperin**, *University of Toronto, ON, Canada*, **Richard Kane**, *University of Western Ontario, London, Canada*, **Stanley O. Kochman**, *York University, Toronto, ON, Canada*, **Mark E. Mahowald**, *Northwestern University, Evanston, IL*, and **Paul S. Selick**, *University of Toronto, Scarborough, ON, Canada*, Editors

This volume presents the proceedings of workshops on stable homotopy theory and on unstable homotopy theory held at The Fields Institute as part of the homotopy program during the year 1996. The papers in the volume describe current research in the subject, and all included works were refereed. Rather than being a summary of work to be published elsewhere, each paper is the unique source for the new material it contains.

The book contains current research from international experts in the subject area, and presents open problems with directions for future research.

Fields Institute Communications, Volume 19; 1998; 316 pages; Hardcover; ISBN 0-8218-0824-9; List $79; Individual member $47; Order code FIC/19RT88

Supplementary Reading

Modern Aspects of Linear Algebra

S. K. Godunov, *Russian Academy of Sciences, Novosibirsk*

This book discusses fundamental ideas of linear algebra. The author presents the spectral theory of nonselfadjoint matrix operators and matrix pencils in a finite dimensional Euclidean space. Statements of computational problems and brief descriptions of numerical algorithms, some of them nontraditional, are given.

Proved in detail are classical problems that are not usually found in standard university courses. In particular, the material shows the role of delicate estimates for the resolvent of an operator and underscores the need for the study and use of such estimates in numerical analysis.

Translations of Mathematical Monographs, Volume 175; 1998; 303 pages; Hardcover; ISBN 0-8218-0888-5; List $119; Individual member $71; Order code MMONO/175RT88

Geometry, Topology, and Dynamics

François Lalonde, *University of Quebec at Montreal, PQ, Canada*, Editor

This volume contains the proceedings from the workshop on "Geometry, Topology and Dynamics" held at CRM at the University of Montreal. The event took place at a crucial time with respect to symplectic developments. During the previous year, Seiberg and Witten had just introduced the famous gauge equations. Taubes then extracted new invariants that were shown to be equivalent in some sense to a particular form of Gromov invariants for symplectic manifolds in dimension 4. With Gromov's deformation theory, this constitutes an important advance in symplectic geometry by furnishing existence criteria.

Meanwhile, contact geometry was rapidly developing. Using both holomorphic arguments in symplectizations of contact manifolds and ad hoc topological arguments—or even gauge theoretic methods—several results were obtained on 3-dimensional contact manifolds and new surprising facts were derived about the Bennequin-Thurston invariant.

Furthermore, a fascinating relation exists between Hofer's geometry, pseudoholomorphic curves and the K-area recently introduced by Gromov. Finally, longstanding conjectures on the flux were resolved in a substantial number of specific cases by comparing various aspects of Floer-Novikov homology with Morse homology.

The papers in this volume are written by leading experts and are all clear, comprehensive, and original. The work covers a complete range of exciting new developments in symplectic and contact geometries.

CRM Proceedings & Lecture Notes, Volume 15; 1998; 148 pages; Softcover; ISBN 0-8218-0877-X; List $35; Individual member $21; Order code CRMP/15RT88

Four-Dimensional Integrable Hamiltonian Systems with Simple Singular Points (Topological Aspects)

L. M. Lerman, *Research Institute for Applied Mathematics and Cybernetics, Nizhni Novgorod, Russia*, and **Ya. L. Umanskiy**, *Total System Services, Inc., Atlanta, GA*

The main topic of this book is the isoenergetic structure of the Liouville foliation generated by an integrable system with two degrees of freedom and the topological structure of the corresponding Poisson action of the group $\mathbb{R}^2$. This is a first step towards understanding the global dynamics of Hamiltonian systems and applying perturbation methods. Emphasis is placed on the topology of this foliation rather than on analytic representation. In contrast to previously published works in this area, here the authors consistently use the dynamical properties of the action to achieve their results.

Translations of Mathematical Monographs, Volume 176; 1998; 177 pages; Hardcover; ISBN 0-8218-0375-1; List $79; Individual member $47; Order code MMONO/176RT88

Supplementary Reading

Independent Study

Algebra in Ancient and Modern Times

V. S. Varadarajan, *University of California, Los Angeles*

This text offers a special account of Indian work in diophantine equations during the 6th through 12th centuries and Italian work on solutions of cubic and biquadratic equations from the 11th through 16th centuries. The volume traces the historical development of algebra and the theory of equations from ancient times to the beginning of modern algebra, outlining some modern themes, such as the fundamental theorem of algebra, Clifford algebras, and quarternions. It is geared toward undergraduates who have no background in calculus.

This book is co-published with the Hindustan Book Agency (New Delhi) and is distributed worldwide, except in India, Sri Lanka, Bangladesh, Pakistan, and Nepal by the American Mathematical Society.

Mathematical World, Volume 12; 1998; approximately 174 pages; Softcover; ISBN 0-8218-0989-X; List $25; All AMS members $20; Order code MAWRLD/12NT88

All prices subject to change. Charges for delivery are $3.00 per order. For optional air delivery outside of the continental U. S., please include $6.50 per item. *Prepayment required.* Order from: **American Mathematical Society**, P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax 1-401-455-4046 or call toll free 1-800-321-4AMS (4267) in the U. S. and Canada, 1-401-455-4000 worldwide. Or place your order through the AMS bookstore at www.ams.org/bookstore. Residents of Canada, please include 7% GST.

AMS
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Mathematics People

Dirac Medals Awarded

The International Center for Theoretical Physics (ICTP) in Trieste, Italy, has awarded the 1997 Dirac Medals to PETER GODDARD of the University of Cambridge and DAVID OLIVE of the University College of Swansea.

Goddard and Olive were recognized for "their farsighted and highly influential contributions to theoretical physics, over an extended period. [They] have contributed many crucial insights that have shaped our emerging understanding of string theory and have also had a far-reaching impact on our understanding of four-dimensional field theory."

Peter Goddard's work on quantization of the relativistic string (with J. Goldstone, C. Rebbi, and C. Thorn) showed definitively that dual resonance models should be understood as string theories. David Olive's work on spacetime supersymmetry of the spinning string theory (with F. Gliozzi and J. Scherk) made possible the whole idea of superstrings, which we now understand as the most natural framework for supersymmetry and string theory.

Goddard and Olive introduced key ideas about the use of current algebra in string theory which were very important in the subsequent discovery of attractive ways to incorporate spacetime gauge symmetry in string theory, thus making it possible for string theory to incorporate the standard model of particle physics.

These discoveries, made in the years 1973–83, were among the most crucial steps in making possible the 'superstring revolution' of 1984–85. The second superstring revolution of the last few years has been equally dependent on pioneering insights about magnetic monopoles made in 1977 by Goddard, Olive, and J. Nuyts, and further extended by Olive and C. Montonen. Their ideas concerning a dual interpretation of magnetic charge, and then about electric-magnetic duality in non-abelian gauge theory, were way ahead of their time and proved to have a far-reaching importance, which we are only now beginning to understand, in governing the dynamics of four-dimensional field theory and of superstring theory.

The ICTP instituted the Paul Adrien Maurice Dirac Medals in 1985. These medals are awarded yearly for contributions to theoretical physics and mathematics. The announcement is made on P. A. M. Dirac's birthday (August 8), and the awarding ceremony takes place at a later date at the ICTP. The medalists also receive a check for $5,000.

An international committee of distinguished scientists selects the winners from among nominated candidates. The committee invites nominations from anyone working in the areas of theoretical physics or mathematics. (The Dirac Medal is not awarded to Nobel Prize or Wolf Foundation Prize winners.) For information, consult the ICTP Web site, http://www.ictp.trieste.it.

—ICTP press release

Ferran Sunyer i Balaguer Prize Awarded

The Institut d'Estudis Catalans has awarded the sixth Ferran Sunyer i Balaguer Prize to JUAN J. MORALES RUÍZ of the Universitat Politècnica de Catalunya for his monograph entitled *Differential Galois Theory and Non-integrability of Hamiltonian Systems*. The monograph is devoted to the connection between the two topics mentioned in the title: differential Galois theory and integrability of Hamiltonian systems. The main point is the relation between integrability in the Liouville-Arnold sense of a Hamiltonian system and the Galois differential integrability of the associated variational equations.

The prize consists of 1,800,000 pesetas (approximately $12,400). According to the terms of the prize, the monograph will be published in the Birkhäuser series Progress in Mathematics. The Ferran Sunyer i Balaguer Prize is awarded each year to a mathematical monograph of an expository nature presenting the latest developments in an active area of mathematics research in which the author(s) has (have) made important contributions.

Note: For information on how to submit manuscripts for consideration for the prize, see the "Mathematics Opportunities" section in this issue of the *Notices*.

—from Institut d'Estudis Catalans announcement

Parzen Prize Awarded

The 1998 Emanuel and Carol Parzen Prize for Statistical Innovation has been awarded to BRADLEY EFRON of Stanford University for "outstanding and influential innovations and breakthroughs in theoretical research in mathematical statistics, and effective applications of theoretical research. Professor Efron has made many pioneering fundamental contributions to bootstrap and computer intensive statistical methods, empirical Bayes methods, survival analysis, clinical trials, differential geometry, likelihood theory, and survey sampling."

The Parzen Prize is awarded in even-numbered years by the Department of Statistics at Texas A&M University. It is awarded to North American statisticians who have made outstanding and influential contributions to the development of applicable and innovative statistical methods. The 1998 Parzen Prize Committee members were: David Brillinger, Herman Chernoff, Joe Newton, Grace Wahba, and Marvin Zelen.

Nominations for the year 2000 Parzen Prize should be submitted (by October 1, 1999) to H. J. Newton, Department of Statistics, Texas A&M University, College Station, TX 77843-3143.

—Department of Statistics, Texas A&M University announcement

National Academy of Engineering Elections

The National Academy of Engineering has announced the election of 84 new members and 7 foreign associates. Among those elected were ARTHUR M. GEOFFRION of the University of California, Los Angeles; EDWARD J. MCCLUSKEY of Stanford University; ROBERT J. MCELIECE of the California Institute of Technology; DAVID MIDDLETON, an independent consultant in New York City; NEIL J. A. SLOANE, of AT&T Laboratories; and MARY F. WHEELER, of the University of Texas, Austin.

—National Academy of Engineering announcement

Karp Receives Harvey Prize

RICHARD KARP of the University of Washington has been awarded this year's Harvey Prize by the Technion-Israel Institute of Technology for his outstanding contributions to the field of computer science. The prize comes with a cash award of $35,000 and the opportunity to lecture at the Technion.

The Harvey Prize was established in 1972 by the late Leo M. Harvey of Los Angeles, a supporter of the American Technion Society, the support organization for the Technion in the United States. The prize honors major contributions to human progress in science, technology, literature of the Middle East, and the advancement of peace in the Middle East. The fund has been maintained by his son, Homer, and the Harvey family. Three Harvey Laureates have received the Nobel Prize since 1990.

—from news release of the American Society for Technion-Israel Institute of Technology

Visiting Mathematicians

(Supplementary List)

Mathematicians visiting other institutions during the 1998–2000 academic years were listed in the June/July 1998 issue of the *Notices*, pp. 730-731. The following is an update to that list (home country is listed in parentheses).

VICTOR GUBA (Russia), Vanderbilt University, Algebra, Group Theory, 1/99–5/99.

ERVIN GYÖRI (Hungary), Vanderbilt University, Graph Theory, 1/99–5/99.

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

UWE F. MAYER (Germany),Vanderbilt University, Partial Differential Equations, Differential Geometry, 5/98–8/98.

LASSI PAIVARINTA (Finland), University of Delaware, Inverse Problems, 9/98–1/99.

ROLAND POTTHAST (Germany), University of Delaware, Inverse Problems, 10/98–11/98.

HENDA SWART (South Africa), Vanderbilt University, Graph Theory, 9/98–12/98.

JOHN SWART (South Africa), Vanderbilt University, Differential Equations, 9/98–12/98.

ALDO URSINI (Italy), Vanderbilt University, Algebra, 9/98–9/98.

Deaths

HELEN E. CLARKSON, of Omaha, Nebraska, died on April 20, 1998. Born on January 11, 1914, she was a member of the Society for 60 years.

BERNARD DWORK, of Princeton University, died on May 9, 1998. Born on May 27, 1923, he was a member of the Society for 48 years.

JAMES R. C. LEITZEL, of the University of New Hampshire, died on February 25, 1998. Born on May 27, 1936, he was a member of the Society for 38 years.

MICHIO SUZUKI, of the University of Illinois at Urbana-Champaign, died on May 31, 1998. Born on October 2, 1926, he was a member of the Society for 44 years.

Mathematics Opportunities

News from the Institute for Mathematics and its Applications

University of Minnesota

The 1998-99 program at the IMA will be **Mathematics in Biology**. The fall 1998 term will be devoted to the topic, **Theoretical Problems in Developmental Biology and Immunology**.

The program will kick off with a tutorial on **Mathematical and Computational Issues in Pattern Formation** (September 3-4, 1998), an introduction to the two back-to-back workshops on developmental biology. It will be followed by the workshop **Pattern Formation and Morphogenesis: The Basic Process** (September 8-12, 1998).

Pattern formation and morphogenesis in developmental biology involves the spatio-temporal coordination of growth, cell-cell signaling, tissue movement, gene expression, and cell determination. The meeting will bring together leading theoreticians from the mathematical and biological communities. The mathematical problems to be discussed include: how patterns are generated reliably in the face of biological variation, the long-term behavior of chemotaxis equations, and how one incorporates information about the microscopic behavior of individual cells into a macroscopic continuum description. Computational aspects that arise include effective methods for computing solutions of systems of reaction diffusion (RD) equations or coupled RD/fluid problems in three space dimensions, and the numerical bifurcation analysis of systems of partial differential equations.

The companion workshop **Pattern Formation and Morphogenesis: Model Systems** will be held September 14-18, 1998. This workshop emphasizes the modeling of complicated biological systems, the qualitative and numerical analysis of the resulting model equations, and the interpretation and modification of models in the light of experimental data. The mathematical topics that arise in these models include dynamical systems theory, partial differential equations, and large-scale numerical simulations. The breadth of model systems involved should lead to extensive cross-fertilization between these areas, encourage new collaborations, and provide new problems in modeling and mathematical analysis.

The immunology portion of the fall program will get under way with a tutorial on **Immunology, Cell Signaling, the Physiology of the Immune System, and the Dynamics of the Immune Response** (October 8-9, 1998). Lectures will be given on cell signaling, the physiology of the immune system, and the dynamics of the immune response in order to provide mathematicians with sufficient background to participate effectively in the workshop **Immune System Modeling and Cell Signaling** (October 12-16, 1998). The general goal of this workshop will be to bring together immune system theorists and experimental immunologists with mathematicians who can become stimulated in this exciting and important area and who may be able to make an impact by contributing new methods and tools of analysis. Participants will consider how cells of the immune system receive and send signals and will then focus on questions concerning the dynamics of interactions among B cells, T cells, and antigen presenting cells, and the regulation of these populations. Events occurring during immune responses will also be examined, including the formation of spatial structures, such as germinal centers, as well as problems dealing with somatic mutation and affinity maturation. The mathematics employed involves systems of nonlinear ordinary differential equations, partial differential equations, cellular automata, stochastic processes, and computer simulation.

During October 19-23, 1998, the IMA will offer a Period of Concentration: **Forging an Appropriate Immune Response as a Problem in Distributed Artificial Intelligence**. How are the vast collections of cells and molecules that comprise the immune system organized to provide appropriate responses (selected from an extensive set of possible responses) to the wide variety of evolving pathogens that attack the organism during its lifetime? It is the premise of this workshop that the "response choice" problem and its solution in natural immune systems can usefully be viewed as an example of bottom-up and distributed artificial intelligence. Relevant concepts of artificial intelligence and computer science will be presented, with examples of their application. One important example concerns computer security against "viruses" and other intrusions, for here the interaction of immunology and computer science has already begun to prove fruitful. This workshop should be mutually beneficial for computer scientists as well as experimental and theoretical immunologists.

The last workshop of the fall term will be **Dynamics and Control of AIDS** (November 9-13, 1998). HIV infection and AIDS are among the major unresolved health problems in this century. Mathematics can serve as an important tool in improving our understanding of the dynamics of this disease. This workshop will focus on modeling HIV dynamics and the interaction of HIV with the immune system. Also, some issues of disease spread at the population level will be examined. Large numbers of cells and organisms and long time scales make differential equations the appropriate and primary tool used to study these phenomena. Delay equations, simulations, and stochastic models also play a role.

The winter term will be devoted to **Mathematical Problems in Physiology**. More detailed descriptions of the winter 1999 program are expected to appear in a future issue of *Notices*.

For more information about this program or about IMA activities in general and how to register, contact the IMA by e-mail: `staff@ima.umn.edu` or through the World Wide Web (`http://www.ima.umn.edu/`).

—IMA announcement

CAREER/PECASE Program Guidelines on Web

Program Guidelines for the National Science Foundation (NSF) CAREER/PECASE programs are now available on the World Wide Web. The new CAREER program announcement can be found at `http://www.nsf.gov/cgi-bin/getpub?nsf98103/`. The announcement number, NSF98-103, replaces NSF 97-87 and appears only on the Web.

The CAREER program is intended for the support of excellent proposals from junior faculty who combine strong research activity with a genuine and substantive involvement in education. Proposals will be evaluated on the basis of both research and education. Proposal requests should be submitted for NSF support totaling at least $200,000 and for an award duration of at least four, but not more than five, years. The deadline is **July 22, 1998**.

Beginning in 1997, NSF will select from the most meritorious awardees supported by the CAREER program nominees for the Presidential Early Career Awards for Scientists and Engineers (PECASE). PECASE awards recognize outstanding scientists and engineers who, early in their careers, show exceptional potential for leadership at the frontiers of knowledge. This presidential award is the highest honor bestowed by the United States government on scientists and engineers beginning their independent careers.

It is expected that the Division of Mathematical Sciences (DMS) will make a small number of CAREER awards. In each of the previous two years, FY 97 and FY 98, four awards were made. The division continues to encourage proposals to its "traditional" research grant programs that integrate research and education activity or that have significant education components. Applicants are encouraged to confer with program directors.

A home page for CAREER and PECASE has been created at `http://www.nsf.gov/home/crssprgm/career/`. Before preparing a CAREER proposal, applicants are strongly encouraged to refer to the CAREER "Frequently Asked Questions (FAQ)" document (CAREER-FAQ), available on the CAREER Web page. The mailing address for the NSF is National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230. The telephone number for the DMS is 703-306-1870.

—National Science Foundation announcement

Ferran Sunyer i Balaguer Prize

Each year the Institut d'Estudis Catalans awards the Ferran Sunyer i Balaguer Prize. This prize honors the memory of Ferran Sunyer i Balaguer (1912-1967), a self-taught Catalan mathematician who, in spite of a serious physical disability, was very active in research in classical analysis and acquired international recognition.

The Ferran Sunyer i Balaguer Prize is awarded to a mathematical monograph of an expository nature presenting the latest developments in an active area of research in mathematics in which the author(s) has (have) made important contributions. The prize of 1,800,000 pesetas (approximately $12,400) is provided by the Ferran Sunyer i Balaguer Foundation. Authors are invited to submit their manuscripts for consideration for the prize.

The manuscript must be original, written in English, and of at least 150 pages. In exceptional cases, manuscripts in other languages may be considered. The winning monograph will be published in Birkhäuser's Progress in

Mathematics series, subject to the usual regulations concerning copyright and author's rights.

The winner of the prize will be proposed by the Scientific Committee, consisting of: Friedrich Hirzebruch, Max-Planck-Institut für Mathematik, Bonn; Paul Malliavin, Université de Paris VI; Joseph Oesterlé, Université de Paris VI; Joan Solà Morales, Universitat Politècnica de Catalunya; and Alan Weinstein, University of California, Berkeley.

Manuscripts should be typeset in TeX. Authors should send a hard copy and two disks with .dvi and PostScript files together with a submission letter to: Institut d'Estudis Catalans, Apartat 50, 08193 Bellaterra, Spain; e-mail: crm@crm.es. This material should be sent before **December 5, 1998**. The name of the prize winner will be announced in Barcelona in April 1999. For further information on the Ferran Sunyer i Balaguer Foundation, consult the Web site http://crm.es/info/ffsb.htm.

Note: An announcement of this year's winner of the Ferran Sunyer i Balaguer Prize appears in the "Mathematics People" section in this issue of the *Notices.*

—from Institut d'Estudis Catalans announcement

Editor's Note: Birkhäuser Basel confirms that it will publish the prize-winning book.

Deadlines and Target Dates at the NSF

The Division of Mathematical Sciences (DMS) of the National Science Foundation has a number of programs in support of mathematical sciences research and education. Listed below are the names of programs having deadlines or target dates coming up in the next several months.

July 22, 1998 (deadline): Faculty Early Career Development (CAREER) Program

September 1, 1998 (deadline): Grants for Vertical Integration of Research and Education (VIGRE)

September 15, 1998 (deadline): Research Experiences for Undergraduates Sites (send inquiries to: reu.dms@nsf.gov)

October 10, 1998 (target date): Algebra & Number Theory

October 10, 1998 (target date): Analysis

October 17, 1998 (deadline): Mathematical Sciences Postdoctoral Research Fellowships (send inquires to: msprf@nsf.gov)

November 7, 1998 (target date): Applied Mathematics (excluding Mathematical Biology)

November 7, 1998 (target date): Statistics & Probability

November 7, 1998 (target date): Geometric Analysis

November 7, 1998 (target date): Topology & Foundations

November 13, 1998 (deadline): University-Industry Cooperative Research Programs in the Mathematical Sciences

November 23, 1998 (full proposal deadline): 1998 Competition for Integrative Graduate Education and Research Training (IGERT)

December 4, 1998 (target date): Computational Mathematics

December 4, 1998 (target date): Mathematical Biology

December 9, 1998 (deadline): Professional Opportunities for Women in Research and Education (POWRE)

February 1, 1999 (full proposal deadline): Knowledge and Distributed Intelligence

February 20, 1999 (deadline): Scientific Computing Research Equipment for the Mathematical Sciences

April 15, 1999 (preproposal deadline) and September 7, 1999 (full proposal deadline): 1999 Competition for Integrative Graduate Education and Research Training (IGERT)

Proposals for Conferences, Workshops, and Special Years that are submitted to the Statistics program or to the Topology & Foundations program can be sent at any time. However, proposals for these activities that are submitted to all other DMS programs (Analysis, Algebra & Number Theory, Applied Mathematics, Computational Mathematics, and Geometric Analysis) must be submitted according to the target dates for those programs. Proposals for supplements for Research Experiences for Undergraduates may be submitted at any time.

For further information consult the DMS Web site at http://www.nsf.gov/mps/dms/. The mailing address is Division of Mathematical Sciences, National Science Foundation, Room 1025, 4201 Wilson Boulevard, Arlington, VA 22230. The telephone number is 703-306-1870.

—DMS

AWM Workshops for Women Graduate Students and Postdocs

Over the past nine years the Association for Women in Mathematics (AWM) has held a series of workshops for women graduate students and recent Ph.D.s in conjunction with major mathematics meetings.

The next AWM workshop to be held in conjunction with the annual Joint Mathematics Meetings will be in San Antonio, Texas, January 13-16, 1999. The workshop will be held on Saturday, January 16, 1999, with an introductory dinner on Thursday evening, January 14, 1999.

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

The AWM also seeks volunteers to lead discussion groups and to act as mentors for workshop participants.

People interested in volunteering, should contact the AWM office.

Applications are welcome from graduate students who have made substantial progress toward their theses and from women who have received their Ph.D.s within approximately the last five years. (The word "postdocs" refers to recent Ph.D.s, whether or not they currently hold a postdoctoral or other academic position.) Women with grants or other sources of support are still welcome to apply. All non-U.S. citizens must have a current U.S. address. All applications should include a curriculum vitae, a concise description of research (2–3 pages), and a title of the proposed talk/poster. All applications should also include at least one letter of recommendation; in particular, graduate students should include a letter of recommendation from their thesis advisors. Nominations by other mathematicians (along with the information described above) are also welcome.

Send *five* complete copies of the application materials (including the cover letter) to: Workshop Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, Maryland 20742-2461. For further information contact the AWM by telephone at 301-405-7892 or by e-mail at `awm@math.umd.edu`. Applications via e-mail or fax are not acceptable.

Applications must be received by **September 1, 1998.**

—*AWM announcement*

For Your Information

Call for Nominations for AWM Schafer Prize

The Executive Committee of the Association for Women in Mathematics (AWM) calls for nominations for the Alice T. Schafer Mathematics Prize to be awarded to an undergraduate woman for excellence in mathematics. All members of the mathematical community are invited to submit nominations for the prize. A nominee may be at any level in her undergraduate career and must either be a U.S. citizen or have a school address in the U.S.

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

The ninth annual Schafer Prize will be awarded at the Joint Prize Session at the Joint Mathematics Meetings in San Antonio, Texas, January 1999.

The letters of nomination should include, but not be limited to, an evaluation of the nominee(s) based on the following criteria: quality of performance in advanced mathematics courses and special programs, demonstration of real interest in mathematics, ability for independent work in mathematics, and performance in mathematical competitions at the local or national level, if any.

Supporting materials (e.g., reports from summer work using mathematics, copies of talks given by members of student chapters, transcripts, etc.) should be enclosed with the nomination.

Send *five* complete copies of nominations for this award to: The Alice T. Schafer Award Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, Maryland 20742-2461. For further information contact the AWM by telephone at 301-405-7892 or by e-mail at `awm@math.umd.edu`. Nominations via e-mail or fax are not acceptable.

The nomination deadline is **September 15, 1998.**

—*AWM announcement*

Correction

The May 1998 issue of the *Notices* carried an announcement about Andrew Wiles receiving the King Faisal International Prize for Science. The announcement incorrectly stated that Wiles received the award in a ceremony in Saudi Arabia on January 6. The prize was announced on that date; the ceremony took place in March. In addition, the listing of Wiles's honors omitted one: he received the Ostrowski Prize in 1996.

About the Cover

This month's cover celebrates the upcoming International Congress of Mathematicians 1998, to be held August 18–27 in Berlin, Germany. The Congress is the venue for the presentation of the Fields Medals, the highest honor in mathematics. The cover collage shows the front and back of the Fields Medal, surrounded by the medalists from the past three Congresses. Clockwise from top left are: Simon Donaldson, Gerd Faltings, Michael Freedman (Berkeley, 1986); Vladimir Drinfeld, Shigefumi Mori, Vaughan Jones, Edward Witten (Kyoto, 1990); Pierre-Louis Lions, Jean Bourgain, Jean-Christophe Yoccoz, Efim Zelmanov (Zurich, 1994). A future issue of the *Notices* will carry information about the Fields Medalists honored at ICM-98.

From the AMS

List of Candidates for 1998 AMS Election

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Philip Hanlon
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Lisa Claire Jeffrey
Douglas Lind
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Add this Cover Sheet to all of your Academic Job Applications

How to use this form

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

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

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

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

JCEO Recommendations for Professional Standards in Hiring Practices

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

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

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

Academic Employment in Mathematics

AMS Standard Cover Sheet

Last Name ______________________________

First Name ______________________________

Middle Names ______________________________

Address *through June 1998* | **Home Phone**

______________________________ | ______________

______________________________ | **e-mail Address**

______________________________ | ______________

Current Institutional Affiliation | **Work Phone**

______________________________ | ______________

Highest Degree and Source ______________________________

Year of Ph.D. (optional) ______________________________

Ph.D. Advisor ______________________________

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

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

Primary Interest ______________________________

Secondary Interests *optional* ______________________________

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

____

____

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

University or Company ______________________________

Position Title ______________________ Dates ______________

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

____

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

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

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

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

☐ ______________________________

☐ ______________________________

☐ ______________________________

☐ ______________________________

This form is provided courtesy of the American Mathematical Society.

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

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

1991 Mathematics Subject Classification

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

Reference

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

Upcoming Deadlines

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

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

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

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

Where to Find It

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

Mathematics Calendar

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

September 1998

* 14-17 **Constraint Programming and Large Scale Discrete Optimization**, DIMACS Center, Rutgers University, Piscataway, New Jersey.

Organizers: E. C. Freuder, e-mail: ecf@cs.unh.edu and R. J. Wallace, e-mail: rjw@cs.unh.edu, Univ. of New Hampshire.

Interests: The workshop is interested in all aspects of constraint programming related to large scale discrete optimization, including contributions from artificial intelligence, discrete mathematics, operations research, and programming languages. It is interested in both theory and practice. Optimization should be taken broadly to include, for example, optimization in the presence of uncertainty or change.

Contacts: For participation, cop@cs.unh.edu.

Local Arrangements: P. Pravato, DIMACS Center, pravato@dimacs.rutgers.edu, tel: 732-445-5929.

Information: http://dimacs.rutgers.edu/Workshops/ConstraintProg/.

October 1998

* 30-November 1 **Midwest Partial Differential Equations Seminar**, University of Illinois at Chicago, Chicago, Illinois.

Focus: The Midwest PDE Seminar is a semi-annual meeting on recent devlopments in partial differential equations.

Organizers: J. Lewis, (jlewis@uic.edu), and D. Tartakoff, (dst@uic.edu).

Speakers: Invited speakers include A. Bove, D. Catlin, J. P. D'Angelo, G. Francsics, N. Hanges, J. J. Kohn, L. Nirenberg, F. Reitich, and F. Treves.

Information: Support for graduate students is available. For infomation contact jlewis@uic.edu or see the Midwest PDE home page at http://www.math.uic.edu/~lewis/midwpde/index.htm.

November 1998

* 9-13 **Fields Institute Workshop on Analysis and Simulation of Communication Networks**, Fields Institute, Toronto, Canada.

Organizing Committee: P. Glynn (Stanford Univ.) and D. McDonald (Univ. of Ottawa).

Speakers: M. Devetsikiotis (Carleton), S. Foss (Novosibirsk), P. Glynn (Stanford), F. Kelly (Cambridge), G. Kesidis (Waterloo), T. Kurtz (Madison), R. Srinivasan (Saskatchewan), G. Takahara (Queen's), S. Turner (Cambridge), J. Walrand (Univ. of California, Berkeley), W. Whitt (AT&T). A series of talks will be held at Nortel (Ottawa), in conjunction with the workshop.

Focus: The workshop is being organized in connection with the Fields Institute program in Probability and its Applications, August 1998 - June 1999.

Information: For further information about the workshop and the program, please see the program Website http://www.fields.utoronto.ca/probability.html, or write to: The Fields Institute for Research in Mathematical Sciences, 222 College Street, Second Floor, Toronto, Ontario, M5T 3J1, Canada; tel: 416-348-9710, fax: 416-348-9385; e-mail: networks@fields.utoronto.ca.

* 18-20 **DIMACS Workshop on Robust Communication Networks: Interconnection and Survivability**, DIMACS Center, Rutgers University, Piscataway, New Jersey.

Organizers: N. Dean (Rice Univ.), nated@caam.rice.edu, F. Hsu (Fordham Univ.), hsu@murray.fordham.edu, R. Ravi (GSIA, Carnegie Mellon Univ.), ravi@cmu.edu.

Aim: Presented under the auspices of the DIMACS Special Year on Networks, a three-day workshop is planned on Robust Communication Networks: Interconnection and Survivability, RCN:IS. Emphasis will be given to foster communication and dialog between theoreticians and practitioners and to provide a distinctive forum where practitioners would tell theorists what the key issues and central problems are and theorists may be

This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete list of meetings of the Society can be found on the last page of each issue.

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

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

In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence **six months** prior to the scheduled date of the meeting.

The complete listing of the Mathematics Calendar will be published only in the September issue of the *Notices*. The March, June, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.

The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through e-MATH on the World Wide Web. To access e-MATH, use the URL: http://e-math.ams.org/ (or http://www.ams.org/). (For those with VT100-type terminals or for those without WWW browsing software, connect to e-MATH via Telnet (telnet e-math.ams.org; login and password e-math) and use the Lynx option from the main menu.)

able to offer crucial insights and provide possible solutions.

Local Arrangements: P. Pravato, DIMACS Center, pravato@dimacs.rutgers.edu, 732-445-5929.

Information: Contact hsu@murray.fordham.edu; WWW information: http://dimacs.rutgers.edu/Workshops/Robust/.

* 23-28 **Conference on Dynamical Systems and Evolutionary Equations, in honor of J. K. Hale**, Instituto Superior Técnico, Lisbon, Portugal.

Invited Speakers: N. Alikakos (Univ. Tennessee), A. Ambrosetti (Scuola Normale Pisa), H. Beirão da Veiga (U. Pisa), S. -N. Chow (Georgia Inst. Tech.), C. Dafermos (Brown Univ.), B. Fiedler (Freie Univ. Berlin), G. Fusco (Univ. L'Aquila), J. K. Hale (Georgia Inst. Tech.), K. Kirchgässner (Univ. Stuttgart), J. Llibre (Univ. Autónoma Barcelona), S. Lunel (Vrije Univ. Amsterdam), J. Mallet-Paret (Brown Univ.), K. Mischaikow (Georgia Inst. Tech.), R. Nussbaum (Rutgers Univ.), C. Olech (Polish Academy of Sciences), W. M. Oliva (Inst. Superior Técnico), G. Sell (Univ. Minnesota), C. Simó (Univ. Barcelona), L. Tartar (Carnegie Mellon Univ.), H. -O. Walther (Justus-Liebig Univ.).

Organizers: F. P. da Costa and C. Rocha (Center for Mathematical Analysis, Dynamical Systems, and Applications, IST).

Registration: Participants should send an application to the organizers not later than September 30, 1998. The registration fee is 5,000 Portuguese escudos (free for students).

Information: For additional information please contact the organizers at the address: Dep. Matemática, Instituto Superior Técnico, Av. Rovisco Pais 1, P-1096 Lisboa, Portugal; fax: 351-1-3523014; e-mail: Hale.Conference@math.ist.utl.pt.

* 27-28 **Short School on Operators on Manifolds with Singularities and Spectral Theory**, Dipartimento di Matematica, Università di Torino, Italy.

Lectures: Eight 1-hour lectures from introductory to advanced level by C. Parenti, E. Schrohe, B. -W. Schulze, D. Vassiliev.

Organizing Committee: E. Buzano, G. Garello, L. Rodino.

Information: Contact E. Buzano, Dipartimento di Matematica, Via Carlo Alberto 10, 10123 Torino, Italy; fax: 39-11-670-2878; e-mail: school@dm.unito.it; WWW: http://www.dm.unito.it/convegniseminari/differential.htm.

December 1998

* 13-15 **CMS Winter 1998 Meeting**, Queen's University and Royal Military College, Kingston, Ontario, Canada.

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

Plenary Speakers: M. Csörgo (Carleton), H. Darmon (McGill), Z. Füredi (Illinois at Urbana, Inst. Hungarian Acad. Sci.), and D. O'Shea (Mt. Holyoke College).

Symposia: There will be symposia in the following areas. The session titles and speakers are: **Algebraic Geometry**: Organizer: P. Milman (Univ. of Toronto); F. Bogomolov (NYU Courant Institute), A. Khovanskii (Univ. of Toronto), D. O'Shea (Mt. Holyoke College), J. Shustin (Tel-Aviv Univ.), Y. Yomdin (Weizmann Institute). **Discrete Geometry**: Organizers: R. Erdahl (Queen's Univ.), M. Senechal (Smith College), W. Whiteley (York Univ.); and speakers to be announced. **Education Session - Identifying and Overcoming Barriers to Teaching and Learning Mathematics at University**: Organizers: M. Orzech and G. Orzech (Queen's Univ.); E. Barbeau (Univ. of Toronto), B. Hodgson (Univ. Laval), D. O'Shea (Mt. Holyoke College) - plenary, T. Rishel (Cornell Univ.), M. Siegel (Towson Univ.), M. Orzech (Queen's Univ.). **Extremal Combinatronics**: Organizer: D. de Caen (Queen's Univ.); Z. Füredi (Univ. of Illinois at Urbana and Math. Inst. Hungarian Acad. Sci.) - plenary, R. Anstee (UBC), J. Brown (Dalhousie), R.Faudree (Memphis), D. Fisher (Colorado), J. Griggs (South Carolina), P. Haxell (Waterloo), F. Lazebnik (Delaware), L. Székely (South Carolina), B. Zhou (Trent). **Number Theory**: Organizers: R. Murty and N. Yui (Queen's Univ.); This session has received additional funding from the Centre de recherches mathématiques. H. Darmon (McGill) - plenary and Coxeter-James Lecturer, C. David (Concordia), J. W. Fabrykowski (Manitoba), E. Goren (McGill), C. Greither (Laval), H. Kisilevsky (Concordia), M. Kolster (McMaster), A. Ledet (Queen's), C. Levesque (Laval), K. Murty (Toronto), W. Nowak (Australia), V. Platonov (Waterloo), D. Roy (Ottawa), G. Walsh (Ottawa), H. Williams (Manitoba), K. Williams (Carleton). **Operator Algebras**: Organizer: J. Mingo (Queen's College); K. Davidson (Waterloo), G. Elliott (Toronto), T. Giordano (Ottawa), A. Nica (Waterloo). **Probability Theory**: Organizer: M. Csörgo (Carleton Univ.); This session has received additional funding from The Fields Institute. There will be 33 invited 1/2-hour speakers, which are to be announced. **Topology**: Organizer: E. Campbell (Queen's Univ.); This session will include talks on the following: Differential Geometry and Global Analysis; Homotopy Theory; Set Theoretic Topology; Symplectic/Low Dimensional Topology; speakers to be announced. **Universal Algebra and Multiple-Value Logic**: Organizer: L. Haddad (Royal Military College); speakers to be announced.

Graduate Student Seminar: A special session is being organized for graduate students. Anyone interested in participating in the organization of this programme should contact the Meeting Director at the following address: md-w98@cms.math.ca.

Contributed Papers: Contributed papers of 15-minutes' duration are invited and **graduate students are particularly urged to participate**. For an abstract to be eligible, the abstract must be received **before September 31, 1998**. The abstract must be accompanied by its contributor's registration form and appropriate fees.

Information: Canadian Mathematical Society, 577 King Edward, Suite 109, POB 450, Station A, Ottawa, Ontario, Canada K1N 6N5; tel: 613-562-5702; fax: 613-565-1539; e-mail: meetings@cms.math.ca; WWW: http://www.camel.math.ca/CMS/Events/winter98/.

January 1999

* 11-14 **Workshop on Coding and Cryptography**, Cercle militaire St. Augustin, Paris, France.

Focus: The purpose is to bring together researchers in all aspects of coding theory, cryptography and related areas, theoretical or applied.

Topics: Coding theory: block codes (linear or nonlinear), cyclic codes, Euclidean codes, covering radius, weight distributions, soft decision decoding; convolutional codes, turbo coding, soft output decoding. Cryptology: block and stream ciphers, hash functions, public key cryptography, digital signature, secret sharing, authentication, cryptanalysis, copyright protection. Connections between these two main areas: finite groups, finite fields, algebraic geometry, function fields, random structures, lattices, combinatorics, designs, Boolean functions, sequences.

Invited Speakers: H. Dobbertin, J. Massey, V. Pless, and others to be announced.

Submissions: Those wishing to contribute a 20-minute talk are invited to submit a 2-10 page extended abstract, before October 2, 1998, by sending either three hard copies to: C. Carlet, Program committee of WCC 99, INRIA, Projet CODES, BP 105, 78153 Le Chesnay Cedex, France; or, preferably, an electronic copy (LaTeX or PostScript) by e-mail to wcc-prog@inria.fr. A volume including the accepted abstracts will be published by INRIA and provided to the participants.

Organizers: Chair of the program committee: C. Carlet; organization: N. Sendrier; local organization: C. Thenault.

Deadlines: Submission by October 2, 1998; notification by November 13, 1998; final version by November 27, 1998.

Information: Web: http://www-rocq.inria.fr/codes/WCC99/; e-mail: wcc-orga@inria.fr.

* 26-30 **Fields Institute Workshop on Probability in Finance**, Fields Institute, Toronto, Canada.

Organizing Committee: C. Albanese (Univ. of Toronto), D. Dawson (Fields Inst.), H. Foellmer (Humboldt Univ.), P. E. Greenwood (Univ. of British Columbia), T. Kurtz (Univ. of Wisconsin), T. Lyons (Imperial College), D. Salopek (York Univ.).

Topics: Major themes will include: Interest

Rates and Currency Models, Credit Risk, Risk Management, Interplay of Finance and Insurance, and Derivative Pricing.
Speakers: M. Crouhy (CIBC), M. Davis (Mitsubishi Bank), F. Delbaen (ETH, Zurich), D. Duffie (Stanford), P. Embrechts (ETH, Zurich), H. Follmer (Humboldt Univ.)-Kolmogorov lecturer, H. Geman (Univ. Paris IX Dauphine and ESSEC), D. Heath (Cornell Univ.), J. Hull (Univ. of Toronto), I. Karatzas (Columbia Univ.), A. Lo (MIT), L. C. G. Rogers (Univ. of Bath), S. Ross (Yale Univ.), S. Shreve (Carnegie Melon Univ.), S. Turnbull (CIBC), M. Yor (Univ. Paris VI).
Focus: The workshop is being organized in connection with the Fields Institute program in Probability and its Applications, August 1998 - June 1999.
Information: For further information about the workshop and the program, please see the program Website `http://www.fields.utoronto.ca/probability.html`, or write to: The Fields Institute for Research in Mathematical Sciences, 222 College Street, Second Floor, Toronto, Ontario, M5T 3J1, Canada; tel: 416-348-9710, fax: 416-348-9385, e-mail: `probfin@fields.utoronto.ca`.

March 1999

* 25-26 **Third International Multidisciplinary Congress in Quality and Reliability**, Paris, France.
Organizers: l'ENSAM and RUFEREQ (Réseau Universitaire Français pour l'Enseignement et la Recherche en Qualité).

May 1999

* 26-28 **Crystallographic Groups and their Generalizations II**, K. U. Leuven (Campus Kortrijk), Kortrijk, Belgium.
Scientific Committee: H. Abels (Bielefeld), Y. Felix (Louvain la Neuve), F. Grunewald (Duesseldorf), P. Igodt (Leuven/Kortrijk).
Invited Speakers: Y. Benoist (Paris), M. Bridson (Oxford), C. Casacuberta (Barcelona), K. Dekimpe (Leuven/Kortrijk), B. Farb (Chicago), W. Goldman (College Park), G. Margulis (Yale, to be confirmed).
Topics: Recent developments concerning crystallographic groups, and all concepts which can be seen as generalizations of them, are the subject of this workshop. A non-exhaustive list of possible topics includes: Affine crystallographic groups and affine manifolds; almost crystallographic groups and infra-nilmanifolds; polynomial structures on polycyclic-by-finite groups and polynomial manifolds; discrete subgroups of Lie groups and homogeneous spaces; localisation problems for groups; finitely generated groups, quasi-isometry and rigidity; geometric group theory.
Information: `http://www.kulak.ac.be/workshop`.

June 1999

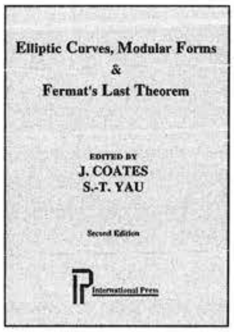
* 17-20 **Mathematics in Physics and Computer Science (Cooperation project between scientists from the CIS and Germany)**, Technische Universitaet Berlin, Germany.
Focus: It's the final meeting of the cooperation project between scientists from the CIS and Germany (in particular mathematicians). Six years of scientific activity and successes will be reviewed. Participants of the "Volkswagen-Project" will give talks on topics related to their particular sub-projects.
Supported By: Generously supported by the Volkswagenstiftung (`http://www.volkswagen-stiftung.de`).
Information: For more information contact: Technische Universitaet Berlin, Fachbereich Mathematik, Sekretariat MA 7-2, Strasse des 17. Juni 136, 10623 Berlin, Germany; tel: 0049-30-31424882; fax: 0049-30-31424413; e-mail: `downes@math.tu-berlin.de` or e-mail: `lang@math.tu-berlin.de`.

August 1999

* 23-27 **International Conference on Topology and its Applications**, Kanagawa University, Yokohama, Japan.
Topics: All areas of topology; especially general/set-theoretic topology, geometric topology, set theory, continuum theory, and dynamical systems, and applications of topology to other areas of mathematics.
Information: Y. Yajima, e-mail: `yuki@cc.kanagawa-u.ac.jp`.

New Publications Offered by the AMS

Algebra and Algebraic Geometry



Elliptic Curves, Modular Forms & Fermat's Last Theorem

John Coates, *University of Cambridge, England*, and **S.-T. Yau**, *Harvard University, Cambridge, MA*, Editors

This is an expanded edition of a prevously published work. Two chapters have been added to this revised edition.

A conference, on the general theme of "Elliptic Curves and Modular Forms" was held in the Mathematics Department of the Chinese University of Hong Kong in December 1993. The impetus for organizing the conference arose from Andrew Wiles' deep and spectacular work on the celebrated conjecture that every elliptic curve over Q is modular, although only some of the lectures at the conference were specifically related to this theme. At the time of the conference, the difficulties in the last hurdle in Wiles' work (the proof of the conjectural upper bound for the order of the Selmer group attached to the symmetric square of a modular form) had still not been overcome. It is now history that Wiles himself, assisted by R. Taylor, found a beautiful proof of the desired upper bound. As a result, we now know today the remarkable fact that every semi-elliptic curve over Q is modular. This proof is not only revolutionary in its own right, but it also provides a proof of Fermat's Last Theorem. This volume is a mixture of the texts of some of these lectures, together with a number of recent articles related to the general theme of the conference.

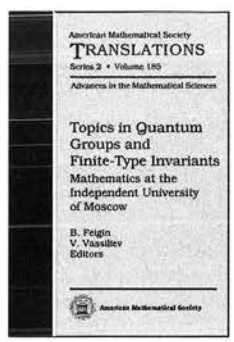
This text will also be of interest to those working in number theory.

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

Contents: H. Darmon, F. Diamond, and **R. Taylor**, Fermat's Last Theorem; **P. Balister**, Characteristic distributions for non-torsion Λ-modules; **J. Coates** and **A. Sydenham**, On the symmetric square of a modular elliptic curve; **F. Diamond**, The refined conjecture of Serre; **N. Elkies**, Wiles minus epsilon implies Fermat; **J.-M. Fontaine** and **B. Mazur**, Geometric Galois representations; **G. Frey**, On elliptic curves; **H. W. Lenstra, Jr.**, Complete intersections and Gorenstein rings; **L. Merel**, Homologie des courbes modulaires; **K. A. Ribet**, Irreducible Galois representation; **K. Rubin** and **A. Silverberg**, Mod p representations of elliptic curves; **J. Tate**, A review of non-Archimedean elliptic functions; **R. Taylor**, On Galois representations associated to Hilbert modular forms II.

International Press

1997, 340 pages, Hardcover, ISBN 1-57146-049-7, 1991 *Mathematics Subject Classification*: 00B25; 11, 06, 14, **All AMS members $34**, List $42, Order code INPR/5N



Topics in Quantum Groups and Finite-Type Invariants

Mathematics at the Independent University of Moscow

B. Feigin and **V. Vassiliev**, *Independent University of Moscow, Russia*, Editors

This volume presents the first collection of articles consisting entirely of work by faculty and students of the Higher Mathematics College of the Independent University of Moscow (IUM). This unique institution was established to train elite students to become research scientists. Covered in the book are two main topics: quantum groups and low-dimensional topology. The articles were written by participants of the Feigin and Vassiliev seminars, two of the most active seminars at the IUM.

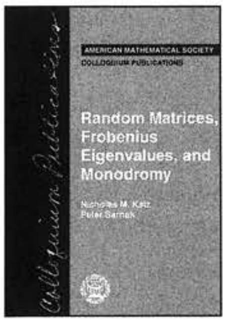
This text will also be of interest to those working in geometry and topology.

Contents: *Algebra:* **S. M. Arkhipov**, Semi-infinite cohomology of quantum groups. II; **David Erschler**, Symmetry groups of regular polyhedra over finite fields; **B. L. Feĭgin** and **A. V. Odesskiĭ**, Coordinate ring of the quantum Grassmannian and intertwiners for the representations of Sklyanin algebras; **B. L. Feĭgin** and **A. V. Odesskiĭ**, Vector bundles on an elliptic curve and Sklyanin algebras; **M. Finkelberg, A. Kuznetsov,** and **I. Mirković**, The singular supports of IC sheaves on spaces of quasimaps are irreducible; **Boris Shoikhet**, Cohomology of the Lie algebras of differential operators: Lifting formulas; *Geom-*

etry: **P. M. Akhmetiev**, On a higher analog of the linking number of two curves; **S. S. Anisov** and **S. K. Lando**, Topological complexity of T^2-bundles over the circle; **S. K. Lando**, Tutte decomposition for graphs, weighted graphs, and symmetric matrices; **V. Turchin**, Homology isomorphism of the complex of 2-connected graphs and the graph-complex of trees; **V. A. Vassiliev**, On invariants and homology of spaces of knots in arbitrary manifolds.

American Mathematical Society Translations—Series 2 (*Advances in the Mathematical Sciences*), Volume 185

June 1998, 182 pages, Hardcover, ISBN 0-8218-1084-7, LC 91-640741, 1991 *Mathematics Subject Classification*: 17Bxx, 57Mxx; 16Wxx, **Individual member $53**, List $89, Institutional member $71, Order code TRANS2/185N



Random Matrices, Frobenius Eigenvalues, and Monodromy

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

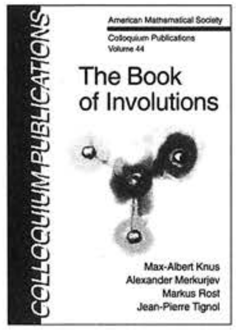
The main topic of this book is the deep relation between the spacings between zeros of zeta and L-functions and spacings between eigenvalues of random elements of large compact classical groups. This relation, the Montgomery-Odlyzko law, is shown to hold for wide classes of zeta and L-functions over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

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

Contents: Statements of the main results; Reformulation of the main results; Reduction steps in proving the main theorems; Test functions; Haar measure; Tail estimates; Large N limits and Fredholm determinants; Several variables; Equidistribution; Monodromy of families of curves; Monodromy of some other families; GUE discreancies in various families; Distribution of low-lying Frobenius eigenvalues in various families; Appendix AD: Densities; Appendix AG: Graphs; References.

Colloquium Publications

October 1998, approximately 416 pages, Hardcover, ISBN 0-8218-1017-0, LC 98-20459, 1991 *Mathematics Subject Classification*: 11G25, 14G10, 60Fxx, 14D05; 11Y35, 82Bxx, 11M06, **Individual member $41**, List $69, Institutional member $55, Order code COLL-KATZN



The Book of Involutions

Max-Albert Knus, *Eidgenössische Technische Hochschule, Zürich, Switzerland*, **Alexander Merkurjev**, *University of California, Los Angeles*, **Markus Rost**, *Universität at Regensburg, Germany*, and **Jean-Pierre Tignol**, *Université Catholique de Louvain, Louvain-la-Neuve, Belgium*

This monograph is an exposition of the theory of central simple algebras with involution, in relation to linear algebraic groups. It provides the algebra-theoretic foundations for much of the recent work on linear algebraic groups over arbitrary fields. Involutions are viewed as twisted forms of (hermitian) quadrics, leading to new developments on the model of the algebraic theory of quadratic forms. In addition to classical groups, phenomena related to triality are also discussed, as well as groups of type F_4 or G_2 arising from exceptional Jordan or composition algebras. Several results and notions appear here for the first time, notably the discriminant algebra of an algebra with unitary involution and the algebra-theoretic counterpart to linear groups of type D_4. This volume also contains a Bibliography and Index.

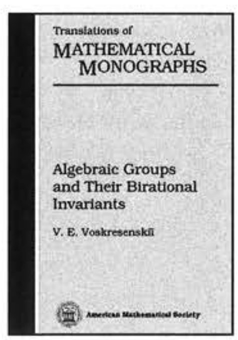
Features:

- original material not in print elsewhere
- a comprehensive discussion of algebra-theoretic and group-theoretic aspects
- extensive notes that give historical perspective and a survey on the literature
- rational methods that allow possible generalization to more general base rings

Contents: Involutions and Hermitian forms; Invariants of involutions; Similitudes; Algebras of degree four; Algebras of degree three; Algebraic groups; Galois cohomology; Composition and triality; Cubic Jordan algebras; Trialitarian central simple algebras; Bibliography; Index; Notation.

Colloquium Publications, Volume 44

August 1998, 593 pages, Hardcover, ISBN 0-8218-0904-0, LC 98-22202, 1991 *Mathematics Subject Classification*: 11E39, 11E57, 11E72; 11E88, 16K20, 16W10, 17A75, 17C40, 20G15, **All AMS members $55**, List $69, Order code COLL/44N



Algebraic Groups and Their Birational Invariants

V. E. Voskresenskiĭ, *Samara State University, Russia*

Since the late 1960s, methods of birational geometry have been used successfully in the theory of linear algebraic groups, especially in arithmetic problems. This book—which can be viewed as a significant revision of the author's book, *Algebraic Tori* (Nauka, Moscow, 1977)—

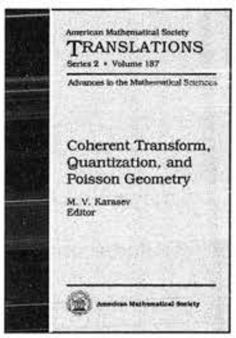
studies birational properties of linear algebraic groups focusing on arithmetic applications. The main topics are forms and Galois cohomology, the Picard group and the Brauer group, birational geometry of algebraic tori, arithmetic of algebraic groups, Tamagawa numbers, R-equivalence, projective toric varieties, invariants of finite transformation groups, and index-formulas. Results and applications are recent. There is an extensive bibliography with additional comments that can serve as a guide for further reading.

Contents: Forms and Galois cohomology; Birational geometry of algebraic tori; Invariants of finite transformation groups; Arithmetic of linear algebraic groups; Tamagawa numbers; R-equivalence in algebraic groups; Index formulas in arithmetic of algebraic tori; Bibliographical remarks; References.

Translations of Mathematical Monographs

September 1998, approximately 227 pages, Hardcover, ISBN 0-8218-0905-9, 1991 *Mathematics Subject Classification*: 20G15, 20G30; 14G05, 14G25, **Individual member $59**, List $99, Institutional member $79, Order code MMONO-VOSKRESENSN

Analysis



Coherent Transform, Quantization, and Poisson Geometry

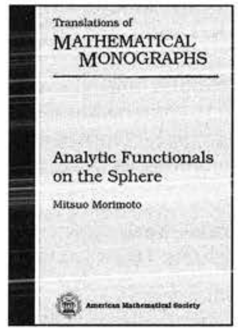
M. V. Karasev, *Moscow Institute of Electronics and Mathematics, Russia*, Editor

This volume contains three extensive articles written by Karasev and his pupils. Topics covered include the following: coherent states and irreducible representations for algebras with non-Lie permutation relations, Hamilton dynamics and quantization over stable isotropic submanifolds, and infinitesimal tensor complexes over degenerate symplectic leaves in Poisson manifolds. The articles contain many examples (including from physics) and complete proofs.

Contents: M. Karasev and **E. Novikova**, Non-Lie permutation relations, coherent states, and quantum embedding; **M. Karasev** and **Y. Vorobjev**, Adapted connections, Hamilton dynamics, geometric phases, and quantization over isotropic submanifolds; **V. Itskov**, **M. Karasev**, and **Y. Vorobjev**, Infinitesimal Poisson cohomology.

American Mathematical Society Translations—Series 2 (*Advances in the Mathematical Sciences*), Volume 187

September 1998, approximately 376 pages, Hardcover, ISBN 0-8218-1178-9, LC 91-640741, 1991 *Mathematics Subject Classification*: 58F05, 81R30, 70H05, 81Sxx; 33Cxx, 51H15, 53C05, **Individual member $71**, List $119, Institutional member $95, Order code TRANS2/187N



Analytic Functionals on the Sphere

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

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

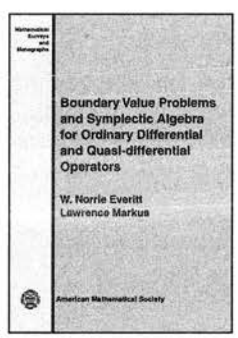
The author first introduces a system of complex neighborhoods of the sphere by means of the Lie norm. He then studies holomorphic functions and analytic functionals on the complex sphere. In the one-dimensional case, this corresponds to the study of holomorphic functions and analytic functionals on the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

Contents: Fourier expansion of hyperfunctions on the circle; Spherical harmonic expansion of functions on the sphere; Harmonic functions on the Lie ball; Holomorphic functions on the complex sphere; Holomorphic functions on the Lie ball; Entire functions of exponential type; Fourier-Borel transformation on the complex sphere; Spherical Fourier-Borel transformation on the Lie ball; Bibliography; Index.

Translations of Mathematical Monographs

September 1998, approximately 170 pages, Hardcover, ISBN 0-8218-0585-1, LC 98-23076, 1991 *Mathematics Subject Classification*: 46F15; 32A25, 32A45, 32C35, 58G07, **Individual member $39**, List $65, Institutional member $52, Order code MMONO-MORIMOTO2N

Differential Equations



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

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

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

Features:

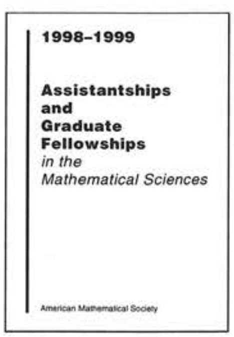
- Authoritative and systematic exposition of the classical theory for self-adjoint linear ordinary differential operators (including a review of all relevant topics in texts of Naimark, and Dunford and Schwartz).
- Introduction and development of new methods of complex symplectic linear algebra and geometry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

Contents: Introduction: Fundamental algebraic and geometric concepts applied to the theory of self-adjoint boundary value problems; Maximal and minimal operators for quasi-differential expressions, and GKN-theory; Symplectic geometry and boundary value problems; Regular boundary value problems; Singular boundary value problems; Appendix A. Constructions for quasi-differential operators; Appendix B. Complexification of real symplectic spaces, and the real GKN-theorem for real operators; References.

Mathematical Surveys and Monographs

October 1998, approximately 200 pages, Hardcover, ISBN 0-8218-1080-4, 1991 *Mathematics Subject Classification*: 34B05, 34L05, 58F05; 11E39, 47B25, 47E05, **Individual member $29**, List $49, Institutional member $39, Order code SURV-EVERITTN

General and Interdisciplinary



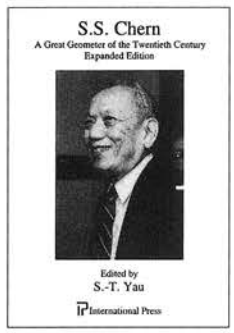
Assistantships and Graduate Fellowships in the Mathematical Sciences, 1998–1999

This publication is an indispensible source of information for students seeking support for graduate study in the mathematical sciences. Providing data from a broad range of academic institutions, it is also a valuable resource for mathematical sciences departments and faculty.

Assistantships and Graduate Fellowships brings together a wealth of information about resources available for graduate study in mathematical sciences departments in the U.S. and Canada. Information on the number of faculty, graduate students, and degrees awarded (bachelor's, master's, and doctoral) is listed for each department when provided. Stipend amounts and the number of awards available are given, as well as information about foreign language requirements. Numerous display advertisements from mathematical sciences departments throughout the country provide additional information.

Also listed are sources of support for graduate study and travel, summer internships, and graduate study in the U.S. for foreign nationals. Finally, a list of reference publications for fellowship information makes *Assistantships and Graduate Fellowships* a centralized and comprehensive resource.

October 1998, approximately 136 pages, Softcover, ISBN 0-8218-1070-7, 1991 *Mathematics Subject Classification*: 00, **Individual member $12**, List $20, Order code ASST/98N



S. S. Chern: A Great Geometer of the Twentieth Century

Expanded Edition

S.-T. Yau, *Harvard University, Cambridge, MA*, Editor

This is an expanded edition of a previous work. Two chapters have been added to this revised edition.

In the summer of 1990, S. Y. Cheng and S.-T. Yau organized a conference in Los Angeles in honor of their professor, S. S. Chern, on the occasion of his seventy-ninth birthday. Published here are personal reminiscences from Chern's large group of friends and students. These lectures reflect the wisdom of this great mathematician and his warmth in interacting with young geometers. The editors hope that through this book, readers might get a glimpse of the life of a great geometer.

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

Contents: **S. S. Chern**, My mathematical education; **R. Palais** and **C. Terng**, The life and mathematics of Shiing-Shen Chern, Dedicated to S. S. Chern for the celebration of his 79th birthday; **C. N. Yang**, S. S. Chern and I; **A. Weil**, S. S. Chern as geometer and friend; **W. Chow**, Shiing-Shen Chern, as friend and mathematician, a reminiscence on the occasion of his 80th birthday; **I. M. Singer**, S. S. Chern at Chicago; **P. C. W. Chu**, Professor S. S. Chern, my father-in-law; **I. Kaplansky**, Shiing-Shen Chern, with admiration as he approaches his 80th birthday; **L. Nirenberg**, Some personal remarks about S. S. Chern; **F. E. Browder**, S. S. Chern; **R. Lashof**, Personal recollection of Chern at Chicago; **R. Bott**, For the Chern volume; **L. Auslander**, S. S. Chern as teacher; **H. Suzuki**, Reminiscences and acknowledgements; **P. A. Griffiths**, Professor S. S. Chern, 79th birthday celebration; **W. Stoll**, Shiing-Shen Chern's influence on value distribution; dedicated to Shiing-Shen Chern; **W. Klingenberg**, My encounters with S. S. Chern; **F. Haab** and **N. H. Kuiper**, On the normal Gauss map of a tight smooth surface in R^3; **J. Simons**, My interaction with S. S. Chern; **M. P. do Carmo**, S. S. Chern: Mathematical influences and reminiscences; **M. Burger**, Riemannian manifolds: From curvature to topology, a brief historical overview; **B. Lawson**, On Chern and youth; **J. Cheeger**, Remarks delivered at Chern's 79th birthday celebration; **A. Weinstein**, Some thoughts about S. S.

Chern; **R. Greene**, Some mathematical and personal reminiscences; **S. Y. Cheng**, My teacher S. S. Chern; **S. M. Webster**, On being a Chern student; **J. P. Bourguignon**, Shiing-Shen Chern, an optimist; **J. Wolfson**, Chern, some recollections; **S.-T. Yau**, S. S. Chern, as my teacher; **S.-T. Yau**, Open problems in differential geometry; **C.-C. Hsiung**, My associations with S. S. Chern; **T. Banchoff**, Becoming and being a Chern student.

International Press

1998, 331 pages, Hardcover, ISBN 1-57146-098-5, 1991 *Mathematics Subject Classification*: 53-03; 01A60, 01A70, **All AMS members $34**, List $42, Order code INPR/14N

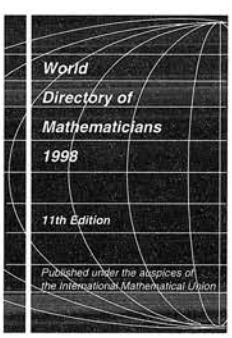
Combined Membership List 1998–1999

The *Combined Membership List* (CML) is a comprehensive directory of the membership of the American Mathematical Society, the American Mathematical Association of Two-Year Colleges, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics.

There are two lists of individual members. The first is a complete alphabetical list of all members in all four organizations. For each member, the CML provides his or her address, title, department, institution, telephone number (if available), and electronic address (if indicated), and also indicates membership in the four participating societies. The second is a list of individual members according to their geographic locations. In addition, the CML lists academic, institutional, and corporate members of the four participating societies providing addresses and telephone numbers of mathematical sciences departments.

The CML is distributed on request to AMS members in even-numbered years. MAA members can request the CML in odd-numbered years from the MAA. The CML is an invaluable reference for keeping in touch with colleagues and for making connections in the mathematical sciences community in the United States and abroad.

November 1998, approximately 392 pages, Softcover, ISBN 0-8218-1089-8, 1991 *Mathematics Subject Classification*: 00, **Individual member $37**, List $62, Institutional member $50, Order code CML/98/99N



World Directory of Mathematicians 1998

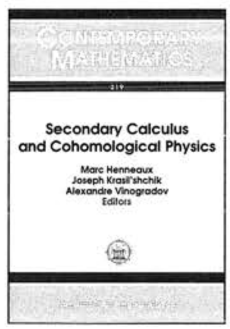
This 11th edition of the *World Directory of Mathematicians* 1998 incorporates updates and corrections to the 1994 edition, as well as nearly 30 percent more names. Published by the International Mathematical Union, this valuable reference contains the names and addresses of over 50,000 mathematicians from 69 countries. There is also an increase in the number of fax numbers and email addresses in this edition. Listings for the directory are arranged both alphabetically and geographically and are based on information supplied by National Committees for Mathematics (or corresponding organizations). Libraries, mathematics departments, and individuals will find this new edition to be a valuable resource for its extensive coverage of the international mathematical community.

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

Published by the International Mathematical Union.

August 1998, 1093 pages, Softcover, 1991 *Mathematics Subject Classification*: 00, **All Individuals $40**, List $65, Order code WRLDIR/11N

Mathematical Physics



Secondary Calculus and Cohomological Physics

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

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

Features:

- An up-to-date and self-contained exposition of the newest results in cohomological aspects of quantum field theory and the geometry of PDEs.
- A new look at interrelations between cohomology theory, the geometry of PDEs, and field theory.
- Application to Batalin-Vilkovisky formalism, BRST formalism, anomalies, and quantum dynamics.

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

Contents: **M. Asorey**, **F. Falceto**, and **G. Luzón**, Unstable bundles in quantum field theory; **G. Barnich**, Brackets in the jet-bundle approach to field theory; **C. Becchi**, **S. Giusto**, and **C. Imbimbo**, The BRST structure of twisted $N = 2$ algebra; **L. Bonora**, **C. S. Chu**, and **M. Rinaldi**, Anomalies and locality in field theories and M-theory; **F. Brandt**, Gauge covariant algebras and local BRST cohomology; **M. Dubois-Violette**, Generalized homologies for $d^N = 0$ and graded q-differential algebras; **M. Fliess**, **J. Lévine**, **P. Martin**, and **P. Rouchon**, Nonlinear control and diffieties, with an application to physics; **M. Henneaux**, Consistent interactions between gauge fields: the cohomological approach; **N. Kamran** and **T. Robart**, A compatible analytic manifold structure for Lie pseudogroups of infinite type; **J. Krasil′shchik**, Cohomology background in geometry of PDE; **N. Maggiore**, Algebraic renormalization of massive supersymmetric theories; **G. Marmo** and **A. Ibort**, A new look at completely integrable systems and double Lie groups; **V. Penna**, **M. Rasetti**, and **M. Spera**, Quantum dynamics of 3-D vortices; **J. D. Stasheff**, The (secret?) homological algebra of the Batalin-Vilkovisky approach; **A. Verbovetsky**, Notes on the horizontal cohomology; **C. M. Viallet**, Invariants of rational transformations and algebraic entropy; **A. Vinogradov**, Introdution to secondary calculus; **A. Vinogradov** and **M. Vinogradov**, On multiple generalizations of Lie algebras and Poisson manifolds.

Contemporary Mathematics, Volume 219

June 1998, 287 pages, Softcover, ISBN 0-8218-0828-1, LC 98-22945, 1991 *Mathematics Subject Classification*: 81T70, 35Qxx; 58-06, 81-06, **Individual member $36**, List $60, Institutional member $48, Order code CONM/219N

AMERICAN MATHEMATICAL SOCIETY

Probability

Local Properties of Distributions of Stochastic Functionals

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

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

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

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

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

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

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

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

Short-Time Geometry of Random Heat Kernels

Richard B. Sowers, *University of Illinois, Urbana*

This volume studies the behavior of the random heat kernel associated with the stochastic partial differential equation $du = \frac{1}{2}\Delta u dt = (\sigma, \quad u) \quad dW_t$, on some Riemannian manifold M. Here Δ is the Laplace-Beltrami operator, σ is some vector field on M, and is the gradient operator. Also, W is a standard Wiener process and denotes Stratonovich integration. The author gives short-time expansion of this heat kernel. He finds that the dominant exponential term is classical and depends only on the Riemannian distance function. The second exponential term is a work term and also has classical meaning. There is also a third non-negligible exponential term which blows up. The author finds an expression for this third exponential term which involves a random translation of the index form and the equations of Jacobi fields. In the process, he develops a method to approximate the heat kernel to any arbitrary degree of precision.

Memoirs of the American Mathematical Society, Volume 132, Number 629; 1998; 130 pages; Softcover; ISBN 0-8218-0649-1; List $41; Individual member $25; Order code MEMO/132/629NA

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AMERICAN MATHEMATICAL SOCIETY

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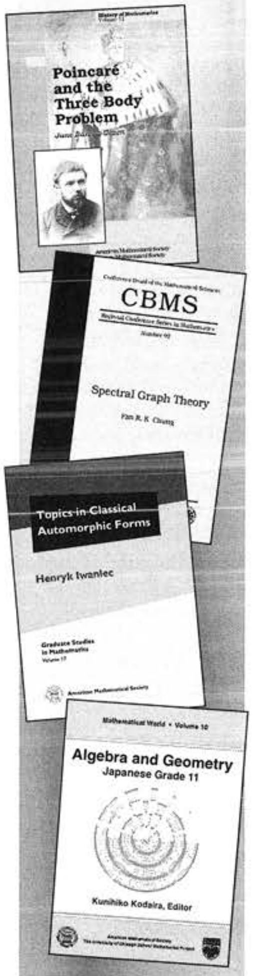
AMERICAN MATHEMATICAL SOCIETY

PUBLICATIONS *of* CONTINUING INTEREST



RECENTLY REVIEWED WORKS

Comments from the following reviews published in reknowned mathematical journals make evident the top-notch material produced by the AMS publishing program. To order, contact AMS Customer Services (see contact info below), or visit us on the Web at www.ams.org/bookstore.

Poincaré and the Three Body Problem

June Barrow-Green, *The Open University, Milton Keynes, UK*

An interesting insight into the late 19th-century mathematical community and an account of [Poincaré's] memoirs reception and impact ... clearly organized, well written, richly documented ... a highly valuable contribution to the history of modern mathematics.

—Zentralblatt für Mathematik

Co-published with the London Mathematical Society. Members of the LMS may order directly from the AMS at the AMS member price. The LMS is registered with the Charity Commissioners.

History of Mathematics, Volume 11; 1996; ISBN 0-8218-0367-0; 272 pages; Softcover; **All AMS members $31**, List $39, Order Code HMATH/11CI88

Independent Study

Spectral Graph Theory

Fan R. K. Chung, *University of Pennsylvania, Philadelphia*

Incorporates a great deal of recent work, much of it due to the author herself ... clear, without being pedantic, and challenging, without being obscure.

—Bulletin of the London Mathematical Society

CBMS Regional Conference Series in Mathematics, Number 92; 1996; ISBN 0-8218-0315-8; 207 pages; Softcover; **All Individuals $20**, List $25, Order Code CBMS/92CI88

Supplementary Reading

Independent Study

Topics in Classical Automorphic Forms

Henryk Iwaniec, *Rutgers University, New Brunswick, NJ*

The author discusses many important topics in the theory of automorphic forms which are rarely seen in the textbooks available on the subject ... the presentation of the proofs ... is ... unusual, and this may give the reader a different flavor of the subject ... graduate students will certainly benefit from this book.

—Mathematical Reviews

Graduate Studies in Mathematics, Volume 17; 1997; ISBN 0-8218-0777-3; 259 pages; Hardcover; **All AMS members $31**, List $39, Order Code GSM/17CI88

Algebra and Geometry: Japanese Grade 11

Kunihiko Kodaira, *Gakushuin University, Tokyo, Japan*, Editor

Contains four chapters of excellent examples and well-designed problems ... the strength of the book lies in the way that each chapter is related to the others through the design of the problems and examples ... would be a good resource for high school algebra teachers and would be an exceptional resource for teachers of analytic geometry.

—The Mathematics Teacher

Mathematical World, Volume 10; 1996; ISBN 0-8218-0581-9; 174 pages; Softcover; **All AMS members $19**, List $24, Order Code MAWRLD/10CI88

Equivariant Homotopy and Cohomology Theory

J. P. May, *University of Chicago, IL*

Absolutely necessary to have this guide-book on the desk ... applies to the advanced student as well as to the educated scientist. The presentation is clear, reliable, informative and motivating ... there is no comparable recent book in algebraic topology ... almost certainly guides further research.

—Bulletin of the London Mathematical Society

CBMS Regional Conference Series in Mathematics, Number 91; 1996; ISBN 0-8218-0319-0; 366 pages; Softcover; **All Individuals $39**, List $49, Order Code CBMS/91CI88

Index Theory, Coarse Geometry, and Topology of Manifolds

John Roe, *University of Oxford, England*

A clear introduction to a subject which is obviously quite complicated ... for those interested in acquainting themselves with the C^*-algebraic index theory and its applications, the entire book should be required reading.

—Bulletin of the London Mathematical Society

CBMS Regional Conference Series in Mathematics, Number 90; 1996; ISBN 0-8218-0413-8; 100 pages; Softcover; **All Individuals $14**, List $17, Order Code CBMS/90CI88

Metrics, Connections and Gluing Theorems

Clifford Henry Taubes, *Harvard University, Cambridge, MA*

Easy to read ... well written in a pleasant, informal style, with occasional humour ... should be accessible to graduate students in differential geometry and others.

—Bulletin of the London Mathematical Society

CBMS Regional Conference Series in Mathematics, Number 89; 1996; ISBN 0-8218-0323-9; 90 pages; Softcover; **All Individuals $12**, List $15, Order Code CBMS/89CI88

Independent Study

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Kenji Ueno, *Kyoto University, Japan*

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*The annual dues for **category-S members,** those who reside in developing countries, are $16. Members can chose only one privilege journal. Please indicate your choice below.*

*Members can purchase a **multi-year membership** by prepaying their current dues rate for either two, three, four or five years. This option is not available to category-S, unemployed, or student members.*

1998 Dues Schedule (January through December)

Ordinary member .... ☐ $96 ☐ $128

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Student member (please verify)[1] .... ☐ $32

Unemployed member (please verify)[2] .... ☐ $32

Reciprocity member (please verify)[3] .... ☐ $64 ☐ $96 ☐ $128

Category-S member[4] .... ☐ $16

Multi-year membership .... $ .... for .... years

[1] ***Student Verification*** (sign below)

I am a full-time student at ....

.... *currently working toward a degree.*

[2] ***Unemployed Verification*** (sign below) *I am currently unemployed and actively seeking employment.*

[3] ***Reciprocity Membership Verification*** (sign below) *I am currently a member of the society indicated on the right and am therefore eligible for reciprocity membership.*

....

Signature

[4] ☐ ***send*** **NOTICES** ☐ ***send*** **BULLETIN**

Reciprocating Societies

- ☐ Allahabad Mathematical Society
- ☐ Australian Mathematical Society
- ☐ Azerbaijan Mathematical Society
- ☐ Balkan Society of Geometers
- ☐ Berliner Mathematische Gessellschaft e.V.
- ☐ Calcutta Mathematical Society
- ☐ Croatian Mathematical Society
- ☐ Cyprus Mathematical Society
- ☐ Dansk Matematisk Forening
- ☐ Deutsche Mathematiker-Vereinigung e.V.
- ☐ Edinburgh Mathematical Society
- ☐ Egyptian Mathematical Society
- ☐ Gesellschaft für Angewandte Mathematik und Mechanik
- ☐ Glasgow Mathematical Association
- ☐ Hellenic Mathematical Society
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- ☐ Palestine Society for Mathematical Sciences
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- ☐ Punjab Mathematical Society
- ☐ Ramanujan Mathematical Society
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- ☐ Sociedad Matemática de la Republica Dominicana
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- ☐ Sociedade Portuguesa de Matemática
- ☐ Societat Catalana de Matemàtiques
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- ☐ Societatea Matematicienilor din Romania
- ☐ Société de Mathématiques Appliquées et Industrielles
- ☐ Société Mathématique de Belgique
- ☐ Société Mathématique de France
- ☐ Société Mathématique Suisse
- ☐ Society of Associations of Mathematicians & Computer Science of Macedonia
- ☐ Society of Mathematicians, Physicists, and Astronomers of Slovenia
- ☐ South African Mathematical Society
- ☐ Southeast Asian Mathematical Society
- ☐ Suomen Matemaattinen Yhdistys
- ☐ Svenska Matematikersamfundet
- ☐ Ukrainian Mathematical Society
- ☐ Union Mathemática Argentina
- ☐ Union of Bulgarian Mathematicians
- ☐ Union of Czech Mathematicians and Physicists
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EXAM COPIES: Complimentary exam copies are available for AMS titles marked "Recommended Text". Other AMS titles are sent on a **30-day examination** basis. To order an exam copy, please forward your request on **university letterhead.** Specify **Course Title, Term Taught, Enrollment,** and the **Current Text Used.** Send the information to: Lori Sprague, Sales Administrator, American Mathematical Society, P. O. Box 6248, Providence, RI 02940-6248. 1-800-321-4AMS (4267), U.S. and Canada, 1-401-455-4000, worldwide. E-mail: las@ams.org, fax: 1-401-331-3842.

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Change of Address

Members of the Society who move or change positions are urged to notify the Providence Office as soon as possible.

Journal mailing lists must be printed four to six weeks before the issue date. Therefore, in order to avoid disruption of service, members are requested to provide the required notice well in advance.

Besides mailing addresses for members, the Society's records contain information about members' positions and their employers (for publication in the Combined Membership List). In addition, the AMS maintains records of members' honors, awards, and information on Society service.

When changing their addresses, members are urged to cooperate by supplying the requested information. The Society's records are of value only to the extent that they are current and accurate.

If your address has changed or will change within the next two or three months, please fill out this form, supply any other information appropriate for the AMS records, and mail it to:

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Meetings & Conferences of the AMS

PROGRAM ALERT: In order that AMS meeting programs include the most timely information for each speaker, abstract deadlines have been moved to dates much closer to the meeting. What this means is that most meeting programs will appear in the *Notices* *after* the meeting takes place. However, complete meeting programs will be available on e-MATH about two to three weeks after the abstract deadline. *Remember*, e-MATH is your most comprehensive source for up-to-date meeting information. See `http://www.ams.org/meetings/`.

Chicago, Illinois

DePaul University-Chicago

September 12-13, 1998

Meeting #935

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: June/July 1998
Program issue of *Notices*: November 1998
Issue of *Abstracts*: Volume 19, Issue 3

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired

For abstracts: July 21, 1998

ATTENTION! PLEASE READ CAREFULLY!

Due to the extraordinary number of people (100,000+) attending a conference on Manufacturing Technology being held in Chicago we have been advised that there are NO hotel rooms available in the immediate area. The AMS has blocked rooms at the O'Hare Hilton. The cost is $125 single or double. Reservations can be made by calling 773-686-8000 or 1-800-455-8667. Mention the American Mathematical Society (AMS) meeting.

Transportation from the Hilton to DePaul is best provided by the "Blue Line" Chicago Transit Authority (CTA) train which runs 24 hours a day, approximately every 10 minutes (every 20 minutes at night). From the trains, exit at Jackson Boulevard (300 south). The fare is $1.50 and exact change is recommended to simplify entering the train stations. The ride between the hotel and DePaul University is approximately 30-35 minutes.

We regret any inconvenience this development may cause. The AMS Website (www.ams.org/meetings/) has been updated to reflect any change in hotel availability.

Invited Addresses

Vitaly Bergelson, Ohio State University, *Number theory, combinatorics and ergodic theorems along polynomials.*

Sheldon Katz, Oklahoma State University, *The mathematics and physics of mirror symmetry.*

Ralf Spatzier, University of Michigan, *Rigidity phenomena in geometry and dynamics.*

Vladimir Voevodsky, Northwestern University, *Motivic homotopy type?*

Special Sessions

Algebraic Coding (Code: AMS SS C1), **William C. Huffman**, Loyola University of Chicago, and **Vera S. Pless**, University of Illinois at Chicago.

Algebraic Combinatorics: Association Schemes and Related Topics (Code: AMS SS L1), **Sung Yell Song**, Iowa State University.

Algebraic Geometry and Mirror Symmetry (Code: AMS SS N1), **Ezra Getzler** and **Mikhail Kapranov**, Northwestern University, and **Sheldon Katz**, Oklahoma State University.

Commutative Algebra (Code: AMS SS J1), **Irena V. Peeva**, Massachusetts Institute of Technology, and **Michael Stillman**, Cornell University.

Complex Dynamics (Code: AMS SS H1), **Shmuel Friedland**, University of Illinois at Chicago.

Complexity of Geometric Structures on Manifolds (Code: AMS SS F1), **Melvin G. Rothenberg** and **Shmuel A. Weinberger**, University of Chicago.

Ergodic Theory and Topological Dynamics (Code: AMS SS G1), **Roger L. Jones**, DePaul University, and **Randall McCutcheon**, Wesleyan College.

Fourier Analysis (Code: AMS SS E1), **Marshall Ash**, DePaul University, and **Mark A. Pinsky**, Northwestern University.

K-Theory and Motivic Cohomology (Code: AMS SS D1), **Kevin Knudson**, Northwestern University, and **Mark Walker**, University of Nebraska-Lincoln.

Nonlinear Partial Differential Equations. (Code: AMS SS O1), **Gui-Qiang Chen** and **Konstantina Trivisa**, Northwestern University.

Number Theory (Code: AMS SS I1), **Jeremy T. Teitelbaum** and **Yuri Tschinkel**, University of Illinois at Chicago.

Orthogonal Polynomial Series, Summability and Conjugates (Code: AMS SS M1), **Calixto P. Calderon**, University of Illinois at Chicago, and **Luis A. Caffarelli**, University of Texas at Austin.

Rigidity in Geometry and Dynamics (Code: AMS SS K1), **Steven E Hurder**, University of Illinois at Chicago, and **Ralf J. Spatzier**, University of Michigan.

Stochastic Analysis (Code: AMS SS A1), **Richard B. Sowers**, University of Illinois-Urbana, and **Elton P. Hsu**, Northwestern University.

Topics in Mathematics and Curriculum Reform (Code: AMS SS B1), **Richard J. Maher**, Loyola University Chicago.

Winston-Salem, North Carolina

Wake Forest University

October 9–10, 1998

Meeting #936

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: August 1998
Program issue of *Notices*: December 1998
Issue of *Abstracts*: Volume 19, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: August 18, 1998

Invited Addresses

David F. Anderson, University of Tennessee, *Unique and nonunique factorization in integral domains.*

Idris Assani, University of Carolina, Chapel Hill, *A.e. multiple recurrence and Wiener Wintner dynamical systems.*

Marcy Barge, Montana State University-Bozeman, *Structure of attractors.*

Roger Temam, Indiana University, *Some mathematical problems related to the equations of the atmosphere and the oceans.*

Special Sessions

Abelian Groups and Modules (Code: AMS SS B1), **Ulrich Albrecht**, Auburn University.

Boundary Value Problems (Code: AMS SS K1), **John V. Baxley** and **Stephen B. Robinson**, Wake Forest University.

Combinatorics and Graph Theory (Code: AMS SS A1), **Bruce Landman**, University of North Carolina.

Commutative Ring Theory (Code: AMS SS E1), **David F. Anderson**, University of Tennessee, Knoxville, and **Evan Houston**, University of North Carolina, Charlotte.

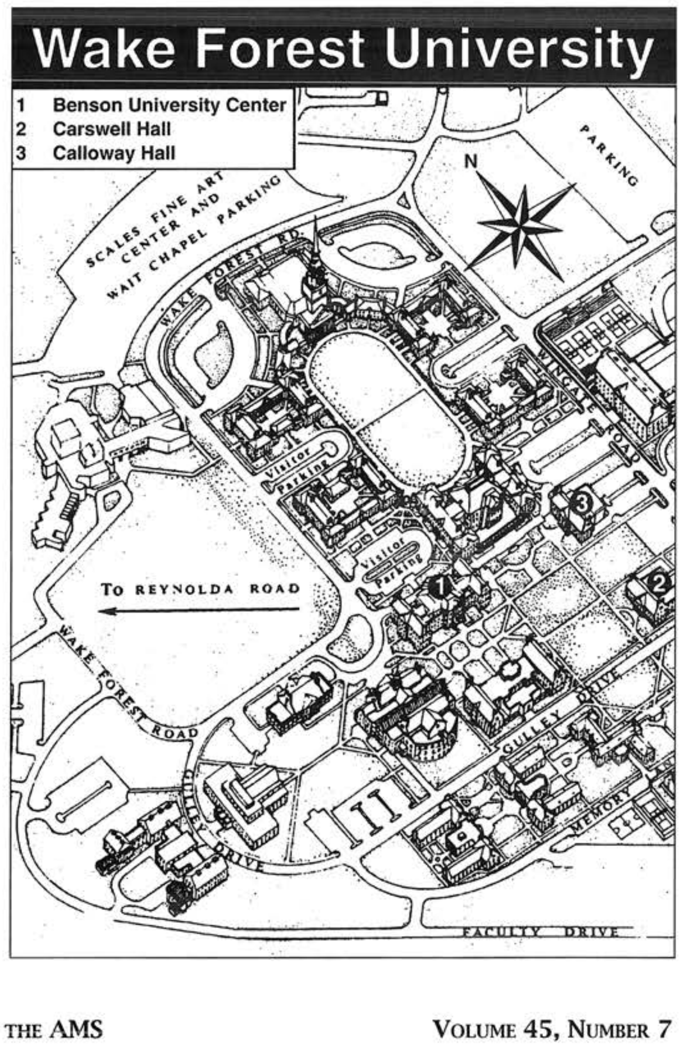
Ergodic Theory (Code: AMS SS F1), **Idris Assani**, University of North Carolina, Chapel Hill.

Modern Methods in Set Theory and General Topology (Code: AMS SS H1), **Winfried Just** and **Paul Szeptycki**, Ohio University.

Noncommutatuve Algebra (Code: AMS SS C1), **Ellen Kirkman** and **James Kuzmanovich**, Wake Forest University.

Operator Theory and Holomorphic Spaces (Code: AMS SS L1), **Tavan T. Trent** and **Zhijian Wu**, University of Alabama.

Recent Results on the Topology of Three-Manifolds (Code: AMS SS D1), **Hugh Nelson Howards**, Wake Forest University.



Spectral Theory of Differential Equations and Applications (Code: AMS SS G1), **Dominic Clemence** and **Alexandra Kurepa**, North Carolina A&T University.

Topology in Dynamics (Code: AMS SS J1), **Marcy Barge**, Montana State University-Bozeman, and **Krystyna M. Kuperberg**, Auburn University.

Accommodations

Participants should make their own arrangements directly with a hotel of their choice. Special rates have been negotiated at the hotels listed below. Participants should state that they are with AMS-WFU Math and Computer Science. **All rooms will be on a space available basis after the deadline given.** The AMS is not responsible for rate changes or for the quality of the accommodations chosen. Because the Winston-Salem area is a popular destination in the fall, participants should **make reservations as early as possible.**

Courtyard By Marriott, 3111 University Parkway, 336-727-1277 (fax: 336-722-8219); $65 single/double; about .8 miles from campus (10-minute walk). Breakfast available. **Deadline for reservations is September 25.**

Ramada Plaza Coliseum, 3050 University Parkway, 336-723-2911 (fax: 336-777-1003); $62 single/double; about .8 miles from campus (10-minute walk). Full- service restaurant on premises. **Deadline for reservations is September 8.**

Holiday Inn Select, 5790 University Parkway, 336-767-9595 (fax: 336-744-1888); $67 single/double; about 3.2 miles from campus. Full-service restaurant on premises. **Deadline for reservations is September 25.**

Food Service and Local Information

Wake Forest campus cafeteria is in Reynolda Hall, open 7:00 a.m. to 7:00 p.m. daily.

Information about the university and the Department of Mathematics and Computer Science can be found at `http://www.wfu.edu/` and `http://www.mthcsc.wfu.edu/` respectively.

Other Activities

AMS Book Sale: Examine the newest titles from AMS. Most books will be available at a special 50% discount offered only at meetings. Complimentary coffee will be served courtesy of AMS Membership Services.

Parking

Free parking is available in the large lots behind Wait Chapel and next to Worrell Law and Management Center.

Registration and Meeting Information

Registration will take place in the main lobby of Benson University Center from 7:30 a.m. to 4:00 p.m. on Friday and 8 a.m. to noon on Saturday. Sessions will take place in Calloway Hall, Carswell Hall, and Benson University Center.

Registration fees: (payable on-site only) $30/AMS members; $45 nonmembers; $10 emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Travel

The closest airport is Piedmont Triad International Airport in Greensboro.

USAirways has been selected as the official airline for the meeting. The following specially negotiated rates are available only for the period October 6-13, 1998: 5% discount off first class and any published USAirways promotional round-trip fare, or 10% discount off unrestricted coach fares with seven-day advance reservations and ticketing required. These discounts are valid providing all rules and restrictions are met and are applicable for travel from the continental U.S., Bahamas, Canada, and San Juan, P.R. Discounts are not combinable with other discounts or promotions. Additional restrictions may apply on international travel. For reservations call (or have your travel agent call) 800-334-8644 between 8:00 a.m. and 9:00 p.m. Eastern Daylight Time. **Refer to Gold File Number 73670341.**

If driving from the airport to the campus, follow the directions below from the northeast and east. Cab fare is about $35 for one or two persons. The Airport Express shuttle, located on the lower level of the airport at the baggage claim area, costs $25 one way or $48 round trip per person.

Driving directions: From the south: Interstate 85 to Charlotte; Interstate 77 to Statesville; Interstate 40 to Winston-Salem; Business 40 at Winston-Salem; Silas Creek Parkway north; bear right 100 yards before the second stoplight; cross Reynolda Road directly into WFU campus.

- From the west: Interstate 40 to Winston-Salem and follow as above.
- From the north and northwest: Interstate 77 to Statesville; Interstate 40 to Winston-Salem and follow as above.
- From the northeast and east: Interstate 85 to Greensboro; Interstate 40 to Winston-Salem and follow as above.
- From the northeast and east (alternate): Interstate 85 to Greensboro; Interstate 40 to Kernersville; Business 40 to Winston-Salem; Cherry Street north which becomes University Parkway at Lawrence Joel Veterans Memorial Coliseum.

Weather

The weather in Winston-Salem during mid-October is typically mild with daytime temperatures between 60° and 70°F. Nighttime temperatures run between 35° and 45°F.

State College, Pennsylvania

Pennsylvania State University

October 24–25, 1998

Meeting #937

Eastern Section
Associate secretary: Lesley M. Sibner

Announcement issue of *Notices*: August 1998
Program issue of *Notices*: January 1999
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: September 1, 1998

Invited Addresses

Jeffrey Adams, University of Maryland, College Park, *Characters of nonlinear groups.*

Nigel D. Higson, Pennsylvania State University, *Title to be announced.*

Tasso J. Kaper, Boston University, *Title to be announced.*

Kate Okikiolu, University of California, San Diego and MIT, *Title to be announced.*

Special Sessions

Automorphic Forms and Arithmetic Geometry (Code: AMS SS H1), **Kevin L. James**, and **Wen-Ching Winnie Li**, Pennsylvania State University.

C-Algebraic Methods in Geometry and Topology* (Code: AMS SS B1), **Nigel D. Higson**, Pennsylvania State University, and **Erik Guentner** and **John D. Trout Jr.**, Dartmouth College.

Least Squares and Total Least Squares (Code: AMS SS G1), **Jesse L. Barlow**, Pennsylvania State University.

Mathematical Modeling of Inhomogeneous Materials: Homogenizaton and Related Topics (Code: AMS SS D1), **Leonid Berlyand**, Pennsylvania State University, and **Karl Voss**, Yale University.

Metric Topology (Code: AMS SS F1), **Steve Armentrout**, **Joseph Borzelino**, **Hossein Movahedi-Lankarani**, and **Robert Wells**, Pennsylvania State University.

1 Willard Building
2 Schwab Auditorium
3 McAllister Bldg (Math Dept)

Modeling of Phase Transitions of Partially Ordered Physical Systems (Code: AMS SS C1), **Maria-Carme T. Calderer**, Pennsylvania State University.

Operator Algebras and Noncommutative Geometry (Code: AMS SS K1), **Victor Nistor, Paul F. Baum**, and **Adrian Ocneanu**, Pennsylvania State University.

Partitions and q-Series (Code: AMS SS A1), **George E. Andrews, Ken Ono**, and **Scott D. Ahlgren**, Pennsylvania State University.

Set Theory (Code: AMS SS J1), **Thomas Jech**, Pennsylvania State University.

Symplectic Geometry and Quantization (Code: AMS SS E1), **Jean-Luc Brylinski, Ranee Brylinski, Boris Tsygan**, and **Ping Xu**, Pennsylvania State University.

Accommodations

Participants should make their own arrangements directly with a hotel of their choice. Special rates have been negotiated at the hotel listed below. Participants should state that they will be attending the AMS Eastern Section Meeting at Pennsylvania State University. **All rooms will be on a space available basis after the deadline given.** The AMS is not responsible for rate changes or for the quality of the accommodations chosen. Because the Penn State area is a popular destination in the fall, participants should **make reservations as early as possible.**

Ramada Inn, 1450 South Atherton St. (Business Route 322), 814-238-3001 (fax: 814-237-1345); $70 single/double (plus 7% tax); approximately 2 miles from the meeting site. **Deadline is October 21, 1998.**

Food Service and Local Information

Several restaurants are located within walking distance. For a restaurant guide and information about State College and Penn State, see `http://www.math. psu/weiss/aboutsc.html`. Also see the page maintained by the math department at `http://www.math.psu.edu`.

Other Activities

AMS Book Sale: Examine the newest titles from AMS. Most books will be available at a special 50% discount offered only at meetings. Complimentary coffee will be served courtesy of AMS Membership Services.

Parking

Parking is free on campus on the weekends, except in posted "24-hour restricted lots". The closest parking lot is off of Pollock Road behind Osmond Laboratory, across from the Hetzel Union Building (HUB). There are two parking garages on campus. The Eisenhower Parking Deck is located behind the Eisenhower Auditorium on Shortledge Road and the HUB Parking Deck located on Shortledge Road next to the Grange Building, corner of Pollock Road and Shortledge Road. Both are a 12-15 minute walk to the meeting.

Registration and Meeting Information

Registration will take place in the lobby of Schwab Auditorium from 7:30 a.m. to 4:00 p.m. on Saturday and 7:30

a.m. to noon on Sunday. Sessions will take place in Schwab Auditorium and the Willard Building next door.

Registration fees: (payable on-site only) $30/AMS members; $45 nonmembers; $10 emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Travel

Pennsylvania State University at University Park is located approximately in the geographic center of the state, in the town of State College. All modes of public transportation and several major highways service the University, making it easily accessible from metropolitan areas.

USAirways has been selected as the official airline for the meeting. The following specially negotiated rates are available only for the period 5–12: 5% discount off first class and any published USAirways promotional round-trip fare, or 10% discount off unrestricted coach fares with seven-day advance reservations and ticketing required. These discounts are valid providing all rules and restrictions are met and are applicable for travel from the continental U.S., Bahamas, Canada, and San Juan, P.R. Discounts are not combinable with other discounts or promotions. Additional restrictions may apply on international travel. For reservations call (or have your travel agent call) 800-334-8644 between 8:00 a.m. and 9:00 p.m. Eastern Daylight Time. **Refer to Gold File Number 73670341.**

Airlines serve the State College area through the University Park Airport (State College, PA) located five miles from campus.

Limousine or taxi service is available for all flights. The approximate cost from the airport to Penn State campus is $11, and airport to the Ramada Inn is $14.

For taxi service call 814-353-6001; limousine service is available by calling 814-353-6000. There is a complimentary phone at the airport to make these calls.

Driving directions: University Park (State College) is readily accessible from both ends of the state via Interstate 80 (I-80):

From New York City, the suggested route is via George Washington Bridge to I-80. In Pennsylvania, exit from I-80 (the Keystone Shortway) at Exit 24 (Bellefonte), and follow Route 26 south to State College. Once in State College Route 26 is known as College Avenue and it runs perpendicular to Atherton Street (Business Route 322).

From Philadelphia, there are two routes. Take the Northeast Extension of the Pennsylvania Turnpike to I-80, leave I-80 at Exit 24 (Route 26-Bellefonte exit and follow Route 26 to State College; or take Philadelphia's Schuylkill Expressway to the Pennsylvania Turnpike, leave the turnpike at Exit 19 (Harrisburg East), and follow I-283 to I-83 and proceed north on I-83 to the I-81 Interchange. Then follow I-81 west to Route 322, 22 west exit. Proceed west on Route 322 through Lewistown to State College. Once you get into State College, take Business Route 322 (Atherton Street).

From Pittsburgh, follow Route 22 to Duncansville, Route 220, bypassing downtown Altoona and Tyrone, through Port Matilda, and then Route 322 east to State College. Once you get into State College, take Business Route 322 (Atherton Street). A scenic route follows Route 22 beyond Duncansville to Water Street, Route 45 to Pine Grove Mills, and Route 26 to State College.

From Washington, D.C., several routes are available. Take Route 270 to Frederick, Route 70 to Breezewood, Route 30 to Everett, and Route 26 to State College (once in State College, Route 26 is known as College Avenue); or follow Route 270 to Frederick, Route 15 past Gettysburg; through Camp Hill to Amity Hall, and then Route 322 west to State College; or take I-95 or the Baltimore-Washington Parkway to Baltimore, west loop I-695 to I-83 north. Continue on I-83 north to the I-81 Interchange. Then follow I-81 west to Route 322/22 Exit. Proceed west on Route 322 to Lewistown and State College. Once into State College, follow Business Route 322 (Atherton Street).

From the west, take I-80 to Exit 20 (Woodland) just east of Clearfield, then Route 322 east to State College. Once into State College, follow Business Route 322 (Atherton Street). One may also exit I-80 at Exit 24 (Bellefonte) and follow Route 26 south to State College. Once into State College, Route 26 is known as College Avenue.

By bus: Trailways and Greyhound Lines connections are available to and from State College. The bus station is a couple of blocks from the meeting rooms on Penn State campus. Call Trailways at 814-238-7362, or Greyhound at 814-237-5865.

Weather

The weather at Penn State during the end of October is typically cool with possible rain showers.

Tucson, Arizona

University of Arizona-Tucson

November 14–15, 1998

Meeting #938

Western Section
Associate secretary: Robert M. Fossum/Bernard Russo
Announcement issue of *Notices*: September 1998
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: July 29, 1998
For abstracts: September 23, 1998

Invited Addresses

Alexandru Buium, University of New Mexico, *Differential algebraic geometry and derivatives of integers.*

Hans Koch, University of Texas at Austin, *Title to be announced.*

Mark Lewis, University of Utah, *Title to be announced.*

Jiang-Hua Lu, University of Arizona, *Title to be announced.*

Special Sessions

Arithemtic Algebraic Geometry (Code: AMS SS H1), **Douglas Ulmer**, University of Arizona.

Classical and Quantum Mechanical Lattice Spin Systems (Code: AMS SS E1), **Tom Kennedy**, University of Arizona.

Conditionally Positive Definite Functions and Interpolation Schemes (Code: AMS SS G1), **Donald Myers**, University of Arizona.

Dynamical Systems (Code: AMS SS F1), **Marek Rychlik** and **Maciej P. Wojtkowski**, University of Arizona.

Filaments, Interfaces and Patterns (Code: AMS SS I1), **Nicholas Ercolani** and **Jerry Moloney**, University of Arizona.

Geometry and Lie Groups (Code: AMS SS B1), **Samuel R. Evens** and **Jiang-Hua Lu**, University of Arizona.

Groups and Computation (Code: AMS SS A1), **Robert Beals**, University of Arizona.

Integrable Systems and Random Matrix Theory (Code: AMS SS K1), **K. T-R McLaughlin**, University of Arizona, and **Craig A. Tracy**, University of California, Davis.

Mathematics and Biology (Code: AMS SS D1), **Jim Cushing** and **Shandelle M. Henson**, University of Arizona.

Spectral Geometry and Its Applications (Code: AMS SS C1), **Xianzhe Dai**, University of Southern California, and **Leonid Friedlander**, University of Arizona.

Striking the Balance: Theory, Technique, and Applications in Lower Division Mathematics Courses (Code: AMS SS J1), **Joseph Watkins**, University of Arizona.

San Antonio, Texas

Henry B. Gonzales Convention Center

January 13-16, 1999

Meeting #939

Joint Mathematics Meetings, including the 105th Annual Meeting of the AMS, 82nd Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 1998
Program issue of *Notices*: January 1998
Issue of *Abstracts*: Volume 20, Issue 1

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: August 6, 1998
For abstracts: October 1, 1998
For summaries of papers to MAA organizers: September 4, 1998

Joint Invited Addresses

Jennifer Tour Chayes, Microsoft, *Title to be announced.*

Joan Feigenbaum, AT&T Bell Laboratories, *Department Head, Algorithms & Distributed Data.*

Joint Special Sessions

Geometry in Dynamics (Code: AMS SS F1), **Krystyna Kuperberg**, Auburn University.

Mathematics and Education Reform (Code: AMS SS M1), **William H. Barker**, Bowdoin College, **Jerry L. Bona**, University of Texas at Austin, **Naomi Fisher**, University of Illinois at Chicago, and **Kenneth C. Millett**, University of California Santa Barbara.

Model Theory and Its Applications (Code: AMS SS S1), **Anand Pillay**, MSRI and University of Illinois, Urbana.

Research in Mathematics by Undergraduates (Code: AMS SS E1), **John E. Meier** and **Leonard A. VanWyk**, Lafayette College.

The History of Mathematics (Code: AMS SS L1), **Karen H. Parshall**, University of Virginia, and **Victor J. Katz**, University of the District of Columbia.

AMS Invited Addresses

Ronald L. Graham, AT&T Labs, *Title to be announced* (AMS Retiring Presidential Address).

Nancy J. Kopell, Boston University, *Title to be announced* (AMS Josiah Willard Gibbs Lecture).

Sorin Popa, University of California Los Angeles, *Title to be announced.*

Chuu-Lian Terng, Northeastern University, *Title to be announced.*

Alan D. Weinstein, University of California, Berkeley, *Title to be announced.*

AMS Special Sessions

Banach Spaces of Holomorphic Functions and Operators on These Spaces (Code: AMS SS D1), **Benjamin A. Lotto**, Vassar College, and **Pamela B. Gorkin**, Bucknell University.

Bergman Spaces and Related Topics (Code: AMS SS B1), **Peter L. Duren**, University of Michigan, Ann Arbor, and **Michael Stessin**, SUNY at Albany.

Combinatorial Topology (Code: AMS SS K1), **Laura M. Anderson** and **Jonathan P. McCammond**, Texas A&M University.

Commutative Algebra (Code: AMS SS G1), **Scott Thomas Chapman**, Trinity University.

Commutative Algebra and Algebraic Geometry (Code: AMS SS J1), **Roger A. Wiegand**, University of Nebraska and Purdue University, and **Susan Elaine Morey**, Southwest Texas State University.

Computational Algebraic Geometry for Curves and Surfaces (Code: AMS SS R1), **Mika K. Seppala**, Florida State University, and **Emil J. Volcheck**, National Security Agency.

Development of Electronic Communications in Mathematics (Code: AMS SS N1), **Alfonso Castro**, University of North Texas, and **Rafael De La Llave**, University of Texas at Austin.

Discrete Models and Difference Equations (Code: AMS SS T1), **Saber Elaydi**, Trinity University, and **Gerry Ladas**, University of Rhode Island.

Dynamical, Spectral, and Arithmetic Zeta-Functions (Code: AMS SS H1), **Michel L. Lapidus**, University of California, Riverside, and **Machiel van Frankenhuysen**, Institut des Hautes Études Scientifiques.

Hamiltonian Mechanics: Applications to Celestial Mechanics and Chemistry (Code: AMS SS Y1), **Michael K. Rudnev**, The University of Texas at Austin, and **Stephen R. Wiggins**, California Institute of Technology.

Mathematics Education and Mistaken Philosophies of Mathematics (Code: AMS SS U1), **Saunders Mac Lane**, University of Chicago, and **Richard A. Askey**, University of Wisconsin-Madison.

Operator Algebras and Applications (Code: AMS SS P1), **Allan P. Donsig**, University of Nebraska-Lincoln, and **Nik Weaver**, Washington University.

Probabilistic Combinatorics (Code: AMS SS C1), **Béla Bollobás**, University of Memphis.

Recent Developments in Differential Geometry (Code: AMS SS V1), **Huai-Dong Cao** and **Jianxin Zhou**, Texas A&M University.

Several Complex Variables (Code: AMS SS A1), **Emil J. Straube** and **Harold P. Boas**, Texas A&M University.

Singularities in Algebraic and Analytic Geometry (Code: AMS SS X1), **Caroline G. Grant**, U.S. Naval Academy, and **Ruth I. Michler**, University of North Texas.

The Functional and Harmonic Analysis of Wavelets (Code: AMS SS Q1), **Lawrence W. Baggett**, University of Colorado, and **David R. Larson**, Texas A&M University.

The Mathematics of the Navier-Stokes Equations (Code: AMS SS W1), **Peter A. Perry** and **Zhong-Wei Shen**, University of Kentucky.

Gainesville, Florida

University of Florida

March 12–13, 1999

Meeting #940

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

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Alexander N. Dranishnikov, University of Florida, *Title to be announced.*

Gregory F. Lawler, Duke University, *Title to be announced.*

Michael P. Loss, Georgia Institute of Technology, *Title to be announced.*

John G. Thompson, University of Florida, *Title to be announced.*

Special Sessions

Algebraic and Geometric Combinatorics (Code: AMS SS P1), **Andrew J. Vince** and **Neil L. White**, University of Florida.

Analytical Problems in Mathematical Physics (Code: AMS SS M1), **Eric A. Carlen**, Georgia Institute of Technology, and **Laszlo Erdos**, Courant Institute, NYU.

Computability Theory (Code: AMS SS G1), **Douglas Cenzer**, University of Florida, **Geoffrey Louis LaForte**, University of West Florida, and **Rick L. Smith**, University of Florida.

Continuum Theory and Dynamical Systems (Code: AMS SS A1), **Philip Boyland** and **Beverly Brechner**, University of Florida, and **John Mayer**, University of Alabama at Birmingham.

Finite Groups and Their Representations (Code: AMS SS D1), **Alexandre Turull**, University of Florida.

Galois Theory (Code: AMS SS E1), **J. G. Thompson** and **H. Voelklein**, University of Florida.

Geometric Topology (Code: AMS SS H1), **James E. Keesling** and **Alexander N. Dranishnikov**, University of Florida.

Geometry of Interacting Particles, Random Walks, and Brownian Motion (Code: AMS SS N1), **Irene Hueter**, University of Florida, and **Gregory F. Lawler**, Duke University.

Groups and Geometries (Code: AMS SS F1), **Chat Ho** and **Peter Sin**, University of Florida.

Linear Operator Theory (Code: AMS SS J1), **Leiba Rodman**, College of William & Mary, and **Scott A. McCullough**, University of Florida.

Markov Processes and Potential Theory (Code: AMS SS C1), **Joe Glover** and **Murali Rao**, University of Florida.

Partial Differential Equations and Applications (Code: AMS SS K1), **Gang Bao** and **Yun-mei Chen**, University of Florida.

Probability on Algebraic Structures (Code: AMS SS Q1), **Gregory M. Budzban** and **Philip Feinsilver**, Southern Illinois University at Carbondale, and **Arunava Mukherjea**, University of South Florida.

Structure and Representation Theory of Lattice-Ordered Groups and f-Rings (Code: AMS SS L1), **Jorge Martinez**, University of Florida.

The Erdős Legacy and Connections to Florida (Code: AMS SS B1), **Krishnaswami Alladi** and **Jean Larson**, University of Florida.

Urbana, Illinois

University of Illinois, Urbana-Champaign

March 18–21, 1999

Meeting #941

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Alexander Beilinson, MIT, *Title to be announced.*

Alexandra Bellow, Northwestern University, *Title to be announced.*

Igor Krichever, Columbia University, *Title to be announced.*

Steven Rallis, Ohio State University, *Title to be announced.*

Trevor Wooley, University of Michigan, *Title to be announced.*

Special Sessions

Algebraic K-Theory (and the 5th Annual Great Lakes K-Theory Conference (Code: AMS SS H1), **Daniel Grayson**, University of Illinois-Urbana.

Combinatorial Designs (Code: AMS SS M1), **Ilene H. Morgan**, University of Missouri-Rolla, and **Walter D. Wallis**, Southern Illinois University-Carbondale.

Diophantine Equations, Inequalities and Related Arithmetic Problems (Code: AMS SS F1), **Michael Bennett**, University of Illinois-Urbana, and **Trevor Wooley**, University of Michigan.

Elementary and Analytic Number Theory (Code: AMS SS E1), **Harold G. Diamond** and **A. J. Hildebrand**, University of Illinois-Urbana.

Galois Representations (Code: AMS SS C1), **Nigel Boston**, University of Illinois-Urbana, and **Michael Larsen**, University of Missouri.

Graph Theory (Code: AMS SS G1), **Douglas B. West**, University of Illinois-Urbana.

Holomorphic Vector Bundles and Complex Geometry (Code: AMS SS L1), **Maarten Bergvelt**, **Steven Bradlow**, and **John P. D'Angelo**, University of Illinois-Urbana, and **Lawrence Ein**, University of Illinois-Chicago.

Integrable Equations (Code: AMS SS I1), **Igor Krichever**, Columbia University, and **Kirill Vaninsky**, Kansas State University.

Martingales and Analysis (Code: AMS SS D1), **Joseph Max Rosenblatt**, **Renming Song**, and **Richard B. Sowers**, University of Illinois-Urbana.

Nonstandard Analysis (Code: AMS SS B1), **C. Ward Henson** and **Peter Loeb**, University of Illinois-Urbana.

Operator Spaces and Their Applications (Code: AMS SS J1), **Gilles Pisier**, Texas A&M, and **Zhong-Jin Ruan**, University of Illinois-Urbana.

Recent Progress in Elementary Geometry (Code: AMS SS A1), **John E. Wetzel**, University of Illinois-Urbana, and **Clark Kimberling**, University of Evansville.

Symplectic Geometry and Topology (Code: AMS SS K1), **Eugene M. Lerman** and **Susan Tolman**, University of Illinois-Urbana.

Las Vegas, Nevada

University of Nevada-Las Vegas

April 10–11, 1999

Meeting #942

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 10, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Analysis and Geometry (Code: AMS SS I1), **Peter Li** and **Song-Ying Li**, University of California, Irvine.

Combinatorial Theory (Code: AMS SS G1), **Kequan Ding**, University of Illinois-Urbana, **Peter Shiue**, University of Las Vegas, Nevada, and **Yeong-Nan Yeh**, Academia Sinica.

Control and Dynamics of Partial Differential Equations (Code: AMS SS A1), **Zhonghai Ding**, University of Nevada-Las Vegas.

Diophantine Problems (Code: AMS SS J1), **Arthur Baragar**, University of Nevada-Las Vegas, and **Michael Bennett**, University of Illinois.

Geometric Group Theory (Code: AMS SS H1), **Eric M. Freden**, Southern Utah University, and **Eric Lewis Swenson**, Brigham Young University.

Graph Theory (Code: AMS SS B1), **Hung-Lin Fu**, University of National Chiao-Tung University-Taiwan, **Chris A. Rodger**, Auburn University, and **Michelle Schultz**, University of Nevada-Las Vegas.

Nonlinear PDEs - Methods and Applications (Code: AMS SS C1), **David Costa**, University of Nevada-Las Vegas.

Number Theory (Code: AMS SS F1), **Gennady Bachman**, University of Nevada-Las Vegas, **Richard A. Mollin**, University of Calgary, and **Peter J. Shiue**, University of Nevada-Las Vegas.

Numerical Analysis and Computational Mathematics (Code: AMS SS E1), **Jun Zhang**, University of Minnesota and University of Kentucky, and **Jennifer Zhao**, University of Michigan, Dearborn.

Set Theory (Code: AMS SS D1), **Douglas Burke** and **Derrick BuBose**, University Nevada-Las Vegas.

Buffalo, New York

State University of New York at Buffalo

April 24–25, 1999

Meeting #943

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

Deadlines

For organizers: July 24, 1998
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Michele M. Audin, University of Louis Pasteur, *Title to be announced.*

Russel Caflisch, University of California, Los Angeles, *Title to be announced.*

Jeff Smith, Purdue University, *Title to be announced.*

Alexander Voronov, MIT, *Title to be announced.*

Gregg J. Zuckerman, Yale University, *Title to be announced.*

Special Sessions

Combinatorics and Graph Theory (Code: AMS SS C1), **Harris Kwong**, SUNY College at Fredonia.

Knot and 3-Manifolds (Code: AMS SS E1), **Thang T.Q. Le**, State University of New York at Buffalo, **William W. Menasco**, SUNY at Buffalo, and **Morwen B. Thistlethwaite**, University of Tennessee.

Mathematical Physics (Code: AMS SS D1), **Jonathan Dimock**, SUNY at Buffalo.

Representations of Lie Algebras (Code: AMS SS F1), **Duncan J. Melville**, Saint Lawrence University.

Smooth Categories in Geometry and Mechanics (Code: AMS SS A1), **F. William Lawvere**, SUNY at Buffalo.

Thin Films: Solid and Liquid (Code: AMS SS B1), **E. Bruce Pitman**, SUNY at Buffalo, and **Brian Spencer**, State University of New York at Buffalo.

Denton, Texas

University of North Texas

May 19–22, 1999

Meeting #944

Fourth International Joint Meeting between the AMS and the Sociedad Matemàtica Mexicana.
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: January 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Melbourne, Australia

Melbourne, Australia

July 12–16, 1999

Meeting #945

First International Joint Meeting of the American Mathematical Society and the Australian Mathematical Society.
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Jennifer Chayes, Microsoft, *Title to be announced.*

Michael Eastwood, University of Adelaide, *Title to be announced.*

Vaughan Jones, University of California, Berkeley, *Title to be announced.*

Hyam Rubinstein, Melbourne University, *Title to be announced.*

Richard M. Schoen, Stanford University, *Title to be announced.*

Neil Trudinger, Australian National University, *Title to be announced.*

Special Sessions

Discrete Groups (Code: AMS SS H1), **Marston Conder**, **Gaven Martin**, and **Eamonn O'Brien**, University of Auckland.

Fluid Dynamics (Code: AMS SS C1), **Susan Friedlander**, Northwestern University, and **Roger H. J. Grimshaw**, Monash University.

Geometric Themes in Group Theory (Code: AMS SS A1), **Gustav I. Lehrer**, University of Sydney, **Cheryl E. Praeger**, University of Western Australia, and **Stephen D. Smith**, University of Illinois at Chicago.

Low Dimensional Topology (Code: AMS SS D1), **William H. Jaco**, Oklahoma State University, and **Hyam Rubinstein**, Melbourne University.

Mathematical Physics: Many Body Systems (Code: AMS SS B1), **Alan L. Carey**, University of Adelaide, **Paul A. Pearce**, University of Melbourne, and **Mary Beth Ruskai**, University of Massachusetts, Lowell.

Mathematics Learning Centers (Code: AMS SS G1), **Judith Baxter**, University of Illinois, Chicago, **Jackie Nicholas**, University of Sidney, and **Jeanne Wald**, Michigan State University.

Moduli Spaces of Riemann Surfaces, Mapping Class Groups and Invariants of 3-manifolds (Code: AMS SS F1), **Ezra Getzler**, Northwestern University, and **Richard Hain**, Duke University.

Probability Theory and Its Applications (Code: AMS SS E1), **Timothy Brown**, University of Melbourne, **Phil Pollett**, University of Queensland, and **Ruth J. Williams**, University of California, San Diego.

Providence, Rhode Island

Providence College

October 2–3, 1999

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

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Austin, Texas

University of Texas-Austin

October 8–10, 1999

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Mikhail Kapranov, Northwestern University, *Title to be announced.*

John Roe, Oxford University and Pennsylvania State University, *Title to be announced.*

Catherine Sulem, University of Toronto, *Title to be announced.*

Tatiana Toro, University of Washington, *Title to be announced.*

Special Sessions

The Development of Topology in the Americas (Code: AMS SS A1), **Cameron Gordon**, University of Texas, Austin, and **Ioan Mackenzie James**, University of Oxford.

Washington, District of Columbia

Marriott Wardman Park Hotel and Omni Shoreham Hotel

January 19–22, 2000

Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM), and the annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Bernard Russo
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 20, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Lowell, Massachusetts

University of Massachusetts, Lowell

April 1–2, 2000

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

Deadlines

For organizers: July 1, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Notre Dame, Indiana

University of Notre Dame

April 7–9, 2000

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 7, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Odense, Denmark

Odense University

June 12–15, 2000

First AMS-Scandinavian International Meeting. Sponsored by the AMS, Dansk Matematisk Forening, Suomen matemaattinen yhdistys, Icelandic Mathematical Society, Norsk Matematisk Forening, and Svenska matematikersamfundet.
Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Toronto, Ontario Canada

University of Toronto

September 22–24, 2000

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New Orleans, Louisiana

New Orleans Marriott and ITT Sheraton New Orleans Hotel

January 10–13, 2001

Joint Mathematics Meetings, including the 107th Annual Meeting of the AMS, 84th Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 11, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Columbia, South Carolina

University of South Carolina

March 16–18, 2001

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

Deadlines

For organizers: June 15, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Williamstown, Massachusetts

Williams College

October 13–14, 2001

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

Deadlines

For organizers: January 11, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Diego, California

San Diego Convention Center

January 6–9, 2002

Joint Mathematics Meetings, including the 108th Annual Meeting of the AMS and 85th Meeting of the Mathematical Association of America (MAA).
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 4, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Western Section: Bernard Russo, Department of Mathematics, University of California, Irvine, CA 92697; e-mail: brusso@math.uci.edu; telephone: 949-824-5505.

Central Section: Susan J. Friedlander, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: susan@math.nwu.edu; telephone: 312-996-3041.

Eastern Section: Lesley M. Sibner, Department of Mathematics, Polytechnic University, Brooklyn, NY 11201-2990; e-mail: lsibner@magnus.poly.edu; telephone: 718-260-3505.

Southeastern Section: Robert J. Daverman, Department of Mathematics, University of Tennessee, Knoxville, TN 37996-1300; e-mail: daverman@novell.math.utk.edu; telephone: 423-974-6577.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Up-to-date meeting and conference information is available on the World Wide Web at www.ams.org/meetings/.

Meetings:

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 150 in the January 1998 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of TeX is necessary to submit an electronic form, although those who use LaTeX, or AMS-LaTeX may submit abstracts with TeX coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html or send mail to abs-submit@ams.org, typing help as the subject line, and descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

1999:

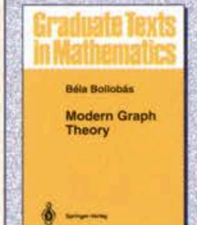
Monday and Tuesday, January 11-12: Short Course on Nonlinear Control, Hilton Palacio Del Rio, San Antonio, Texas. Organizer: Hector J. Sussman (Rutgers University); co-organizer: Kevin Grasse (University of Oklahoma).

SPRINGER FOR MATHEMATICS

NEW GRADUATE TEXTS IN MATHEMATICS

BÉLA BOLLOBÁS, University of Memphis, TN

MODERN GRAPH THEORY



The time has now come for graph theory to be a part of the education of every serious student of mathematics and computer science, both for its own sake and to enhance the appreciation of mathematics as a whole. This book is an in-depth account of graph theory, written with such a student in mind; it reflects the current state of the subject and emphasizes connections with other branches of pure mathematics. The volume grew out of the author's earlier book, *Graph Theory — An Introductory Course*, but its length is well over twice that of its predecessor, allowing it to reveal many exciting new developments in the subject. Recognizing that graph theory is one of several courses competing for the attention of a student, the book contains extensive descriptive passages designed to convey the flavor of the subject and to arouse interest.

In addition to a modern treatment of the classical areas of graph theory such as coloring, matching, extremal theory, and algebraic graph theory, the book presents a detailed account of newer topics, including Szemer'edi's Regularity Lemma and its use, Shelah's extension of the Hales-Jewett Theorem, the precise nature of the phase transition in a random graph process, the connection between electrical networks and random walks on graphs, and the Tutte polynomial and its cousins in knot theory.

In no other branch of mathematics is it as vital to tackle and solve challenging exercises in order to master the subject. To this end, the book contains an unusually large number of well thought-out exercises: over 600 in total. Although some are straightforward, most of them are substantial, and others will stretch even the most able reader.

1998/408 PP., 114 ILLUS./HARDCOVER/$59.95/ISBN 0-387-98491-7
Also Available in Softcover: $34.95/ISBN 0-387-98488-7
GRADUATE TEXTS IN MATHEMATICS, VOLUME 184

ROBERT E. MEGGINSON, University of Michigan, Ann Arbor

AN INTRODUCTION TO BANACH SPACE THEORY

Many important reference works have appeared since Banach's *Theorie des Operations Lineaires;* the impetus for the development of modern space theory. While these works are classical starting points for the graduate student wishing to do research in Banach space theory, they can be formidable reading for the student who has just completed a course in measure theory and would like to know more about Banach spaces in general.

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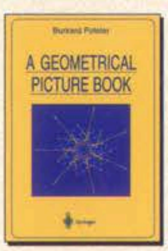

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