

Notices

of the American Mathematical Society

October 2011

Volume 58, Number 9

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(1911-2004)

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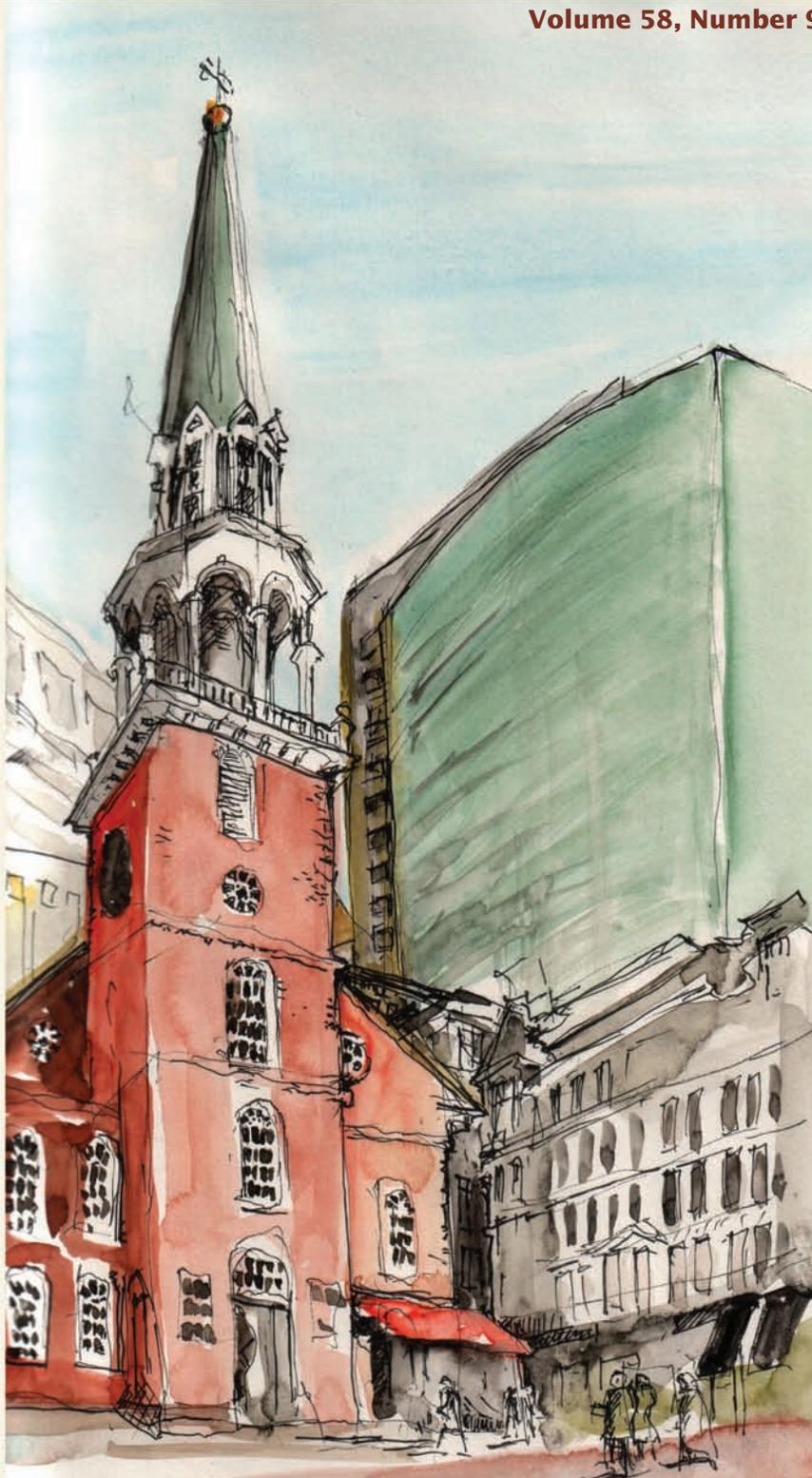
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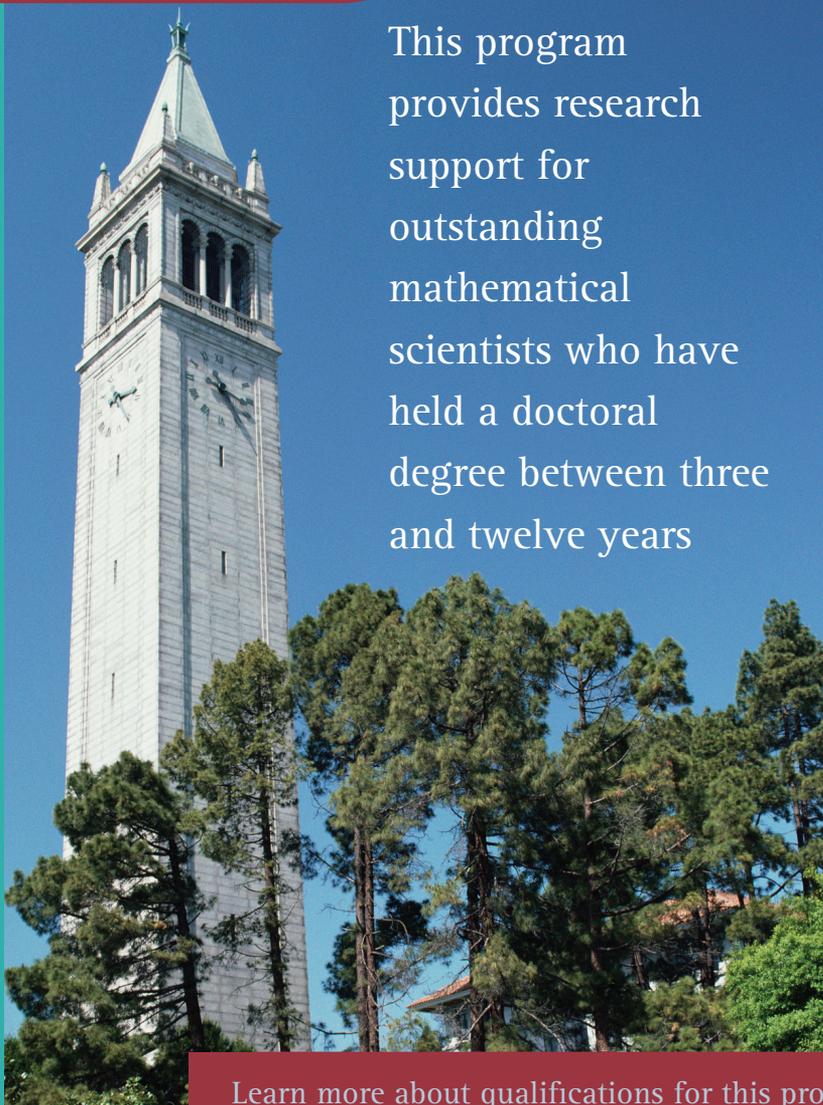


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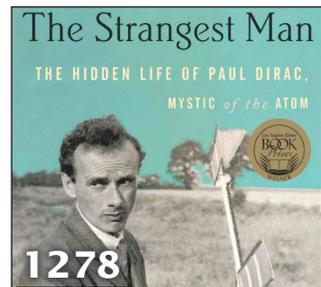
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Features

October 2011 is the one-hundredth anniversary of the birth of the eminent differential geometer Shiing-Shen Chern. He was beloved both for his mathematics and for his warm personality. His student S.-T. Yau has organized a memorial article for Chern in this issue of the *Notices*. This month we also feature an article by Frank Quinn that presents an innovative approach to mathematics education. Finally, we have a feature article by Christian Rosendal that offers an approach via logic to functional analysis.

—Steven G. Krantz, Editor

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Notices

of the American Mathematical Society

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I thank Randi D. Ruden for her splendid editorial work, and for helping to assemble this issue. She is essential to everything that I do.

—Steven G. Krantz, Editor



Blogs offered by or in cooperation with the American Mathematical Society

PhD + epsilon Blog

Adriana Salerno, *Bates College*, writes about her experiences and challenges as an early-career mathematician. All mathematicians are encouraged to join the community of her followers and post comments.

blogs.ams.org/phdplus

On The Market

On The Market is a job search blog for the mathematical sciences community by the Joint Committee on Employment Opportunities. This blog is moderated by Sue Geller, *Texas A&M University*.

blogs.ams.org/onthemarket

Joint Mathematics Meetings Blogs

These blogs are about the scientific program sessions, events, and other aspects of the annual Joint Mathematics Meetings of the American Mathematical Society and Mathematical Association of America.

jointmathematicsmeetings.org/blog/jmm2011

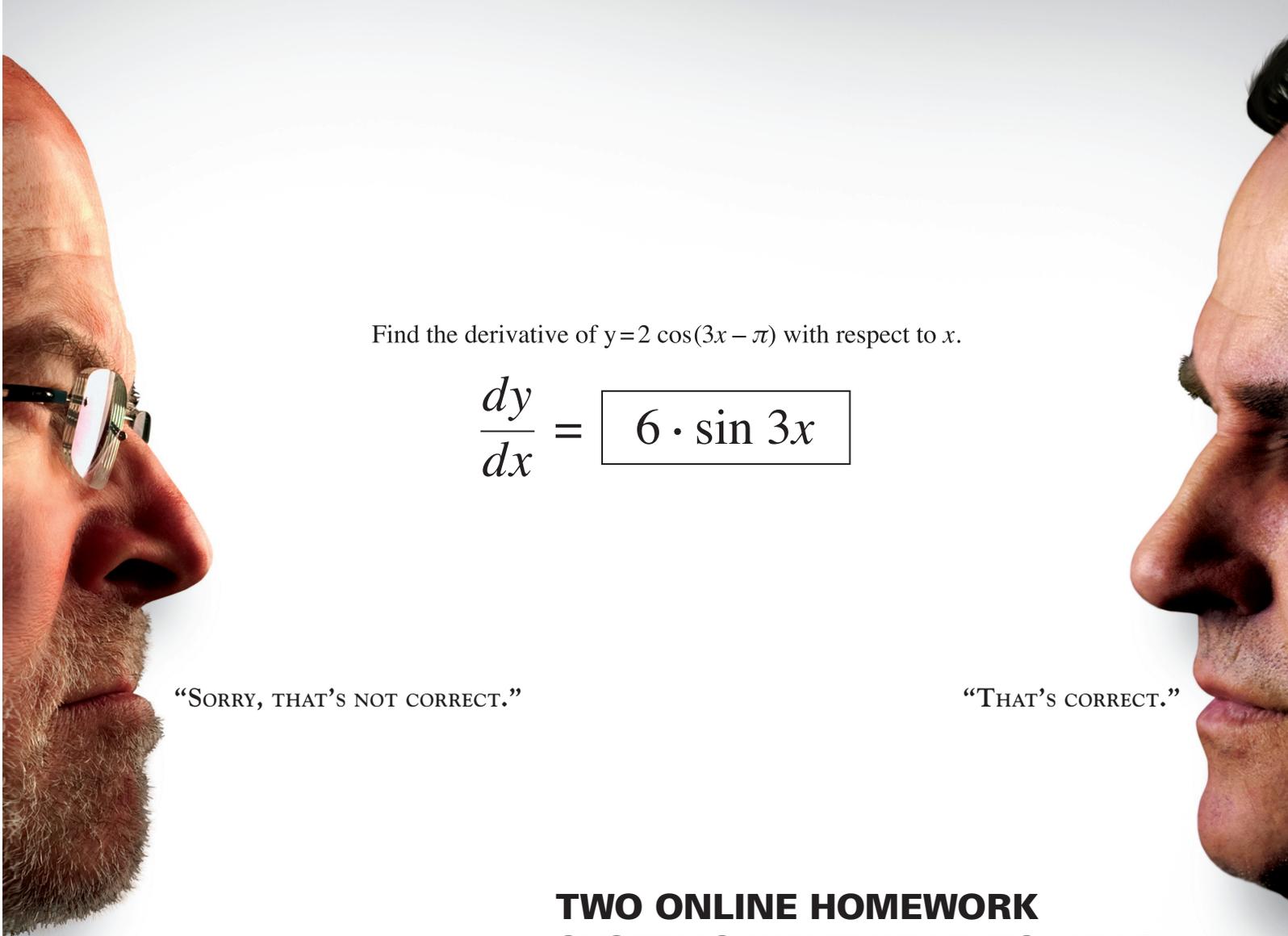
AMS Graduate Student Blog

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Topics include advice, announcements, interviews, mathematics, math games, how to organize a seminar, math in pop culture, conferences, and teaching.

mathgradblog.williams.edu

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Find the derivative of $y = 2 \cos(3x - \pi)$ with respect to x .

$$\frac{dy}{dx} = \boxed{6 \cdot \sin 3x}$$

“SORRY, THAT’S NOT CORRECT.”

“THAT’S CORRECT.”

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What good is an online homework system if it can't recognize right from wrong? Our sentiments exactly. Which is why we decided to compare WebAssign with the other leading homework system for math. The results were surprising. The other system failed to recognize correct answers to free response questions time and time again. That means students who were actually answering correctly were receiving failing grades. WebAssign, on the other hand, was designed to recognize and accept more iterations of a correct answer. In other words, WebAssign grades a lot more like a living, breathing professor and a lot less like, well, that other system.

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Driven by the Data?

Regarding John Ewing's article "Mathematical intimidation: Driven by the data" (*Notices*, May 2011, pp. 667–673): In fact, there are serious scientific and statistical problems in trying to develop valid value added models for assessing teacher quality. The problem is separating the "teacher effect" from the entire "classroom effect". Statistician Howard Wainer has given a lucid explanation in "Value-added models to evaluate teachers: A cry for help", *Chance* 24 (1), accessible at <http://chance.amstat.org/2011/02/value-added-models/>, with further comments in "The first step toward wisdom", *Chance* 24 (2), accessible at <http://chance.amstat.org/2011/05/visualrev/>. Each article includes suggestions for further reading. *Notices* readers may also be interested in Wainer's forthcoming book, *Uneducated Guesses: Using Evidence to Uncover Misguided Educational Policies*, Princeton University Press.

—Martha K. Smith, *emerita*
University of Texas at Austin
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The State of Textbooks

For the past thirty years, I have tried to get my foot in the door of the textbook publishers. I have published research articles and expository articles, professional fiction, and light verse. I have submitted many proposals, with sample chapters, to essentially all of the publishers of grade school and high school textbooks in the United States. I have never gotten a reply.

Let me say that again. It is not that my proposals have been rejected, not even with a form letter. None of my proposals have ever received a reply from any publisher.

Would the textbooks I want to write be better than the books quoted in Guershon Harel and W. Stephen Wilson's article, "The state of high

school textbooks," *Notices*, June/July 2011? I think so, but I could be wrong. But I'm not wrong about this. There are many professional mathematicians who are excellent writers, know math well, and would love to write textbooks. Do they also experience the silence of the textbook publishers?

Why doesn't the American Mathematical Society publish its own series of textbooks?

—Rick Norwood
East Tennessee State University
norwoodr@etsu.edu

Response to Norwood letter: The American Mathematical Society has a robust textbook program covering all areas of mathematics on the graduate and advanced undergraduate levels. High school textbooks are very different, and currently the AMS is not well positioned to properly publish and promote them.

—Sergei Gelfand, *Publisher*
AMS

Mathematics or Not Mathematics

Teaching mathematics in schools is quite important. Yet it is known that most students will not be mathematicians. Hence teaching math as an abstract subject, I believe, is harmful. Relating math to real life is important, especially for such students. Almost every student should feel that math will be relevant to his/her career. Regrettably a strong tendency in many mathematicians is to neglect applications or even consider them as nonmath. Such a tendency will arise in their students who will be the future teachers!! I hope that this problem is seriously studied soon.

—E. Ahmed
Mansoura University, Egypt
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Received July 11, 2011

Plea to Publishers and Authors: Please Help Blind Mathematicians

For more than twenty-five years, $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ has imposed itself as the most efficient software for editing mathematical texts, and its use by publishers is nowadays standard. A marginal but notable consequence of this general use of $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ is that the whole present-day mathematical production is in principle accessible to blind people. Indeed, $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ typesetting is based on source files consisting only of ASCII characters, and each of these characters has a Braille translation, so every $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ source file can be read directly by a blind person using a Braille display connected to a computer. Of course, the readability of source files is sometimes questionable and strongly depends on the carefulness of authors, but it can easily be improved with very little effort (in particular, by removing all $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ commands which are useless for understanding the content and the structure of the text), and, anyway, it is infinitely better to have these files, which contain the complete information, rather than text without formulas (as one can get sometimes using converters from PDF to TXT) or just nothing. On the other hand, as for writing mathematics, it is remarkable and commendable that $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ puts blind people exactly on the same footing as sighted people.

All this is really great. The only problem is that $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ source files, though they do exist, are most often not available. Subscriptions to electronic versions of journals only give access to PDF files, in which mathematical notations and formulas are no longer encoded in ASCII characters, and therefore cannot be faithfully translated into Braille. Similarly, articles and books that can be found on professional webpages of their authors are available only in PDF or PS format. There is actually one important exception: the mathematical

Professor of Mathematics

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Letters to the Editor

arXiv, where the $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ source files are (almost) systematically available—and hence, electronic journals which post the papers they publish on arXiv make the source files available. This is something for which I am personally thankful every day.

As a conclusion, here is my plea to publishers and authors: please find a way of making the $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ source files of your publications available. Remove from them, if you wish, all the editing parameters which are necessary to print out but not to understand the text: the files will be even more readable. But please be aware that, for a (small but nonzero) number of mathematicians, $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ is the only accessible document format.

Editor's Note: This letter originally appeared in the *European Mathematical Society Newsletter*, issue 79, March 2011.

—Emmanuel Giroux
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I invite readers to browse the mathematical holdings at Project Gutenberg and to contact me with comments, questions, or suggestions.

—Andrew D. Hwang
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Correction

Due to a production error, the “References” section for the article “*Scripta Manent: Journals in Flux*” by Peter Olver (*Notices*, September 2011) included five references from a previous article. The correct list should have included only references [1] through [8].

Correction

Incorrect information sent to the AMS Membership and Customer Services department led to the erroneous listing of the name of Adriano M. Garsia in the “Deaths of AMS Members” in the September 2011 issue of the *Notices*. The *Notices* regrets this error and apologizes to Professor Garsia.

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Shiing-Shen Chern (1911–2004)

I was asked by Steve Krantz to collect essays in memory of my former teacher Shiing-Shen Chern, who was a great geometer. He passed away in December of 2004 in Tianjin in China.

This year would have been his 100th birthday. Many of his friends and his former students would like to take this occasion to express our admiration of our beloved mentor in mathematics. Some of the articles that we publish here have some overlap with the previous published account on Chern, including the essay by Singer, which was published by International Press about ten years ago.

One of the essays in this collection is written by Wen-Ling Huang and Karin Reich, who are not so closely related to Chern. It gives a good account of the unknown history when Chern was in Hamburg. I believe it is a worthwhile document to be read by the readers of the *Notices*.

—Shing-Tung Yau

Shing-Tung Yau

Chern's Work in Geometry

It is my honor to have had a great mathematician as my teacher; S.-S. Chern had a deep influence on my career, both mathematically and personally.

Looking back at the history of differential geometry, I would equate É. Cartan with the grandfather and S.-S. Chern the father of modern differential geometry. Together they had set the foundation of a beautiful subject that has reached out to every branch of mathematics and physics.

Immediately before his passing, Chern told others that he was going to see the Greek geometers. No doubt he had reached the same status as those giants.

The foundation of geometry had been laid by ancient geometers. Modern geometers have been standing on their shoulders and making spectacular achievements. This sentiment is reflected in an article written about thirty years ago by Weil. In the preface to *Selected Papers of S.-S. Chern*, he wrote: "The psychological aspects of true

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This is the speech given at the Harvard Memorial Conference for S.-S. Chern.

geometric intuition will perhaps never be cleared up. ...Whatever the truth of the matter, mathematics in our century would not have made such impressive progress without the geometric sense of Élie Cartan, Heinz Hopf, Chern and a very few more. It seems safe to predict that such men will always be needed if mathematics is to go on as before."

Chern: Father of Global Intrinsic Geometry

Both Cartan and Chern saw the importance of fiber bundles to problems in differential geometry.

It is certainly true that global differential geometry was studied by other great mathematicians: Cohn-Vossen, Minkowski, Hilbert, and Weyl, among others. However, most of their works focused on global surfaces in three-dimensional Euclidean space.

Chern was the first who succeeded in building a bridge between intrinsic geometry and algebraic topology for manifolds of all dimensions, not just surface. (Cartan's work in differential geometry was more local in nature, except his investigation of Lie groups and symmetric spaces.) The theory of fiber bundles was his major tool.

Reflecting on intrinsic geometry, Chern commented: "Riemannian geometry and its generalization in differential geometry are local in character. It seems a mystery to me that we do need a whole

space to piece the neighborhood together. This is achieved by topology.”

Equivalence Problem

Most of the works of Chern were related to the problem of equivalence.

In 1869 E. Christoffel and R. Lipschitz solved the fundamental problem in Riemannian geometry—the form problem:

To determine when two ds^2 's differ by a change of coordinates, Christoffel introduced covariant differentiation, which is now called the Levi-Civita connection.

Cartan generalized this problem to a much more general setting; it is called the equivalence problem.

Given a Lie group $G \in GL(n, \mathbb{R})$, given two sets of linearly independent linear differential forms θ^i and θ^{*j} in the coordinates x^k and x^{*l} respectively, $1 \leq i, j, k, l \leq n$, find conditions under which there are functions

$$x^{*i} = x^{*i}(x^1, x^2, \dots, x^n)$$

such that θ^{*j} , after the substitution of these functions, differ from θ^i by a transformation of G .

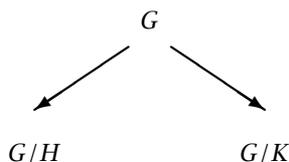
This problem involves local invariants. Cartan provided a procedure to generate such invariants. Almost all of the work of Chern is related to this problem.

Chern (1932–1943)

During the eleven-year period from 1932 to 1943, Chern studied web geometry, projective line geometry, invariants of the contact of pairs of submanifolds in projective space, and transformations of surfaces related to the Bäcklund transform in soliton theory. Chern continued this line of research in his collaborations with Griffiths and Terng later.

Between 1940 and 1942, Chern [5] started to generalize the theory of integral geometry, an area initially developed by Crofton and Blaschke. He observed that this theory can best be understood in terms of two homogeneous spaces with the same Lie group G (see also Weil's review [20]).

This leads to the diagram associated to two subgroups H and K of G :



Two cosets aH and bK are incident to each other if they intersect in G . This notion fits nicely in modern investigations of the Funk-Radon problem of

determining a function on a manifold in terms of its integrals over certain submanifolds. Although the focus of this work is “classical” integral geometry, the double fibration diagrams depicted above prefigure in an uncanny way a different, more modern type of integral geometry: the theory of generalized Radon transforms developed by Gelfand and Graev in the late fifties and early sixties.

Using this approach, Chern generalized many important formulas of Crofton. In 1952 he [8] also generalized the kinematic formula of Poincaré, Santaló, and Blaschke.

On the impact of these generalizations by Chern, Weil commented: “It lifted the whole subject at one stroke to a higher plane than where Blaschke’s school had lifted it. I was impressed by the unusual talent and depth of understanding that shone through it.”

Chern’s Visit to Princeton (1943–1945)

In 1943 Chern left Kunming for Princeton. He arrived at the moment when fiber bundle theory was beginning to evolve from the works of Cartan and Whitney.

When he arrived at Princeton, Weil had just published his work with Allendoerfer on the Gauss-Bonnet formula. Weil directed Chern toward the works of Todd and Eger on “canonical classes” in algebraic geometry. He pointed out to Chern that their work on characteristic classes for complex manifolds had only been completed in the spirit of Italian geometry and rested upon some unproved assumptions.

The first fundamental work Chern did on global intrinsic geometry was his intrinsic proof of the Gauss-Bonnet formula [6], re-proving the recent work of Allendoerfer and Weil [2] for general closed Riemannian manifolds. The proof of Allendoerfer-Weil rested on the use of local embeddings of the manifold in Euclidean space, isometric for an approximating real analytic metric. (The existence of local isometric embeddings for real analytic metrics had been established earlier by Burstin, Cartan, and Janet.)

Weil commented on Chern’s proof of the Gauss-Bonnet formula: “Following the footsteps of H. Weyl and other writers, the latter proof, resting on the consideration of ‘tubes’, did depend (although this was not apparent at that time) on the construction of a sphere-bundle, but of a nonintrinsic one, viz. the transversal bundle for a given immersion. ...Chern’s proof operated explicitly for the first time with an intrinsic bundle, the bundle of tangent vectors of length one, thus clarifying the whole subject once and for all.”

A century earlier, Gauss established the concept of intrinsic geometry. Chern’s proof of Gauss-Bonnet opened up a new horizon. Global topology was now linked with intrinsic geometry through the concept of fiber bundle and transgression on

the intrinsic tangent sphere bundle. A new era of global intrinsic geometry arrived.

While Hopf's vector field theorem had clearly influenced Chern's thinking, the proof was a tour de force based on Chern's insights and powerful algebraic manipulation. Hopf declared that Chern's proof had brought differential geometry into a new era. In particular, it gave rise to the idea of transgression. Chern's proof remains one of the most admired proofs in the modern history of mathematics.

Chern Classes

Reflecting upon his early encounter with Chern classes, Chern said: "My introduction to the characteristic class was through the Gauss-Bonnet formula, known to every student of surface theory. Long before 1943, when I gave an intrinsic proof of the n -dimensional Gauss-Bonnet formula, I knew, by using orthonormal frames in surface theory, that the classical Gauss-Bonnet is but a global consequence of the Gauss formula which expresses the 'theorima egregium'. The algebraic aspect of this proof is the first instance of a construction later known as a transgression, which was destined to play a fundamental role in the homology theory of fiber bundles and in other problems."

Cartan's work on frame bundles and de Rham's theorem always stayed close to Chern's thinking. The concept of fiber bundles stands at the very heart of modern mathematics. It's a central unifying notion for many important objects in mathematics and physics. It is fitting to give a brief description of its history.

In 1937 E. Stiefel (1936) and H. Whitney (1937) introduced Stiefel-Whitney classes; they were only defined modulo integer two.

From 1939 to 1944 J. Feldbau (1939), C. Ehresmann (1941, 1942, 1943), Chern (1944, 1945) and N. Steenrod (1944) made a systematic study of the topology of fiber bundles.

In 1942 L. Pontryagin introduced the Pontryagin class. In 1944 he associated topological invariants using the curvature of Riemannian manifolds. His papers were published in the *Doklady* journal. He was short in proving that these curvature invariants are the same as Pontryagin classes.

Let me describe what is needed to prove the equivalence of the curvature and topological definitions of characteristic classes.

Recall that, in the proof of the Gauss-Bonnet formula, one uses vector fields s_1, \dots, s_k in general position. In his thesis in 1936 Stiefel proved that

the locus at which the vector fields are linearly dependent forms a $(k - 1)$ -dimensional cycle whose homology class is independent of the choice of s_i .

In 1937 Whitney [21] considered sections for more general sphere bundles from the point of view of obstruction theory. Whitney noticed the importance of the universal bundle over the Grassmannian $G(q, N)$ of q planes in \mathbb{R}^N . He showed that any rank q bundle over the manifold is isomorphic to the pullback of the universal bundle under a map $f : M \rightarrow G(q, N)$.

Pontryagin (1942) and Steenrod [19] observed that, when N is large, the map f is unique up to homotopy. The characteristic classes of the bundle are given by

$$f^*H^*(Gr(q, N)) \subset H^*(M)$$

In 1934 Ehresmann [17] studied the cohomology of $H^*(Gr(q, N))$ and showed that it is generated by Schubert cells.

At first, Chern tried to prove the equivalence of the Pontryagin classes defined using Schubert cells and classes defined using the curvature form. The difficulty was how to integrate these differential forms defined by the curvature form over the Schubert cells.

Chern quickly realized that it was easier to handle the case over complex numbers. Speaking of this discovery, Chern said: "It was a trivial observation and a stroke of luck, when I saw in 1944 that the situation for complex vector bundles is far simpler, because most of the classical complex spaces, such as the classical complex Grassmann manifolds, the complex Stiefel manifolds, etc., have no torsion."

For a complex vector bundle E , the Chern classes $c_i(E)$ belong to $H^{2i}(M, \mathbb{Z})$. By his discovery, Chern proved the equivalence of three definitions of characteristic classes: one using obstruction theory, one using Schubert cells, and the third using curvature forms of a connection on the bundle.

The Fundamental Paper of Chern (1946)

In the paper [7], Chern laid the foundation of Hermitian geometry on complex manifolds.

In this paper, Chern introduced the concept of Hermitian connections; using the curvature form Ω of the Hermitian connection, Chern defined

$$\det \left(I + \frac{\sqrt{-1}}{2\pi} \Omega \right) = 1 + c_1(\Omega) + \dots + c_q(\Omega).$$

The importance of defining Chern classes by differential forms cannot be overstated in mathematics. It also provides fundamental tools in modern physics. An example is the concept of transgression introduced by Chern.

Let φ be the connection form defined on the frame bundle associated with the vector bundle.

The curvature form is

$$\Omega = d\varphi - \varphi \wedge \varphi$$

and

$$\begin{aligned} c_1(\Omega) &= \frac{\sqrt{-1}}{2\pi} \text{Tr} \Omega = \frac{\sqrt{-1}}{2\pi} d(\text{Tr} \varphi) \\ \text{Tr}(\Omega \wedge \Omega) &= d(\text{Tr}(d\varphi \wedge \varphi)) \\ &\quad + \frac{1}{3} \text{Tr}(\varphi \wedge \varphi \wedge \varphi) = d(CS(\varphi)). \end{aligned}$$

The forms $\text{Tr} \varphi$ and $CS(\varphi)$ are the transgressed forms for $c_1(\Omega)$ and $\text{Tr}(\Omega \wedge \Omega)$, respectively.

The term $CS(\varphi)$ is called the Chern-Simons form. It was introduced by Chern and Simons [15] in the early seventies. It has played a fundamental role in three-dimensional manifolds, in anomaly cancellation in string theory, and in solid state physics.

Performing transgression on the form level also gives rise to secondary operations on homology, like the Massey product, which was used in K. T. Chen's work on iterated integrals.

For a complex manifold, we can write

$$d = \partial + \bar{\partial}.$$

In their fundamental paper, Bott-Chern (1965) [4] found a double transgression form, which was a canonically constructed (local) $(i-1, i-1)$ -form $\tilde{T}c_i(\Omega)$, so that $c_i(\Omega) = \bar{\partial}\partial\tilde{T}(c_i(\Omega))$.

Chern made use of this theorem to generalize Nevanlinna's theory of value distribution to holomorphic maps between higher-dimensional complex manifolds. The form $\tilde{T}c_i(\Omega)$ also plays a fundamental role in Arakelov theory developed later.

Donaldson used the case of $i=2$ to prove the Donaldson-Uhlenbeck-Yau theorem for the existence of the Hermitian Yang-Mills connection on algebraic surfaces.

For a complex manifold X with Hermitian $h_{i\bar{j}}$,

$$c_1(T_X) = -\frac{\sqrt{-1}}{2\pi} \partial\bar{\partial} \log \det(h_{i\bar{j}}).$$

The right-hand side is the Ricci tensor of the metric. The simplicity of the first Chern form motivated the Calabi conjecture, which was eventually solved by me. Chern was excited by this development.

The curvature representation of Chern class means that all the Chern numbers are obtained by integrating some densities defined by curvatures alone. This allows Hirzebruch to derive the proportionality principle for locally symmetric space: that the ratio of the Chern numbers of covering spaces is proportional to the ratio of the volume. Similarly, it motivated me [22] to give a proof of the Miyaoka-Yau inequality based on Kähler-Einstein metrics. All these theorems would have been impossible without Chern's work on representing Chern classes by curvature forms.

As Chern himself observed many times, the simplicity and beauty of geometry over complex numbers can never be exaggerated.

Return to China after the War

After Chern established his two spectacular works in Princeton, he returned to China in April 1946. He was recruited by the national government to help one of his former teachers, Chiang, who taught him in Nankai University. While Chiang was the formal director, Chern was the one who ran the day-to-day business in the Mathematical Institute in the Academic Sinica. He lectured on contemporary research works in topology. He had many students, and postdoctoral fellows participated in his seminars. They include K. T. Chen, H. C. Wang, W. Wu, C. T. Yang, Z. D. Yan, and many others. This group of people later became leading mathematicians in China.

Chicago Days

On December 31, 1948, at the invitation of Veblen and Weyl, Chern left Shanghai for the Institute for Advanced Study in Princeton and spent the next winter term there. He was then offered a professorship by Marshall Stone in Chicago. His friend Weil played an important role in this offer. He settled down in Chicago and ran seminars with Weil, Singer, Sternberg, Kadison, and others in his class. His influence on geometry in America is deep. Singer respected Chern and called him his teacher. During this period of time, he trained several outstanding students, such as S. D. Liao, Wolf, and Nomizu.

After his fundamental paper on Chern classes in 1946, Chern began to explore the multiplicative structure of the characteristic classes in even greater detail. In 1951 he wrote a paper with E. Spanier on the Gysin sequence on a fiber bundle. They proved the Thom isomorphism, independent of the work of Thom.

In his 1953 paper [9], Chern showed that by considering an associated bundle with the flag manifold as fibers, the characteristic classes can be defined in terms of line bundles. As a consequence, the dual homology class of a characteristic class of an algebraic manifold can be represented by algebraic cycles. This paper gives rise to Hirzebruch's splitting principle in K -theory.

Subsequently, Washnitzer, and later Grothendieck in a more general setting, combined the splitting principle with the Thom isomorphism to define Chern classes of the associated bundles.

Hodge had studied the problem of representing homology classes using algebraic cycles. He also tried to prove this theorem of Chern. However, he proved only the case in which the manifold is a complete intersection of nonsingular hypersurface in a projective space.

This theorem of Chern is the only known general statement of the “Hodge conjecture” besides the case of dimension one and codimension one cycles, which is a relatively easy consequence of the Lefschetz (1,1) theorem. Chern’s theorem also provided a direct link between holomorphic K -theory and algebraic cycles.

In Chicago, Chern and Lashof [12] studied the concept of tight embedding of hypersurfaces in Euclidean spaces. This work was generalized and continued by Kuiper and Banchoff.

Berkeley Days and Return to China

Chern moved to Berkeley in 1961. He spent all his years in Berkeley until his retirement in 1979; he served at the math department for three more years after his retirement. The arrival of Chern and Smale in Berkeley coincided with the period when the mathematics department at Berkeley rose to become a major leading department in the world. Building on the strength of the existing faculties hired by Evans, Tarski, Morrey, Kelly, and others, Chern had hired many outstanding geometers and topologists who set up Berkeley to be the center in geometry and topology. Berkeley in the 1960s was an extraordinarily exciting place for people interested in geometry: students, faculty, and visiting mathematicians alike. The graduate students felt as if they were in the center of the universe of geometry. Everyone else in the world of geometry came to visit.

Chern trained many outstanding students in the period when he was in Berkeley. This group includes Garland, do Carmo, Shiffman, Weinstein, Banchoff, Millson, S. Y. Cheng, Peter Li, Webster, Donnelly, and Wolfson, not counting myself. Chern organized the training of his Ph.D. students through the help of some of his older students and his friends. For example, Garland got advice from H. C. Wang, Millson from Jim Simons. The charm of Chern was essential to keeping this large group of outstanding geometers working together in Campbell Hall and in Evans Hall in Berkeley. The geometry seminar and the colloquium in Berkeley were always packed with students, faculty members, and visitors. It is well known that Chern treated every visitor with a splendid dinner in a Chinese restaurant or else an elegant party in his house. His wife was able to entertain everybody with grace and nice Chinese food. This period of Berkeley days is unforgettable to two generations of geometers.

In Berkeley, Chern studied minimal surface theory along with Calabi and Osserman [14]. He also tried to generalize Nevanlinna theory to a broader setting; his effort led to the discovery of the Bott-Chern form and the Chern-Levine-Nirenberg intrinsic norms; all of these have had much impact in complex geometry beyond the original purpose. His work with Simons has had deep influence

in geometry and physics, including knot theory. The work with Moser [13] on local invariants of real hypersurfaces in complex Euclidean spaces is fundamental in several complex variables. He and Griffiths [11] generalized his old work on web geometry.

In the early eighties, along with Singer and Moore, Chern founded MSRI at Berkeley. Later, he retired and returned to China. In China he formed a mathematics center in Nankai. That center is considered to be successful and influential.

Conclusion

Chern’s ability to create invariants for important geometric structures was unsurpassed by any mathematician whom I have ever known. His works on the Gauss-Bonnet formula, on Chern classes, on projective differential geometry, on affine geometry, and on Chern-Moser invariants for pseudo-convex domains demonstrate his strength. Before he died, he had embarked on the major undertaking of applying the Cartan-Kähler system to a more general geometric setting.

Chern once said: “The importance of complex numbers in geometry is a mystery to me. It is well organized and complete.”

Chern always regretted that ancient Chinese mathematicians never discovered complex numbers. Chern’s everlasting works in complex geometry made up for the earlier losses by Chinese mathematics over the last two thousand years.

The Chinese astronomers named a star after Chern. May his accomplishments always shine on the future generations of mathematicians.

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F. Hirzebruch

Why Do I Like Chern, and Why Do I Like Chern Classes?

In 1949–50 I studied for three semesters at the ETH in Zurich and learned a lot from Heinz Hopf and Beno Eckmann [1], also about Chern classes, their applications, and their relations to Stiefel-Whitney classes ([2], [3], [4], [5]). Chern classes are defined for a complex vector bundle E over a reasonable space X with fiber \mathbb{C}^n . They are elements of the cohomology ring of X . The i th Chern class of E is an element of $H^{2i}(X, \mathbb{Z})$ where $0 \leq i \leq n$ and $c_0 = 1$. They are used for the investigation of fields of r -tuples of sections of the vector bundle, in particular if X is a compact complex manifold and E the tangent bundle of X . Then we have the basic fact: If there exists an r -tuple of sections which are linearly independent in every point of X , then

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$c_i = 0$ for $i \geq n - r + 1$. For real differentiable manifolds such questions are treated in the dissertation of Hopf’s student Stiefel [4], later a well-known computer scientist. For a compact complex manifold X of dimension n , the n -dimensional products of the Chern classes of the tangent bundle (all dimensions complex) give the Chern numbers, when integrated over X , for example $c_n[X]$ is the Euler-Poincaré characteristic (Poincaré-Hopf theorem).

From 1950 to 1952 I was scientific assistant in Erlangen and wrote the paper [6] where ideas of Hopf entered [2]. Some of the results could have been generalized to higher dimensions. But the so-called “duality formula” was not yet proved. This formula says that the total Chern class $1 + c_1 + c_2 + \dots$ of the direct sum of two complex vector bundles equals the product of the total Chern classes of the summands. The paper [6] has a remark written during proofreading that Chern and Kodaira told me that the “duality formula” is proved in a forthcoming paper of Chern [7]. In the commentary to my paper [6] in volume 1 of my *Collected Papers* (Springer 1987), I write that my knowledge about Chern classes increased with the speed of a flash when I came to Princeton in August 1952 as a member of the Institute for Advanced Study and talked with K. Kodaira, D. C. Spencer, and, a little later, with A. Borel, who told me about his thesis containing his theory about the cohomology of the classifying spaces of compact Lie groups. For the unitary group $U(n)$, this implies that the Chern class c_i can be considered in a natural way as the i th elementary symmetric function in certain variables x_1, x_2, \dots, x_n .

My two years (1952–54) at the Institute for Advanced Study were formative for my mathematical career ([8],[9]). I had to study and develop fundamental properties of Chern classes, introduced the Chern character, which later (joint work with M. F. Atiyah) became a functor from K-theory to rational cohomology. I began to publish my results in 1953. The main theorem is announced in [10]. It concerns the Euler number of a projective algebraic variety V with coefficients in the sheaf of holomorphic sections of a complex analytic vector bundle W over V . Chern classes everywhere! I quote from [10]: “The main theorem expresses this Euler-Poincaré characteristic as a polynomial in the Chern classes of the tangential bundle of V and in the Chern classes of the bundle W .”

The Chern classes accompanied me throughout all my mathematical life; for example: In 2009 I gave the annual Oberwolfach lecture about Chern classes [11].

My fiancée joined me in Princeton in November 1952. We married. A “marriage tour” was organized, for which Spencer gave me some support from his Air Force project. I lectured in seven places during this trip, including Chicago, where we met the great master Shiing-Shen Chern and his

charming wife. He was forty-one, I was twenty-five. For me he was a gentleman advanced in age. But all shyness disappeared. He was interested in my progress in Princeton about which I also talked in my lecture. We must have spoken about his papers [3] and [7]. Chern begins in [3] with a study of the Grassmannian $H(n, N)$ of linear subspaces of dimension n in the complex vector space of dimension $n + N$. He defines the Chern classes of the n -dimension tautological bundle over the Grassmannian in terms of Schubert calculus. From here Chern comes to the definition using r -tuples of sections. For $N \rightarrow \infty$, the Grassmannian becomes the classifying space of $U(n)$, and we are close to what I learned from Borel. For Hermitian manifolds Chern shows how to represent the Chern classes by differential forms.

The paper [7] has the following definition of Chern classes: Let E be a complex vector bundle of dimension n over the base B . Let P be the associated projective bundle with fiber $\mathbb{P}_{n-1}(\mathbb{C})$. Let L be the tautological line bundle over P and $g = -c_1(L)$. Then g restricted to the fiber of P is the positive generator of $H^2(P_{n-1}(\mathbb{C}), \mathbb{Z})$. Integration of g^{n-1+m} over the fiber in P gives \bar{c}_m , the m th “dual” Chern class of E . The total “dual” Chern class $\bar{c} = 1 + \bar{c}_1 + \bar{c}_2 + \cdots$ is defined by

$$c \cdot \bar{c} = 1.$$

If $B = H(n, N)$, then \bar{c} is the total Chern class of the complementary N -dimensional tautological bundle over B .

Chern uses this to prove that the Chern classes are represented by algebraic cycles if everything happens in the projective algebraic category.

The Cherns invited my wife and me for dinner in their home. For the first time we enjoyed the cooking of Mrs. Chern. Many meals in Berkeley would follow. The Chern family, with their two children in 1950, can be seen in the photograph on page XX of his *Selected Papers* (Springer 1978). Chern presented me a copy of this book with the dedication “To Fritz. Warmest regards. June 1979”. The signature is in Chinese characters.

During 1955–56 I was an assistant professor at Princeton University. I gave a course on my book [12]. Chern and Serre attended at least occasionally. Chern, Serre, and I wrote a paper, “On the index of a fibered manifold”, which was submitted in September 1956 [13]. There the multiplicativity of the signature [= index] is proved for fibrations of compact connected oriented manifolds provided the fundamental group of the base acts trivially on the rational cohomology of the fiber.

In 1960 Chern became a professor in Berkeley. I visited him there in 1962, 1963, 1967, 1968, 1973, 1974, 1979, 1983, 1986, and 1998, always with part of my family. Chern inspired an official offer to me by the University of California (November 1968). He wrote to me: “We all hope that you will find

Berkeley sufficiently attractive to deserve your serious consideration. Some disturbances are expected but they need not concern you. I am going to submit to the NSF a new proposal for research support and will be glad to include you in the proposal.” In Bonn I was very involved in discussions with the protesting students and expected to have a quieter life in Berkeley as a new faculty member with more time for mathematics. Finally I decided to stay in Bonn. Chern was very disappointed. But the invitations to Berkeley continued. The Cherns were always very helpful in many practical problems: picking us up at the airport, finding a house, lending us things useful for housekeeping, even lending us a car, depositing items in their house we had bought to be used during the next visit...We enjoyed the Cherns’ hospitality in their beautiful home in El Cerrito, overlooking the Bay with the famous Bay Bridge, or in excellent Chinese restaurants in Berkeley and Oakland where the Cherns were highly respected guests. There were always interesting conversations with the Cherns and the other dinner guests.

In 1979 there was a conference, “The Chern Symposium”, on the occasion of Chern’s retirement as a professor of the university. In the *Proceedings* [14] I. M. Singer writes: “The conference also reflected Professor Chern’s personality, active yet relaxed, mixed with gentleness and good humor. We wish him good health, a long life, happiness, and a continuation of his extraordinary deep and original contributions to mathematics.” This came also from my heart.

Chern did not really retire. In 1981 he became the first director of the Mathematical Sciences Research Institute in Berkeley. When the MSRI building was ready, I sometimes used Chern’s beautiful office with a wonderful view.

In 1981 I nominated Chern for the “Alexander von Humboldt-Preis”. He received it and spent part of the summers of 1982 and 1984 in Bonn. He talked at the Arbeitstagungen of these years on the topics “web geometry” and “some applications of the method of moving frames”.

In 1998 I was invited to be one of the first Chern professors in Berkeley. These visiting professorships are financed by Robert G. Uomini, a former student of Chern, who had won an enormous sum in the lottery. In my case a one-day Chern symposium was held, followed by a four-week course. The title of my Chern lecture in the symposium was “Why do I like Chern classes?” I gave four answers:

- (1) *The Chern classes remind me of my youth.*
I hope this became clear in the beginning of this contribution.
- (2) *The Chern classes have so many different definitions.* As a joke I added: *I especially like that all these definitions are equivalent.* There are the definitions in Chern’s papers [3] and [7]. The statement in the joke

needed some work, which was carried out by Borel and me and perhaps by others, too. The difficulty consisted in sign questions: Are we dealing with a complex vector bundle V or its dual V^* ?

(3) “Chern has a beautiful character.”

There was the story that during a lecture about K-theory and its functor ch to rational cohomology I cried out, “Chern has a beautiful character!” Chern was present and smiled.

(4) *Chern classes have so many applications.*

In 1998 Chern was eighty-seven years old. He did not appear so old to me. He came to my Chern lecture and also to some lectures in my four-week course. The Cherns came to an official dinner. They invited us to a Chinese restaurant.

Berkeley 1998! The last time I saw Chern. The Cherns gradually moved to China.

But we stayed in contact. We edited the two volumes on the Wolf Prize winners in mathematics (published by World Scientific in 2000 and 2001).

My retirement as director of the Max Planck Institute for Mathematics in Bonn in 1995 was celebrated by a “party” with informal lectures, performances, music, lunches and dinners organized by Don Zagier. It lasted two or three days. Zagier had the idea to produce a book with essays or short statements by the participants and by some other people who could not attend. Chern did not come. But one page is by him (see Figure 1).

In 2005 the School of Mathematics of the Institute for Advanced Study in Princeton had its seventy-fifth anniversary. Of the older members Chern, Bott, Hirzebruch, and Atiyah were invited to present to the inner circle how the time at the Institute was formative for their careers, Chern by television. But he died in 2004. I also gave a mathematical lecture in which Borel and Chern figured prominently. Chern classes everywhere! Borel and I had shown in the 1950s how to calculate the Chern classes and the Chern numbers of compact complex homogeneous spaces. An example (in a formulation by E. Calabi):

Let X be the projective contravariant tangent bundle of $\mathbb{P}_3(\mathbb{C})$ and Y the projective covariant tangent bundle. Then the Chern number c_1^5 of these five-dimensional complex homogeneous spaces X and Y , respectively, equals 4500 and 4860. This is interesting because X and Y are diffeomorphic (compare [11] and the work of D. Kotschick mentioned there).

Remark. It is unavoidable that this contribution has some overlap with [15] and with my interview

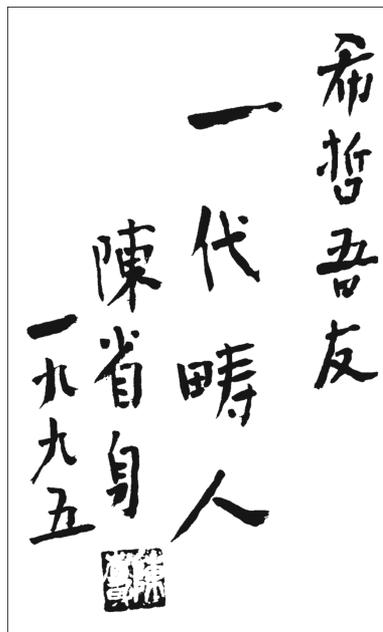


Figure 1.

about Chern of December 6, 2010, here in Bonn [Zala Films with George Csicsery for MSRI].

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Michael Atiyah

Memories of S.-S. Chern

I first met Chern in Chicago in 1956. I had gone to the Institute for Advanced Study in Princeton after my Ph.D., and Chern invited me to give a seminar. He was a senior professor and I a raw Ph.D., but he took good care of my wife and me for our week in Chicago. We remained in frequent touch over the subsequent years, and the last time we saw him was as his houseguests on the campus of Nankai University, shortly before his death. One clear memory I have of him is at a conference in Durham, England, where, despite advancing years, he valiantly walked along Hadrian's Wall with the younger generation.

Chern was a geometer of the old school. His work had none of the polish of the postwar generation, his methods were direct and intuitive and at times cumbersome. For this reason I and others of my generation underestimated him. What he may have lacked in elegance he made up for by his breadth of interest and his deep geometrical insight. This took him in many pioneering directions and led to his extensive collaborations with diverse mathematicians such as Moser, Bott, Simons, and Griffiths. His connection with physicists such as C. N. Yang and T. D. Lee paved the way for the remarkable interaction between geometry and physics of the past few decades.

He was of course a legendary figure in China (and in Chinese restaurants in Berkeley), and it was through him that I and many other mathematicians were introduced to China. The Chern Institute at Nankai is a lasting tribute to his role in revitalizing Chinese mathematics.

I also owe Chern a debt of gratitude for persuading me, at an early stage, to publish my collected works and to make them available in China. As someone who has not fully adapted to modern

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technology, I find books more friendly and accessible than the electronic media.

Chern's influence, and the widespread affection felt for him by colleagues of all ages, is due in no small part to his personality. Despite becoming the grand old man of Chinese mathematics, he remained modest and unassuming, always willing to listen and to encourage the young. His photograph is one of the few in my study. Alongside it is a framed Chinese poem in beautiful calligraphy that Chern composed on the plane that flew him to England in 1976 for the joint LMS/AMS bicentennial meeting. Since I was LMS president at the time he presented it to me, together with an English translation, discreetly placed on the back.

Manfredo do Carmo

On Collaborating with Chern

Chern was probably the most important influence of my life as a mathematician. As time goes by, I find myself using more and more in my work what I learned from him during the times I stayed in Berkeley, first as his student and later as a post-doctoral fellow. He was not a forceful person, and his teachings had to be found in his almost casual remarks and mostly in his personality that was, in a mysterious way, very kind but very firm.

I have already written somewhere else [1] my reminiscences as Chern's student; I now want to make some comments on the experience of collaborating with Chern.

In the winter of 1968 Chern gave a course on a preprint by Jim Simons, "Minimal varieties in Riemannian manifolds", later published in [2]. The paper was a breakthrough in the theory of minimal surfaces, and Chern decided to present the subject from the beginning using the method of moving frames; he worked miracles with this method, and it was beautiful to see how things would develop in a natural way through his treatment. For me, the course was an important opening. I had a secret love for the theory of minimal surfaces, but I had not been able to form a clear view of the subject. But then, sometime along the course, I began to feel at home with the beauty of the topic. One characteristic of any Chern course was the presence of interesting open problems, and this course was no exception. Implicit in Simons's paper was a question that Chern made explicit and proposed as a problem in one of the lectures of the course. I had followed the course closely, and that particular problem attracted me. I worked hard and found a solution that I sketched before the following class. After the class, I approached Chern to show my solution. From the other side,

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there came Kobayashi with a solution in the form of a paper already typed. After hearing both sides, Chern suggested, generously, that we should join our efforts in a common project. The final version of the Chern-do-Carmo-Kobayashi paper [3] was written by Kobayashi and became a much-quoted paper. This paper and Chern's course were the main sources of my interest in minimal submanifolds, in which I did a large portion of my research work.

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Robert E. Greene

Recollections of S.-S. Chern from Berkeley in the 1960s and 1970s

I was happy to oblige when S. T. Yau suggested that I might write down a few recollections of my years as a graduate student at Berkeley and in particular my memories of Professor Chern, as we all called him, even in private. (Everybody else in their absence was just called by their last name or, if we knew them well, their first names. But Professor Chern was always called just that, title included.)

While from the viewpoint of history in its broader-brush aspects, to arrive in Berkeley in early 1965, as I did as a beginning graduate student, was to descend into a cauldron of political ferment, for me it was to arrive in a world of differential geometric activity beyond anything that a graduate student of geometry had any right to expect. There can have been few moments or places that offered grander opportunities to be present at the creation of everything that was being created at that active time in geometry. And, like all the graduate students with an interest in geometry, I awaited with eagerness the chance to learn from Professor Chern.

This chance came immediately, when Professor Chern was presenting a course in geometry, naturally to a packed house. Excitement was at a high level. Whatever the attitude of those around us in the outside world of political Berkeley (“Don’t trust anyone over thirty”, “Tune in, turn on, drop out”),

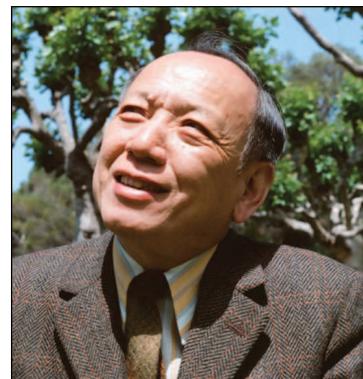
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we were all on the contrary most anxious to benefit to the full from sitting at the feet of one of the greatest of great masters.

The experience was startling. After a few preliminaries, Chern began to talk about his own work on characteristic classes. He was the soul of modesty and always referred to Chern classes as “so-called Chern classes”, for example. But at the same time, the experience was awe-inspiring, because he would come in every day and fill the blackboards with the long calculations that are needed in treating the subject in terms of differential forms. He never brought any notes, never paused to pursue any elusive recollection, and never made mistakes. The whole subject unfolded as smoothly and gracefully as if he were reading from a perfectly written book.

Finally, one of the more courageous students asked him after class how this was possible. He replied quietly that in fact he had developed the whole subject to begin with without writing anything down. He said it was as if he had a blackboard in his mind on which things could be written and stayed forever. This was said so gently that it did not come across as immodest in the least, just a simple explanation of his inimitable lecture style. Then he added with a tone of slight regret, “Nowadays I sometimes have to use a pencil and paper a little when I am thinking of something new.”

To say that this overawed the students would understate the case. At some point soon after, I asked H. H. Wu, with whom I would later write my Ph.D. dissertation, whether such computational power was needed to work in differential



Berkeley: top—1968, middle—1974, bottom—1977.

geometry, and I expressed the feeling that if so, I should look for some other field. He chuckled and said “If one had to be like Professor Chern to be a differential geometer, there would be very few differential geometers,” and assured me that this kind of computational power was not required.

While I was more than happy, as who would not have been, to hear Professor Chern’s ideas about complex manifold matters and anything else he might care to present in courses, he had at that time a great many students—eight, as I recall—and I felt diffident about being one of so many. And I felt equally in sympathy, perhaps even more so, with Wu’s approach to complex manifolds. My estimate that Wu and I would be in sympathy mathematically proved to be an accurate one. He and I wrote a long sequence of papers together during the late 1960s, 1970s, and on into the 1980s, and we have remained good friends, personally and mathematically, ever since.

While I was not Professor Chern’s Ph.D. student as such, I, like everyone in geometry, not just at Berkeley but everywhere, remained under his influence and guiding spirit. And around him, the whole world of geometry at Berkeley orbited. Part of the excitement of the scene was that it seemed that everyone came to Berkeley to present their results, whether or not they were directly related to Chern’s own explicit research interests. I recall, for example, Detlef Gromoll coming as a Miller Fellow (in 1966) and introducing us all to his approach to the differentiable pinching problem for spheres. What is intriguing

to note here is that even though the kind of geodesic geometry that was Gromoll’s specialty, then and later, was quite remote from Professor Chern’s own direct interests, it seemed perfectly natural for Gromoll, like any other geometer, to come to Berkeley. Professor Chern had created a situation in which geometry in all directions flourished, geometry of all kinds.

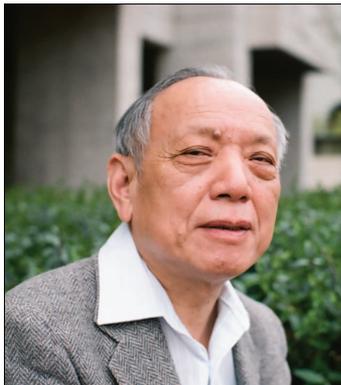
One surprising aspect of how much in touch with all developments Chern was is his extraordinary feeling for what would happen next, for where mathematics would go. For example, the idea goes back in effect to Poincaré that the number of parameters in local holomorphic diffeomorphisms of real analytic hypersurfaces up to a given order is smaller than the number of parameters for the hypersurfaces themselves so that not all (strongly pseudo-convex) hypersurfaces can be locally biholomorphically equivalent. But this observation acquires extra significance from Fefferman’s result that biholomorphic maps of C^∞ strongly pseudoconvex domains are smooth to the boundary. Fefferman’s result was published in 1974, almost simultaneously with the work of Chern and Moser on biholomorphic boundary invariants. This sort of anticipation of history, as it were, could seem almost uncanny. Without Fefferman’s result, Chern-Moser invariants would have had much less significance in complex analysis.

Rutherford is supposed to have remarked in answer to the question of how he was always ahead of the wave in nuclear physics, “Well, I made the wave, didn’t I?” Professor Chern would never have been so immodest as to have said a thing like that. But the comparison did come to mind. Chern was not only a great initiator himself, but he seemed to see the shape of things to come in a surprising way.

To return to the personal level, I left Berkeley for a Courant Institute postdoctoral instructorship in 1969. By that time, Wu and I were working regularly together, so I kept in close touch with Professor Chern at one remove, since Wu talked to him frequently about our work together. Chern was particularly intrigued by Wu’s and my work together on the rigidity of punctured surfaces of positive curvature. He was so kind as to mention it in his survey article on differential geometry for the 1974 edition of the *Encyclopaedia Britannica*. This gave a real lift to my confidence in my youth. (My nine-year-old niece brought me down to earth by remarking that it did not amount to much, since I did not have a personal entry.)

After my two years at the Courant Institute, I joined the UCLA faculty and thus had occasions often to visit Berkeley again, especially since Wu and I were continuing our joint work apace. Thus I once again had more direct contact with Professor Chern. And the geometric activity at Berkeley was as extensive as ever. The abundance of visitors showed that still “all roads lead to Berkeley” for geometers.

I remember the arrival of Mikhail Gromov, who had just left the Soviet Union and was making one of his earliest public appearances in the United States. Gromov gave a brilliant and inspiring lecture, but it was entirely spoken. At the end of the lecture, only a single symbol had been written on



**Top—1984,
middle—1998,
bottom—1999.**

the blackboard, a large script V (for manifold, in the French style [*variete*]). Professor Chern rose—he was master of ceremonies for the occasion—after the vigorous applause and thanked Gromov for his remarkable lecture and then said, with the tact and gentleness of which he was a master, “Would you mind writing down just one theorem for us?”

While I had been at the Courant Institute, in the fall of 1969, another mathematician had arrived at Berkeley, not as a visitor but as a new graduate student. Berkeley had many graduate students, and new arrivals were not always much noticed. But Yau was an exception. I hope it will embarrass neither Wu nor Yau to quote from a letter that Wu sent me in New York soon after Yau arrived as a student. Wu wrote “A young man has arrived from China who I believe will change the face of differential geometry.”

Few prophecies can have been more farsighted. I was surprised at the time, but Wu’s remarkable words turned out to be simple truth. Only six years later, while Yau was visiting UCLA, in the autumn of 1976, occupying the office next to my own, he met me one day in the corridor next to our offices and said “I have finished the proof of the Calabi conjecture. Would you like to look at it?” I still have the same office, and I think of this often as I come to work in the morning, of being on a landmark location for mathematics, the place where the whole direction of a subject suddenly changed and a new set of possibilities for mathematics was revealed. (If California were Germany, there would be a plaque or perhaps a statue!)

The new generation for geometry had indeed arrived. And yet, one thinks still of Professor Chern. And after all, the Calabi conjecture is about Chern classes. Generations pass and new ones arrive, but great mathematics is eternal.

Wen-ling Huang and Karin Reich

Shiing-Shen Chern in Hamburg Hamburg University and Wilhelm Blaschke

Hamburg University was founded in 1919. Its initial faculty consisted of Wilhelm Blaschke (1885–1962, geometry), Erich Hecke (1887–1947,

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We sincerely thank Udo Simon for suggesting that we write this essay for the Notices of the AMS on Chern’s studies in Hamburg. A long version in the Chinese language has appeared in Mathmedia 35, no. 2 (2001), Taipei.

analysis), and Johann Radon (1887–1956, applied mathematics). In 1922 Emil Artin (1898–1962) joined the Mathematical Seminar. With these four extraordinary mathematicians on staff, Hamburg University became an excellent center of mathematics [5].

Wilhelm Blaschke enjoyed travel. In 1932 he traveled around the world and visited China. In Peking, Blaschke gave lectures on “Topological questions in differential geometry”, and Shiing-Shen Chern (1911–2004) was in the audience. At the same time, Blaschke recommended Emanuel Sperner (1905–1980) as a guest professor in Peking. As a result, Emmanuel Sperner became a professor at National Peking University, where he stayed for two years.

Chern later recalled these first meetings with Blaschke, that he was immediately impressed by Blaschke’s insistence that mathematics be a lively and intelligible subject [1, 2]. When a fellowship was offered to him in 1934 to study abroad, Chern decided to go to Hamburg.

Chern as a Student in Hamburg 1934–1936



S. S. Chern, 1934, in Hamburg (source: Chern Institute of Mathematics at Nankai University).

Chern enrolled in Hamburg University on October 19, 1934. He wanted to earn his doctorate and to become a teacher. He stayed in Hamburg until 1936. Chern was not the only Chinese student studying mathematics in Germany at that time. Chiuntze C. Tsen (1898–1940), for example, was a student of Emmy Noether (1882–1935) in Göttingen.

Chern at the Mathematical Seminar in Hamburg and His Friendship with Erich Kähler. When the Third Reich began, many things changed. Famous universities such as Göttingen, Berlin, and Frankfurt lost many of their best mathematicians. And the young Hamburg University became the leading mathematical center in Germany. Blaschke, Hecke, and Artin got support from Erich Kähler

(1906–2000). Blaschke and Kähler traveled together to Moscow in 1934, where Kähler met Élie Cartan (1869–1951). During this journey, Kähler finished his book *Introduction to the Theory of Systems of Differential Equations*, which contained the later-named “Cartan-Kähler theorem”. Chern participated in the celebration of the publication of Kähler’s book. All the mathematicians present received a free copy of the work. Chern developed a good relationship with Kähler, and they met frequently for discussions. Blaschke sometimes joined them.¹ Chern also attended lectures by Artin, Blaschke, Hecke, the astronomer Richard Schorr (1867–1951), and the sinologist Fritz Jäger (1886–1957).

Chern recalled later that the contents of Kähler’s lectures were very difficult and that student attendance declined constantly. At the end, Chern was the only remaining participant. When Kähler was a prisoner of war in France in the years 1945–1947, he wrote to Chern asking him for books and tea.² Chern sent him many books, so Kähler was able to continue his work. Chern stated later that Kähler was like a teacher to him. During a meeting in 1999 Kähler said that Chern was like a brother to him [3, p. 17]. In October of 1979 Chern sent his *Selected Papers* to Kähler with the personal dedication: *Herrn Professor Kähler, mit lieblicher Verehrung, Chern Oktober 1979.*

Chern’s Thesis. On November 7, 1935, Chern submitted his graduation proposal. The thesis title was “Eine Invariantentheorie der Dreigewebe aus r -dimensionalen Mannigfaltigkeiten im R_{2r} ”. Blaschke reported the following [6]:

Several geometers like Reidemeister and Thomsen have treated the 3-webs of curves and the figures connected with these. I had found out that these figures may be transferred to surface webs in the four-dimensional space. It was Mr. Chern’s task to investigate these webs, which are even attractive when they are considered from the axiomatic point of view. At first Mr. Chern had studied the difficult theory of partial differential equations due to Élie Cartan. By means of this theory he was able to solve a broad range of problems, achieving very beautiful results. I hold this work to be *very good*.

¹[4, p. 861], [3, p. 17], *conversation with Charlotte Kähler in 2010.*

²*Charlotte Kähler retains a copy of this letter.*

Chern’s Relationship to Hamburg after Graduation

For Chern’s postdoctoral work Blaschke suggested to him either to stay in Hamburg and work with Artin on number theory or to go to Paris and work with Élie Cartan. He decided on Paris [2, p. 6]. Even after Chern had left Hamburg, he stayed in close contact with Blaschke by letter. One letter, still in Blaschke’s estate, is dated July 20, 1949:

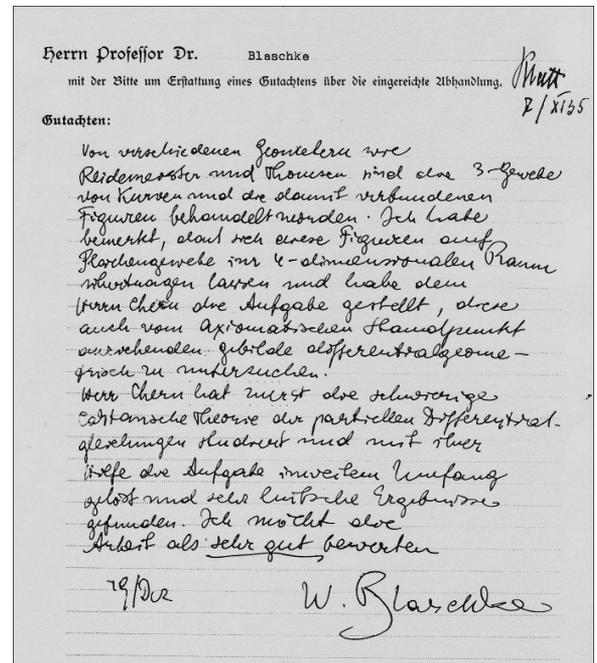


Figure 2. Blaschke’s report on Chern’s thesis [6].

Dear Mr. Chern,

I was very pleased by your letter of July 15 and by the news that you became a professor in Chicago at the Eckhart Hall, which I know. So you still have the possibility to continue successfully your work in mathematics. [...]

In 1971 Hamburg University awarded Chern an honorary doctorate. On July 14, 1972, a Festkolloquium in honor of Chern took place in Hamburg, where Chern himself, Wilhelm Klingenberg from Bonn, and Kurt Leichtweiss from Stuttgart delivered talks. Chern’s talk was “The mathematical works of Wilhelm Blaschke” [1].

In the 1980s Chern carried on intensive correspondence with Walter Benz (1931) regarding editing Blaschke’s collected works. Benz was Sperner’s successor at the Mathematical Seminar and the chairman of the Wilhelm Blaschke Memorial Foundation. On May 17, 1981, Chern traveled to Hamburg to aid in the work. He also delivered a talk at his “old university”.

On September 6 and 7, 1985, one week before Blaschke's 100th birthday on September 13, 1885, the 100th anniversary colloquium for Blaschke took place in Hamburg. Mrs. Blaschke and the members of Blaschke's family, Chern and his wife, Kähler and his wife, and many others took part in the ceremony. Chern's talk was titled "On the geometry of webs". Chern visited Erich Kähler and his wife Charlotte in Hamburg during his two visits to that city in 1981 and 1985.

On April 30, 2001, the Wilhelm Blaschke Memorial Foundation of Hamburg decided to award the Blaschke Medal to Chern. In October 2001 Chern also received an honorary doctorate from the Technical University of Berlin in a ceremony in Tianjin.

Acknowledgments

We would like to thank the following people for their help: Christina Ahrens, Walter Benz, May Chu, Paul Chu, Roland Höfer, Charlotte Kähler, Eckart Krause, Alexander Kreuzer, Mike Lemke, Honghai Lv, Rainer Nicolaysen, Elena Roussanova, Sabine Simon, Udo Simon.

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Lizhen Ji

Seeking Roots: My Academic Grandfather Professor S.-S. Chern

My grandfather passed away when I was too young to speak, and I could not remember anything about him. I also never had the chance to talk to my academic grandfather Shiing-Shen Chern. It was only six years after he passed away that I first visited the Chern Institute of Mathematics at Nankai University,¹ established by my academic grandfather.

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¹*The Chern Institute of Mathematics was originally called "Nankai Institute of Mathematics" and changed to the*

Certainly I have heard many things about Professor Chern: a star was named after him, there are three major awards for mathematicians named after him, and after he died, thousands of students and nonacademics mourned for him.

I have also heard of Chern classes, Chern-Simons theory, Chern-Moser theory, and his intrinsic proof of the Gauss-Bonnet formula. These are great achievements for a great mathematician. As my academic father, Professor Shing-Tung Yau, said in his summary *Chern's Work in Geometry*:

It's fair to say that Élie Cartan is the grandfather of differential geometry and S.-S. Chern is the father of modern differential geometry. Together they have created a beautiful and rich subject that has reached out to every branch of mathematics and physics. Right before he died, Chern said that he is going to see the great Greek geometers. There is no doubt that he had reached the same status as these great geometers.

There must be something else that made him loved by many different people and allowed him to achieve so much in mathematics and within the mathematics community. I wanted to know more about my academic grandfather and, in doing so, discover more about my mathematical roots.

The great Benjamin Franklin wrote a classic autobiography so that his descendants could learn of his struggles and successes and acquire the keys to happiness. Unfortunately, I could not find an autobiography written by Professor Chern. Instead, I found an interview of his published in the *Notices of the AMS* in 1998. Two memorable quotes from this interview include "I don't think I have big views. I only have small problems" and "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."

I asked myself, are these really candid and fair statements? I was intrigued by them. I wanted to find out more about Professor Chern. What I found is that he is second to none with respect to many things, and he had a grand vision for the development of Chinese mathematics and the confidence to carry out important initial steps for this purpose. For example, he started the Chern Institute of Mathematics in 1985 for the whole country of

current name on December 3, 2005, in memory of Professor Chern.

China and secured the necessary funding when China was not as rich as now. Before he died, he was working furiously on a famous long-standing open problem in complex geometry.

He was also a very sentimental and caring person. He was a romantic, pragmatist, and idealist all wrapped into one. Yes, he lived for math and also died for math, but he led a very rich life that encompassed many different aspects.

I asked myself, how should I begin to seek my mathematical roots? In early June 2010, I went to UC Berkeley for a conference. During the first morning there, I crossed a small creek that separates the University faculty club and Evans Hall (the math department), and I wondered what I could find out about my academic grandfather. After all, this is where he helped build one of the best geometry groups in the world and spent over thirty years of his prime mathematical life. There must be things that remind one of his presence and glories during those years. I searched in and outside the building. Yes, the campus around Evans Hall is beautiful, but I could not find traces of him. Time has washed away many things. Maybe only mathematics lasts forever and is the best testimony to the achievements of mathematicians. I was disappointed, and people told me that MSRI should have some materials about him. Unfortunately, I was then reminded that MSRI was closed only during this period for yearly maintenance. This was bad luck and very disappointing.

Then it occurred to me that I should go and visit Nankai University. This is where Professor Chern's math career began and ended. He was an undergraduate in Nankai, returned later in life to work intensively on a famous open problem in geometry, and passed away while still struggling to resolve the problem. It was certainly a very special place for him. I wondered if there were things there that tell stories of his life. What contributed to the thoughts of his youth and his reflections and longings near the end of such a glorious life?

Among the three math institutes he established, the Nankai Institute of Math (or Chern Institute of Math) was the last and probably the most dear to Professor Chern.

I decided to visit Nankai on July 28 and talk with people who had worked with Professor Chern to develop the institute and ask them questions regarding all aspects of his life. Much has been mentioned of his mathematical achievements, but I wanted to learn more about him as a human being and about his nonmathematical life. What I found deepened my respect for him and opened my eyes to a lively and charming man.

Going to Nankai

I got up very early on the morning of July 28, hoping to maximize my time at Nankai University. After a slow taxi ride from Tsinghua University to the

Beijing South train station and a train ride to Tianjing, I arrived at the Chern Institute of Mathematics quite early. The deputy manager of the office, Ms. Li Hongqin, was waiting for me at the entrance. I showed her the digital voice recorder and camera I bought for this trip and insisted that I was better prepared this time. She smiled. I had met her last year during a workshop in Nankai, and we also talked about Professor Chern at that time.

She took me directly to the director of the Chern Institute, Professor Long Yiming. When I entered his spacious office, what caught my eye immediately was an elegant plant on the coffee table. This is the first time I entered an office of a professor at the Chern Institute, and I was impressed.

A Great Mathematician and Diplomat

I asked Professor Long what he remembered most about Professor Chern. He said that one unique thing about Chern was that his abilities were not limited to mathematics but that he was also a great diplomat because of his charming and noble character. Establishing such an institute in 1985 and building a huge new building required dealing with people at many levels. For example, convincing top leaders in the central government of China to generously support the math institute was no small task.

He continued that the program of academic years Professor Chern started in 1985 has had a great impact on Chinese mathematics.² Most well-known Chinese mathematicians had been trained in these programs. This can be counted among Professor Chern's great contributions to Chinese math. It was one of the first attempts to include both Chinese and Western mathematicians. Convincing distinguished speakers to come and give lectures was not easy. For example, in 1985, some very distinguished Chinese mathematicians came and spent the whole year in Nankai preparing students for more advanced topics to be presented by experts from the West. Leaving home for one year is a nontrivial matter. Furthermore, everyone came and worked peacefully and willingly together for the same goal. This shows Professor Chern's great leadership. I asked him what Professor Chern's secret was. Professor Long said that since Professor Chern's achievements in math were admired by many people, naturally he had great influence in the mathematics community at large. More importantly, his charming and noble character and skill in dealing with people made him a truly exceptional character among great mathematicians. Yes, indeed there are many great

²*In each academic year, there is a major theme, with various activities supporting this theme. This is the reason for the name "academic year" program.*

mathematicians, but it is not easy to find a great mathematician who is also a great diplomat.

This point of view was also emphasized by Professor Chern's colleague at Berkeley, Hung-Hsi Wu: "He (Professor Chern) was a man of great leadership, notable for unique diplomatic skills that made him an outstanding administrator."

The current building for the Chern Institute is magnificent. It is one of the largest math institutes that I've seen. On the left side of the entrance, there is a couplet in honor of Professor Chern, composed by S. T. Yau, Professor Chern's academic son.

I wondered how they could secure the funding to build it. Professor Long said that Professor Hu Guoding probably knew more about the details. My next stop was to visit Professor Hu Guoding. Before I left, Professor Long warned me that Professor Hu may not have the energy to speak with me for more than half an hour, due to a serious car accident he had a few years ago.

How the Chern Institute Was Started

Professor Hu was an old friend of Professor Chern's and was the second director of the Chern Institute. He was one of the key figures in developing the Chern Institute and also secured much of the funding necessary for the main buildings. I prepared a list of questions to ask during this trip, but for Professor Hu, my list was not necessary. He said "Let me start to tell you about the Chern Institute and Chern, and you can ask some questions later." Due to the car accident, he could not move much in his sofa, but his voice was strong. He was full of energy and talked for over an hour. Those exciting years brought back dear memories of his work with Professor Chern to organize the institute program of academic years.

I listened and listened, wishing to hear more. Ms. Lin Hongqin, who accompanied me, became worried that the continuous talking might tire Professor Hu, and the meeting soon ended.

At the beginning, Professor Hu said that it should be made clear that everything was done by Professor Chern. After the Cultural Revolution, the state of Chinese mathematics was in ruins. Professor Chern encouraged Hu and other Chinese mathematicians by saying that they should be on equal footing with Western mathematicians. There was no reason why they could not participate at the international level. There were two options to train young Chinese mathematicians: send them abroad to study in the West, or gather the best Chinese students in one location and invite leading experts from around the world to give lectures. Chern felt that the second option was more practical and a better deal. The idea of such an academic program at Nankai was proposed. Using his influence, Professor Chern invited speakers from the West, and the best Chinese mathematicians and students were selected to participate.

During this process, a problem was looming in the background. The foreign experts could stay in hotels, but they also needed office space. More importantly, housing was needed for the Chinese participants. They needed money for new buildings, but the funding was limited. Professor Chern told Professor Hu not to worry and these problems would find solutions.

In the early 1980s the ministry of education encouraged universities to reform their localized approaches, i.e., to open their resources and share with developing universities. Few places were actually doing this. Professor Hu mentioned one example. One physics department obtained funds for a lab by claiming that this lab would be shared with other universities. They then declared that the lab would be used by their department during the daytime and that other departments could use the lab at night.

During a dinner with the minister of education, Chern explained the vision and goals of the program of academic years to train young Chinese mathematicians from the entire country. The minister told Chern that he and his fellow administrators were really "reforming and opening up". The ministry of education gave special funds to construct a building used to house the participants during the first academic year, 1985.

After ten years of the successful program of academic years, the Chinese math community was much bigger and stronger than before. Professor Chern admitted to Professor Hu that Chinese mathematics still had a long way to go. In order to transform China into a "big" country of mathematics, the Math Institute should have an impressive building with better facilities. Professor Hu then talked about how through his personal connection with former President Jiang, he was able to convey Professor Chern's dream and secured funding for the current math building. Before the liberation, Hu was a Communist Party member and the leader of the student union of Shanghai Jiao-Tung University. President Jiang was also an active member of the union.

Professor Long invited me for lunch and was waiting for me at the restaurant. He did not expect my meeting with Professor Hu to last as long as it did.

Chern's Life at Nin Yuan (His House in Nankai)

After lunch Ms. Li took me to meet Mr. Hu Delin, Professor Chern's former driver and private secretary. Hu Delin was probably the person closest to Professor Chern in Nankai. In fact, after the death of Professor Chern's wife in 2000, Hu played a very special role in his daily life. So I put forward a general request: tell me about Professor Chern's everyday life.

We talked for nearly an hour and a half, and he told me many unforgettable things about Chern. Probably the most touching moment came when he started to cry. Hu said that Professor Chern was such a good person. His sobbing voice and hands trying to cover his tears will stay in my memory forever. I will describe several stories Hu told me.

a) Chern's Wife

Chern's wife died in January of 2000. Chern went back to California in April to settle her affairs and then moved to China permanently in August.

According to Hu, he could see visible changes in Chern after he came back. Chern told him that there was no one he could talk to anymore, and people could not understand him. Hu sometimes tried to comfort him and said, "You have experienced other difficult things in life and time will ease things." Professor Chern asked Hu how he could forget sixty years of life together, and there was no one that could replace her.

Sixty years is an important cycle and certainly a long time for a marriage. It certainly represents deep commitment and a lifetime love. I asked Hu if Professor Chern had ever talked about his marriage and how he met and courted his wife.

Hu told me that when Chern went to Tsinghua University, his future father-in-law was a professor of mathematics there. C. N. Yang's father was also a professor of mathematics at Tsinghua, and both faculty members recognized Chern's talent and potential. They often invited Chern to their house parties, allowing ample opportunity for Chern and his future wife to meet. After Chern came back from Europe and went to the Southwest United University, the marriage of the couple came to fruition.

Hu said that Professor Chern was a very devoted and caring person. In his heart, he had a place for everyone in his life. He always remembered people who had passed through his life. Even after seventy years, memories could instantly come back to him. Hu said that Professor Chern had probably never forgotten the people he met.

Hu shared the following story with me. I think it shows Professor Chern's sincere nature and his kind and thoughtful heart.

b) An Unexpected Visitor on a Cold Day

It was a very cold day in December 2002. There was a knock on the front door of Chern's house at Nankai. Hu opened the door and saw a stranger. The stranger told him that he wanted to see Professor Chern. Hu was surprised. According to the rules of the Math Institute and Nankai University, any person who wanted to see Professor Chern should either be invited or go through the Math Institute first for approval. Thus, Hu denied the visitor. The stranger said, "Wait! I have a picture of Professor Chern when he was young." In this picture, Professor Chern was surrounded by mem-

bers of two families. The visitor explained the situation.

When Professor Chern was in Nankai attending college, his mother had a very good friend (a kind of sister) who lived nearby. The neighbor had two daughters. The older one was about Professor Chern's age. The two families were talking about marrying Professor Chern, the oldest son in his family, to the oldest daughter of the other family. After Professor Chern went to Tsinghua and then Europe, the potential for marriage was not discussed further. The picture showed the members of both families.

The stranger, Mr. Shen, was a son of the older sister. His mother had died six years earlier, but the younger sister never married and lived with her nephew. During and after the ICM 2002, there were many newspaper articles and television reports about Professor Chern. The younger sister learned that her old neighbor (Chern) worked in Nankai University. She asked her nephew to go and look for Professor Chern. Mr. Shen said that if Hu mentioned the name of his mother and aunt, Professor Chern would remember them.

After hearing this story, Hu thought that Mr. Shen should probably see Professor Chern. He told Mr. Shen to wait in the reception room and took the picture to Professor Chern. Hu repeated the story and showed Professor Chern the picture. Professor Chern said that he did remember the people in the picture and asked for the visitor's age. When Hu told him that he was about sixty, Professor Chern immediately said that Mr. Shen could not be in the picture since he was too young. Hu was amazed that after seventy years, Professor Chern could remember all these things clearly and instantly.

Professor Chern immediately asked Mr. Shen to come upstairs and inquired about his family. Later, he visited the home of Mr. Shen and the younger sister. They lived in a poor building. The heating was provided by a coal stove. Professor Chern immediately offered to buy them an electric heating unit. The little sister refused at first. Professor Chern said that even though he was not rich, he had more money than she and could help her, and then he elaborated on the dangers of using coal heat. Professor Chern also offered to pay for the electricity necessary to run the heater. From then on, Professor Chern invited the younger sister and her family to come to his house once a month to have a meal and chat. Near the end of each year, Professor Chern also gave them some money.

c) Professor Chern as a Kind Person

Hu commented that Professor Chern valued friendship. For example, one reason he came to Nankai to start a math institute was that he had several classmates from college working at Nankai.

Not only was Professor Chern nice to his relatives and friends, but he was also very kind to

everyone around him. Many bigshots may not bother with such things, but not Professor Chern.

Here are two stories that depict his good nature. After he came back to Nankai in August 2000, Professor Chern had to use a wheelchair. Two nurses were hired to take care of him. Before he died, Professor Chern said to the director of the Math Institute and other university officials that if it were possible, he hoped that the Math Institute could find jobs for the two nurses in the event they wanted to stay in Nankai. Hu said that they both currently work for the Chern Institute.

After Professor Chern died, his daughter May Chu came and told Hu that her father asked her to give some money to every staff member at Nin Yuan (his house at Nankai). Professor Chern arranging gifts for people who worked around him after he died; this really touched me. Hu said that Professor Chern always thought of others and was such a good person. As he said this, he started to cry. It was a very touching moment. Even now as I am writing this paragraph, my eyes moisten. It is difficult not to love such a caring person regardless of their achievements in math.

d) Professor Chern's Diplomatic Skills

Hu also said that Professor Chern knew how to handle people and situations in a very diplomatic and smooth manner. He mentioned the following incident.

The 2002 ICM was certainly an important event in China, and Professor Chern contributed much to its successful opening in Beijing. He played a prominent role throughout the congress. Many reporters requested a press conference with him. As a kind person, he could not say no, even though he had a severe cold. On the fourth day of the congress, he had an open hour before lunch but was booked with important meetings during the afternoon.

Many reporters asked questions, and Professor Chern answered them patiently, even though some were repeated. It was getting late and he had to leave, but the questions kept on coming. How could he solve this problem? Hu became worried. Professor Chern said that it was not a problem and he would handle it. He turned to the reporters and said "You have asked me many questions. Now it is my turn to ask you a question. If you can answer my question, then you can ask more. Here is my question. There have been many different theories about the cause of death of the famous historian, Sima Qian. Could you tell me a new theory about his death?" The reporters were stunned, and no one could answer. Chern then said, "After you find an answer, you can come to Nankai and ask me more questions."

Hu once told Professor Chern that he would make a good politician. He said, "Yes, I can do it,

but I don't want to do it. I don't want to fight with people in those kind of places."

Professor Chern's diplomatic skills were also confirmed by Lv Honghai, the office manager at the Chern Institute. On the way back to the train station, Lv chatted with me. I asked him how he would best characterize Professor Chern. Lv said that Professor Chern was very patriotic, much more than many people who spent their entire lives in China. I asked Lv for a story about Professor Chern, and he told me the following.

During banquets in China, seating arrangements are important, especially determining who will sit at the main table. Professor Chern always disliked this. Once there was a major event with many important guests. They could not all sit at the main table. How can one solve this delicate problem? Professor and Mrs. Chern came up with a good solution. They assigned a number to each table. At the entrance, Mrs. Chern held a bag containing numbered pieces of paper and with a smiling face, told guests that they were to take a piece of paper and sit at the table with the corresponding number. What an original and interesting way to solve an otherwise embarrassing and difficult problem!

d) Professor Chern's Final Days at Nankai

Professor Chern told Hu that it was a good thing that the ICM was held in 2002. If it were scheduled for 2003, it would probably be postponed due to SARS. Nevertheless, the virus affected the final stage of Professor Chern's life.

Hu mentioned that during the SARS pandemic, Nankai University was very concerned about Professor Chern's health. Before the outbreak, the two nurses replaced each other after a full twenty-four-hour shift. During the pandemic, each nurse stayed with Professor Chern for one month. Before changing shifts, the nurses were subject to a thorough physical examination. The nurse on duty lived in the upstairs quarters and could come down only to fetch Professor Chern's meals. Hu could talk to Professor Chern only over the phone from downstairs.

After a while, Professor Chern became upset. He told Hu "You are putting me into a prison" and demanded "I want you to come upstairs right away and talk to me!"

Professor Chern was very busy at other times with visitors and invitations to conferences. Now he had some free time to work on a famous open problem in differential geometry: the nonexistence of complex structures on S^6 . According to Hu, Professor Chern had already worked on this in the 1970s.

After much work, he wrote up a preliminary version of his paper. In a conference held in Nankai during August of 2004, some gaps were found. This was a blow to Professor Chern. Some tried to convince him to halt work on this problem. Several

mathematicians told Hu that such a problem was not for a person over ninety, or even fifty, and that only young people could try to work on it. Professor Chern was stubborn, and he told Hu that there were gaps in his methods, but he believed that he could solve it.

Hu was worried about Professor Chern's health. Even though there was a nurse present at all times, Hu also stayed and lived upstairs to make sure that everything went accordingly.

Professor Chern could not sleep well in those times. He needed sleeping pills to fall asleep. Every night Professor Chern would get up around one o'clock in the morning and ask the nurse to help position him in a sofa with a small table in front. Then he would do computations with pencil and paper.

Professor Chern's health deteriorated fast. Some discouraged his late-night hours, but he was persistent. Sometimes he lost his temper toward those who tried to convince him not to work. Professor Hu thought it possible that Professor Chern sensed his life coming to an end, and he felt the need to resolve this long-standing problem.

After a very successful and long life, Professor Chern died on December 3, 2004.

Hu also commented that Professor Chern led a very simple life. His oldest shirt was thirty years old, and his newest was over ten years old. When he received the Shaw Prize in September 2004, his daughter bought him a new shirt for the award ceremony. Hu said that Professor Chern donated three cars to the Chern Institute, and all these came out of his savings.

Concluding Remarks

Before I left Nankai, I wanted to take some pictures of the entrance of Nin Yuan, Professor Chern's house.

Standing there, I was thinking about what a great academic grandfather I had. He had achieved so much in math and in life. He was such a well-balanced person and had led a full and rich life. Until his last days, he was still trying to solve a famous problem: the nonexistence of complex structures on S^6 is not a small problem at all!

During the trip, I was hoping to find more about the roots of Professor Chern's mathematics and his secrets to success. Instead, I heard many stories about him as a normal human being: a caring, sentimental, considerate person well liked by many people. Maybe these are the qualities that made him stand out among the great mathematicians.

I wondered if he had some other dreams and longings in the last years of his life and how he thought of his life in his youth. I wished that I could have a chance to talk to such a charming, interesting, and kind person, as a grandson with his grandfather.

Acknowledgments

I would like to thank Professor S. T. Yau, Professor Yang Lo for suggestions on how to make this trip fruitful, Professor Long Yiming for giving me the chance to talk to various people and his hospitality during the trip, and Professor Hu Guoding for the unforgettable conversation in spite of his health condition. I would also like to thank Ms. Li Hongqin, Mr. Lv Honghai, and Mr. Hu Delin for their conversations and help with the trip. The detailed stories from Mr. Hu Delin were especially appreciated. Finally I would like to thank Patrick and Julee Boland for reading a preliminary version of this article carefully and making many helpful suggestions which greatly improve this article.

Jun Li

Read Classical, Chern Told Us

It was during my junior year that I first learned Chern classes. I consider this my first academic acquaintance with Chern. During this period of time, I studied extensively the characteristic classes, Chern's treatment of Chern classes, and Chern classes and Riemann surfaces. To a student who was anxious in setting a foot in research mathematics, I felt a great reverence for the name Chern.

I first met him when I was a graduate student at San Diego. He gave a lecture in the department, and he came to the welcome party hosted by Yau. With many students of Yau, I was present at the party. I still vividly recall that Chern asked the name of and chatted briefly with each of us students; his wife put down our names in her small notebook.

It was in the early 1990s during the year I visited MSRI that I began to meet and chat with him regularly. I was present at many lunches and dinners Chern hosted for his colleagues and friends; I visited him and his wife many times during my stay in MSRI. This tradition of visiting him whenever I got a chance continued even after he moved to China.

It is my privilege to have had many occasions, while my wife and his wife sat at the kitchen table, to have sat with Chern on his teak couch chatting. The topics usually began with my explaining to him my research interests, then his telling me the stories of many of his contemporaries. Once on hearing that I came back from Oberwolfach, he told me that the treasure of Oberwolfach was its library, where much classical mathematics literature was on open shelves. He told me several times, "it is important to read original writing of great mathematicians," followed by, "have you?"

Over the years, I began to regret that I had not followed more on his advice. The ideas of great

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minds are timeless. We may have moved to more elaborate and sophisticated mathematical tools and languages; however, the new developments usually are rooted in the classical mathematics, where simplicity and insights are most treasured.

An example is Chern's introduction and treatment of the Chern class, an idea of timeless beauty.

Ernest Kuh and Y. Ron Shen

Remembering Our Dear Friend Professor S.-S. Chern

On behalf of Chern's Chinese colleagues in Berkeley, we offer in this short article a tribute to our most respected elder and dear friend; his life in Berkeley; his impact on our lives. Besides his scientific prowess and his distinguished work in geometry, Chern was a wonderful individual of culture who always inspired people around him, especially the young. Yet he was a very modest person. Despite his status, he was never intimidating. He and Mrs. Chern always enjoyed getting together with acquaintances. Over the years we enjoyed our friendship and good times with them. We also learned a lot from his wisdom.

Chern came to Berkeley from Chicago in 1960. There were very few faculty of Chinese origin at Berkeley in the 1960s, and Chern soon became a leader and known to everyone in the local Chinese community. Because of his pleasant personality and vast knowledge of Chinese culture and history, he naturally attracted everyone around him. He served as a bridge between the young and the old generations (famous among them are Y. R. Chao in linguistics, S. H. Chen in Chinese literature, and T. Y. Lin in civil engineering and architecture). He had very broad interests outside mathematics, ranging from culture and literature to history and politics. Conversation with him never had a dull moment. He was a most welcomed person in any social function. Before long we discovered that he also enjoyed good food. He easily made friends with chefs, waiters/waitresses, and owners of restaurants, especially the Chinese restaurants. When we went out with him to any restaurants we always got special treatment.

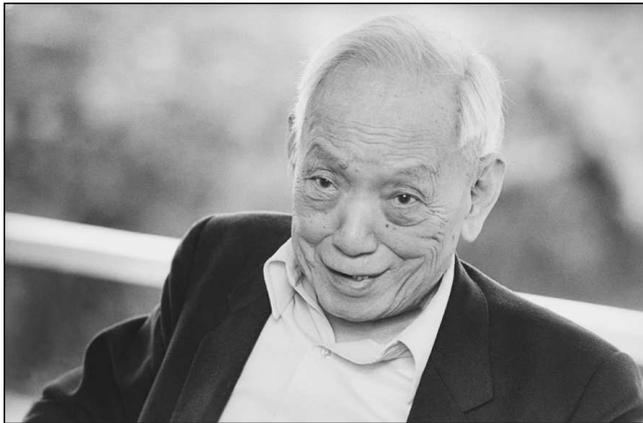
Chern attracted many visitors to Berkeley. They were not necessarily his friends and students in mathematics. Among them were C. N. Yang and T. D. Lee, the famous theoretical physicists who

won the Nobel Prize in 1957. Yang and Lee consider themselves former students (at the Southwest United University during World War II) and dear friends of Chern. They would always come to pay him respect whenever they happened to be in the San Francisco Bay area. Jin Yong, the famous writer of Chinese martial arts novels, was Chern's admirer and presented him with a complete set of autographed volumes of his novels that Chern had enjoyed reading.

In 1972 when President Nixon opened the door to China, almost immediately Chern followed. Many of us also visited China in the following year or two. The whole nation was crazed about China at that time. Conversation topics in our circle naturally also focused on topics on China. Chern had many old friends in China and was most informative about China. Again he was very much the center of our gathering. The Berkeley Chinese community in the meantime became more active and organized. A faculty group of Chinese origin started regular social dinner parties, and the Cherns were among the most enthusiastic members of the group. Toward the late 1970s, numerous Chinese delegations visited Berkeley. The Cherns often served as the local hosts, welcoming them at their beautiful El Cerrito home overlooking the San Francisco Bay and the Golden Gate Bridge. Meanwhile, his life also changed somewhat as the United States started to allow Chinese students and visitors to come for long-term stays. Chern became busier and naturally received many requests for research supervision. He was the first faculty member to welcome long-term researchers and students from China to Berkeley. Chern officially retired from Berkeley in 1979 but was as busy as ever after retirement. He co-founded the NSF Mathematics Science Research Institute (MSRI) in 1981 and served as its founding director. The famous MSRI located on top of the Berkeley hill has attracted generations of visitors in various fields of mathematics. After stepping down from the directorship in 1984, he immediately assumed the founding directorship of the Mathematics Institute at Nankai University in Tianjin, China. Ever since the opening of China, he had sensed his responsibility to help the development of mathematical science in China. He strongly believed that China could become a nation superb in mathematical science. Nankai University is his undergraduate alma mater, and he would use his influence to help Nankai form a world center in mathematics. His early proposal to establish a math institute in China at Nankai University was warmly received by the Chinese leaders, who provided the needed budget, and by the university with a new building. As expected, soon after the Institute was set up, many established mathematicians around the world flocked to Nankai, making Nankai

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S.-S. Chern during an interview for the *Notices* in 1998.

instantly a mathematics center for scholarship and research.

Born and educated in China, Chern loved his native country. He was willing to do anything to serve the country. He remembered well the Japanese invasion and atrocities in China before and during World War II. So when the overseas Chinese organized the strong movement in 1971 protesting against the Japanese occupation of the Diao Yu Dai Islands, he was among the notables who signed the open letter in the *New York Times* calling on President Nixon “to take appropriate measures to ensure the Chinese sovereignty over these islands.”

In the 1980s Chern had more time to pursue his other interests besides mathematics. During our social gatherings he talked about what he recently learned on the early history of the Tsing dynasty, how the queen grandmother, Xiao Zhuang, of the early emperor, Kang Xi, contributed through her influence on the emperors to the most prosperous period of the dynasty. He even wrote an article on this that was published in the Chinese *Journal of Biographical Literature*. He became more interested in physics and relations between physics and mathematics. He was very much intrigued by the surprisingly close connection

between the Chern-Simons theory and the Yang-Mills theory. He borrowed books to learn about Feynman path integrals. He was extremely proud of the 1987 discovery of his son-in-law, Paul Chu, on high-temperature superconductors that created a huge splash in physics. He would certainly be very happy to learn that the well-known Chern class and Chern number have emerged as common words in theoretical physics in recent years. Chern also became more keenly interested in politics and in China.

As the years went by, more dinner parties were organized, some small and some large. We became closer to him and Mrs. Chern, having frequent meals together at each others' homes. The Cherns actively resumed contacts with their old friends in China and warmly welcomed them at their home, and they helped to take care of their siblings who visited the United States. As a matter of fact, one of us (YRS) is indebted to the Cherns for meeting his wife, Hsiaolin, at the Cherns' house for the first time. Hsiaolin is the daughter of one of his old friends in China and had come to the Berkeley area to study after the Cultural Revolution. The Cherns' house was her home away from home during holidays. We remember well the happiest party for everyone who attended the wonderful event of the Cherns' sixtieth wedding anniversary at the East Ocean Restaurant in Emeryville. The whole front room was packed by their families and friends. When Chern stood up to thank everyone, he was obviously very excited. He talked at length about his life but then forgot to acknowledge his wife, Shining, to whom he was always appreciative for having supported him so well throughout the years. Someone in the audience wanted to remind him, shouting “where is the bride?”

Starting in late 1970s, the Cherns visited China very often. He was a towering figure and commanded great respect, certainly no less than Yang and Lee, in China. He was a person the leaders of the Chinese government and universities were always anxious to consult. He was received by the top leaders, including Vice Premier Deng Xiaoping and President Jiang Zemin, every time he visited China.

With the families of Chern's son and daughter far away, independent living became more difficult for the old couple, despite the fact that all their friends were more than willing to help. On the other hand, life in China seemed attractive since it could be much easier with hired helpers readily available. In late 1999 they finally decided to move back and settle in Nankai University, Tianjin. The university built a house on campus for them and made sure that they received all the care they needed to enjoy the campus life. Chern was delighted to have again a life surrounded by students and young colleagues.

One of Chern's great assets was being able to easily interact with others. He was particularly helpful to the young faculty through such frequent interactions. This happened in Berkeley and in Nankai. He was an extremely modest person in spite of his towering reputation. He could inspire others in a casual conversation and in a seemingly very natural manner. We all learned a great deal from him, especially on being a person and on the philosophy of life.

We visited him and Mrs. Chern a few times at Nankai. They were apparently happy with their life in China, having more occasions to meet with old acquaintances and more opportunities to interact with young students and colleagues. Almost immediately, Chern became one of the most famous persons in Tianjin. The mayor and party secretary of the city would come to his house to pay him respect every year. Once during our visit, he happily mentioned that his bronze head figure would soon be placed in the city park with the other famous Tianjin citizens. He clearly enjoyed his status in China. Our last visits were shortly before he passed away (Kuh's in the summer of 2000 and Shen's in October 2004). We had dinners at his house, where his chef and servant served a wonderful meal, and we had a very pleasant time. Even in October 2004, he looked very healthy and was in a very good mood to talk. He mentioned he was looking forward to the visit of C. N. Yang the following week. He talked about his recent happy reunion with his friend of seventy years ago and showed us the poems they had written on the occasion. There was no sign that his body would soon give up.

We have lost a giant in science and will miss a great friend in life.

I. M. Singer

Reprinted from *S. S. Chern: A Great Geometer of the Twentieth Century*, International Press, Boston 1998.

Last term I gave some extra evening lectures to my class in geometry and quantum field theory. The younger graduate students needed the geometric background for gauge theories. I happily talked about connections on fiber bundles, curvature, characteristic and secondary characteristic classes. I reviewed the many excellent treatments but finally followed Chern's classic "Geometry of characteristic classes". I urged the class to study this short, concrete, elegant, and deep paper.

Rereading it brought back vivid memories of Chern's course at the University of Chicago in 1949–50. Differential forms were not well known

then. In fact, a year earlier, André Weil had introduced us to differential forms in a seminar (for graduate students and faculty) in which he recast the calculus of several real variables in the language of forms. Barely familiar with Grassman algebras, students in Chern's course were amazed and intrigued at Chern's effective use of forms in local and global geometry.

Because I was writing a dissertation at the time, I was a passive participant in the many student discussions, trying to understand and absorb the material in Chern's lectures. However, a year later at M.I.T., Warren Ambrose was eager to learn differential geometry. He organized a seminar in which I lectured on my notes of Chern's course. Like many others, I struggled with Chern's "Let p be a point and dp its differential" and finally understood how convenient a notation it was for the identity map and its differential.

My recent evening lectures reminded me of our seminar over forty years ago held in the same room—with blackboards on three walls. We filled all the blackboards with the definition of a connection. We hadn't yet learned to first expose the properties of principle bundles and of Lie groups. Chern does that very neatly in the paper cited above. Only long experience has taught me how much goes into making deep ideas simple, as Chern did. To quote him, "This train of ideas is so simple and natural that its importance can hardly be exaggerated." Under Chern's influence, both Ambrose and I taught courses in differential geometry at M.I.T. Others did the same elsewhere. Books were written and the subject flourished. I need hardly dwell on what we all know: Chern introduced global differential geometry to American mathematics, as well as the use of differential forms in a host of subjects. Geometry is harder to define than most mathematical disciplines. Whatever it is, Chern showed us for half a century how to do differential geometry. Each time we met, he showed me something new—and I wish I had been a more attentive student. Why didn't I listen more carefully to his discussion of Bäcklund transformations, or his exposition of Finsler geometry?

In time, Chern's course and Ambrose's seminar had their effect. I switched from functional analysis to global geometry. My present interest is in quantum field theory. Because the ideas of interest in physics are geometric, I continue to be immersed in global geometry. In fact, what's missing in physics is some quantized version of geometry that we only dimly perceive in string theory.

I have emphasized Chern's scientific influence. His personal influence has been just as strong. He was very encouraging and gentle with students and younger colleagues. And he ran conferences or institutes with the same directness and elegant simplicity as in his papers.

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It was a privilege to know Chern and his wife, Shih Ning, as friends. In fact it was fun—I can recall the many Chinese restaurants, famous or fancy, in which we discussed mathematics, politics, family, and life.

In my view, Chern was one of the great figures in twentieth-century mathematics.

Alan Weinstein

Almost every differential geometer is in some way a student of Chern. I had the honor and pleasure of being one of his “official” students, as well as his colleague. Chern’s role in creating a world-famous department at Berkeley is amply documented in Calvin Moore’s book, *Mathematics at Berkeley: A History* (A K Peters, 2007), so I will confine myself here to some personal remarks.

As his student, I learned, of course, much about differential geometry, though I realized only many years later how much I had learned. But I also learned, and gained, many other things from having been Chern’s student.

I learned how to listen. I was always amazed by how much time Chern seemed to find for me across a desk covered with papers. I would go in and tell him what I was doing. He listened, asked me questions, and gave some advice and lots of encouragement.

A degree from Chern was a ticket into the wider mathematical world. In 1967 I finished my thesis a few months before the end of the spring semester. Chern was a visitor at IHES at the time, and he arranged for me to be invited there, though I was officially still a student. This was the beginning of two lifelong relationships—with France, particularly the mathematical life in Paris, and with my wife Margo, to whom I was married in Orsay. Shortly before our wedding that May, Professor and Mrs. Chern invited us to dinner in Paris at la Méditerranée, a favorite restaurant of Jean Cocteau, where we had a wonderful meal. As with Chinese meals with Chern, when we went back there later without him, it was not the same.

As a student of Chern, I got to ride on his coattails as a descendant of everyone from whom he was descended. Nowadays, we can find all the names at the website of the Mathematics Genealogy Project. Chern was a student of Wilhelm Blaschke, who was a student of Wirtinger. Skipping back for a few generations, we find Möbius, before him Pfaff; going forward from Pfaff, we come to a mathematical great, great, ...uncle: Gauss.

Genealogy goes forward as well as backward, and it is again to Chern that I owe some of my own

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best students, including a series of graduates of Peking University. In 1983 I went to Beijing for the fourth in a series of meetings on differential geometry and differential equations, initiated by Chern to improve relations between Chinese and foreign mathematicians as China opened up to the outside world after the Cultural Revolution. There I met Jiang-Hua Lu, an undergraduate student of Qian Min. Qian had earlier come to Berkeley as Chern’s guest; since I was Chern’s student, he felt quite confident in sending to me not just Lu but eventually five students in all.

Despite the widespread use of genealogical terminology in academia, it is only some advisors who provide a real feeling of “family” among their students. With Chern it was a privilege to feel like part not only of his mathematical family but of his immediate family as well. His wife Shi-Ning’s hospitality at home was renowned, as was Chern’s reputation at the Chinese restaurants of the San Francisco Bay Area, where he seemed to know all the best chefs.

My wife, our daughter Asha, and I had the privilege in 1999 of being the Cherns’ guests at a fine restaurant near the West Lake in China. Chern described it as one of Chairman Mao’s favorite resorts; although he was no fan of Mao, he was not immune to the importance of such a designation. But, like the ancient Master,¹ who “acts without doing anything and teaches without saying anything”, Chern had a very different style. His kind and subtle but firm leadership set an example which remains as an essential part of his legacy.

Joseph A. Wolf

Recollections of Professor S.-S. Chern

I met Chern when I was a fourth-year undergraduate at the University of Chicago. In 1955 I took Chern’s course on differentiable manifolds and Riemannian geometry. It was tough going because the course was rigorous and my background was weak. At one point he called me into his office, asked me how old I was (I had just turned nineteen), asked me what I’d published (nothing), showed slight but definite disapproval, and told me that it was better to start publishing when you are young. Then he told me to read Whitney’s paper on real analytic embeddings and explain it to the class. Doing that, I had my first hint of what it was to understand mathematics in an active way. I continued on as a grad student at Chicago and took courses in geometry and Lie

¹*From the Tao te Ching, translation by Stephen Mitchell, Harper and Row, 1988.*

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theory from Chern, Spanier, Kaplansky, Reinhart, Palais, and Helgason. In the meantime Chern gave me informal “homework” problems, e.g., work out the structure equations and sectional curvature for hypersurfaces obtained by rotating graphs. Then, with Chern’s active encouragement, I helped organize a seminar on Riemannian symmetric spaces.

At that time the math department at Chicago was a fairly small place. There was a lot of social interaction between grad students, visitors, and faculty. In my second year as a grad student I started thesis work with Chern, and my wife Lois and I were often invited to social events at the Cherns’. I remember one such event—a buffet dinner—where everyone took chopsticks, except that Chern took a fork, explaining that it was more efficient.

Chern directed me to the papers of Preissmann and Hadamard, and soon I was working on Riemannian curvature and the structure of manifolds that satisfy various curvature conditions. I decided to solve the Clifford-Klein spherical space form problem for my thesis, but Chern gently let me know that I didn’t know enough finite group theory to do that. So instead I pushed some of the then-available information about spherical space forms from spheres to some other Riemannian homogeneous spaces. This involved some Lie group theory, and at the time Chern was not fond of Lie groups, so he sent me to Princeton for a few days to talk to Borel—who, to my relief, approved of my efforts and made some useful suggestions.

Early in the 1958–59 academic year, Chern told me that he would spend the following year in Paris and would not return to Chicago. Instead, he would go to Berkeley starting in fall 1960, and I should go to Berkeley as a grad student in fall 1959 to redo language exams, qualifying exams, residency requirements, and so forth. It seemed to me that it would be more interesting to finish my thesis and follow Chern to Paris, and Lois agreed, so that worked out. The gracious hospitality of the Cherns, and Chern’s suggestions for getting around in the Sorbonne and the École Polytechnique, were very helpful. Also, and this certainly smoothed the way for me, Chern introduced me to André Weil, Henri Cartan, Jean Dieudonné, Charles Ehresmann, Armand Borel, Jacques Tits, Friedrich Hirzebruch, Georges de Rham, and André Lichnerowicz as a colleague. (Weil and Dieudonné already knew me as a student, and it was quite something to be reintroduced to them as a colleague.)

I spent 1960–61 and 1961–62 at the Institute in Princeton. There most of my work was on Riemannian and pseudo-Riemannian homogeneous spaces, and I also had a lot of correspondence with Chern. In 1962, with Chern’s encouragement and support, I came to Berkeley. Here in Berkeley the geometry-topology group was extremely active and cohesive, both mathematically and socially,

and everyone gave parties and dinners. In 1964 I followed Chern’s indirect advice to learn enough finite group theory to settle the Clifford-Klein spherical space form problem. My calculations didn’t all agree with some results in Zassenhaus’s thesis, so I first thought that I had it wrong, but Chern had been in Hamburg when the errors were found in Zassenhaus’s thesis, and Zassenhaus had promised (but never published) a correction. With that information and encouragement from Chern, I completed Zassenhaus’s thesis and settled the space form problem.

In the late 1960s and 1970s Berkeley was very political, and at the same time the field of differential geometry was fragmenting, so Chern’s geometry group became less cohesive. Chern moved toward PDE, Hsiang toward transformation groups, and Wu toward potential theory. I was moving more and more into the representation theory of semisimple Lie groups. Then in the 1980s and 1990s Chern’s interests were focused more and more on his Nankai Institute. As a result we saw each other less often, and then mostly in the math department. My last mathematical contact with Chern was when he and David Bao had just finished their book on Finsler spaces. Chern suggested that I look at the structure of Finsler symmetric spaces, starting with Berwald symmetric spaces. This was a remarkable insight because it turned out that, as homogeneous spaces, they were the same as Riemannian symmetric spaces. Unfortunately Chern passed away before I could tell him the result of his suggestion. To me, Chern’s passing was the loss of a great colleague, friend, and mentor.

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The connection between mathematics and art goes back thousands of years. Mathematics has been used in the design of Gothic cathedrals, Rose windows, oriental rugs, mosaics and tilings. Geometric forms were fundamental to the cubists and many abstract expressionists, and award-winning sculptors have used topology as the basis for their pieces. Dutch artist M.C. Escher represented infinity, Möbius bands, tessellations, deformations, reflections, Platonic solids, spirals, symmetry, and the hyperbolic plane in his works.

Mathematicians and artists continue to create stunning works in all media and to explore the visualization of mathematics--origami, computer-generated landscapes, tessellations, fractals, anamorphic art, and more.

A mathematician, like a painter or poet, is a maker of patterns. If his patterns are more permanent than theirs, it is because they are made with ideas.

—G. H. Hardy,
A Mathematician's Apology

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2009 Mathematical Art Exhibition



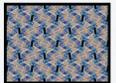
The Mathematical Art Exhibition held at the 2009 Fathauer was the curator of the exhibition, and along with Nat Friedman and Reza Sarhangi. Mathematical Society and the Mathematical A (32), 2006." Second Prize to Carlo Séquin, for No. 1, 2008." The Prize "for aesthetically pleasing to the American Mathematical Society by an a mathematicians expressed in a visual art form. T

Crocheted Lorenz Manifolds



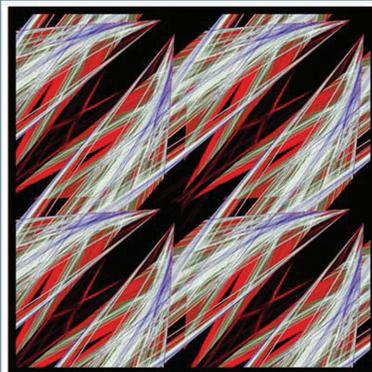
Dr. Hinke Osinga and Professor Bernd Krausk (Engineering Mathematics, University of Bristol) have turned the famous Lorenz equations into a beautiful real-life object, by crocheting computer-generated instructions of the Lorenz manifold.

Mike Field : Realizations



An aspect of my art work that I particularly enjoy is that I write the software for all the programs I use and build the computers that run the software. In this sense, I like to feel that theory (mathematics), art (outcome), software (algorithms) and engineering (hardware) are integrated and interdependent and that no part survives without the others.

—Mike Field



"InHoPursuit", by Mike Field (University of Houston)



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Descriptive Classification Theory and Separable Banach Spaces

Christian Rosendal

Three Notions of Classification

Consider your favorite class of mathematical structures, be it groups, modules, measure-preserving transformations, C^* -algebras, Lie groups, smooth manifolds, or something completely different. With some probability, the classification problem for these objects, that is, the problem of determining the structures up to some relevant notion of isomorphism, is, or has been, one of the central problems of the corresponding field of study.

Of course, inasmuch as mathematical theories stem from attempts to model or organize physical or other phenomena, the classification problem might not be the primordial challenge. But once the basic theorems of a theory have been worked out, there is often an internal motivation to categorize its different models.

For example, the definition of a Banach space as a complete normed vector space is motivated by the study of function spaces as the potential solution sets to various differential equations modeling physical phenomena. But, as is known to all of us, the common aspects of the individual problems often simplify through abstraction, whence the concept of an abstract Banach space. And therefore having an isomorphic classification of Banach spaces would certainly be helpful when dealing with more concrete problems involving these spaces.

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Without doubt, one the most gratifying examples of classification is that of finite simple groups. In this case, we have a catalogue or explicit listing of all isomorphism types of finite simple groups, something we certainly cannot hope for in all other classes of mathematical objects. So with finite simple groups as our paragon, an optimal classification of some class \mathcal{A} of mathematical structures up to a corresponding notion of isomorphism would seem to be an explicit listing of all isomorphism types of \mathcal{A} -structures, plus perhaps some reasonable algorithm or procedure for deciding the isomorphism type of each \mathcal{A} -structure.

In order to better understand what we mean by an isomorphic classification, we must first make the distinction between the isomorphism types and the concrete instances or realizations of these. It is the latter that we wish to classify. For example, by a *classification* of finitely generated groups, we understand some abstract procedure that given two presentations of finitely generated groups decides whether these are presentations of the same group up to isomorphism, i.e., if they are instances of the same isomorphism type. From our perspective, the isomorphism types themselves are abstract platonic objects that can be grasped and concretely manipulated only in special instances, namely, when the isomorphism relation is “smooth” and thus the types correspond to points in a sufficiently nice topological space (we shall come back to this later).

With this in mind, we can, with some amount of simplification, distinguish at least three notions of classification:

- An explicit listing of all isomorphism types of elements of \mathcal{A} .

- A classification of the objects of \mathcal{A} via an assignment of complete invariants.
- A determination of the “irreducible” or “prime” \mathcal{A} -objects.

Assigning to every object $X \in \mathcal{A}$ a complete invariant from another class of mathematical objects \mathcal{B} would ideally mean a function $\phi: \mathcal{A} \rightarrow \mathcal{B}$ such that two \mathcal{A} -objects X and Y are isomorphic if and only if $\phi(X) = \phi(Y)$. However, this holds only if we consider the \mathcal{B} -objects as *isomorphism types*. Thus, to avoid presupposing that we already understand the isomorphism types of \mathcal{B} -objects, we see that the right formulation is rather that $\phi: \mathcal{A} \rightarrow \mathcal{B}$ should be *isomorphism invariant*, i.e.,

$$X \cong Y \Rightarrow \phi(X) \cong \phi(Y),$$

and *complete*, i.e.,

$$\phi(X) \cong \phi(Y) \Rightarrow X \cong Y.$$

Prominent examples of classification by complete invariants include the Elliot classification of approximately finite-dimensional C^* -algebras via their dimension groups and the Ornstein classification of Bernoulli shifts by their entropy.

The third type of classification sometimes can lead to complete classification results, provided that any \mathcal{A} -object can be uniquely represented in terms of its irreducible or prime components. But, oftentimes, one can hope only to isolate the irreducible parts without an actual reconstruction of the full object from these. We shall return to this later in the article in connection with Banach spaces.

Parametrizations and Standard Borel Spaces

When parametrizing a class of mathematical objects, we choose a particular method of presenting these and then regard the totality of such presentations. For example, the finitely generated groups can be parametrized by infinite tuples

$$G = \langle a_1, a_2, \dots, a_n \mid w_1 = 1, w_2 = 1, \dots \rangle,$$

where a_1, \dots, a_n is a distinguished set of generators and $w_i = w_i(a_1, \dots, a_n)$ are group words in these generators listed in some canonical way. An only slightly different way of presenting such G would be as quotients of the free group \mathbb{F}_∞ on the alphabet a_1, a_2, \dots by normal subgroups $N \trianglelefteq \mathbb{F}_\infty$ such that $a_n \in N$ for all but finitely many n . So, the set \mathcal{G} of these special normal subgroups of \mathbb{F}_∞ can be seen as a parametrization of the class of finitely generated groups. The space \mathcal{G} is called the *space of finitely generated groups* and has some very interesting properties making it a particularly well-behaved model. In particular, if $\text{Aut}_f(\mathbb{F}_\infty)$ denotes the group of automorphisms ϕ of \mathbb{F}_∞ such that $\phi(a_n) = a_n$ for all but finitely many n , then $\text{Aut}_f(\mathbb{F}_\infty)$ is countable. Also, if $N, M \in \mathcal{G}$, then the two groups \mathbb{F}_∞/N and \mathbb{F}_∞/M are

isomorphic if and only if for some $\phi \in \text{Aut}_f(\mathbb{F}_\infty)$ we have $\phi[N] = M$. In other words, the relation of isomorphism between quotient groups \mathbb{F}_∞/N for $N \in \mathcal{G}$ is induced by the countable group $\text{Aut}_f(\mathbb{F}_\infty)$ acting on \mathcal{G} (C. Champetier (2000)).

A convenient framework for dealing with classification problems is that of Polish and standard Borel spaces.

Definition 1. A topological space (X, τ) is said to be *Polish* if it is separable and its topology can be given by a complete metric on X .

A measurable space (X, \mathfrak{B}) , i.e., a set X equipped with a σ -algebra of subsets \mathfrak{B} , is said to be *standard Borel* if there is a Polish topology τ on X with respect to which \mathfrak{B} is the class of Borel sets.

In the latter case, the sets in \mathfrak{B} are called the Borel sets of X .

For example, the space \mathcal{G} of finitely generated groups can be made into a standard Borel space by equipping it with the σ -algebra generated by sets of the form

$$\{N \in \mathcal{G} \mid g \in N\},$$

where g varies over elements of \mathbb{F}_∞ .

Another example, which will figure prominently here, is that of separable Banach spaces. By the Banach-Mazur theorem, any separable Banach space embeds linearly isometrically into the space $C([0, 1])$ of continuous functions on $[0, 1]$. Thus one way of parametrizing separable Banach spaces is as the set \mathcal{SB} of closed linear subspaces of $C([0, 1])$. Of course, there are other equally natural parametrizations, for example, any separable Banach space X is linearly isometric to a quotient of ℓ_1 by a closed linear subspace $Y \subseteq \ell_1$, and hence we can use the set $\mathcal{SB}(\ell_1)$ of closed linear subspaces Y of ℓ_1 as another parametrization. In order to make these sets into standard Borel spaces, we equip them with the *Effros Borel structure*, which is the σ -algebra generated by the sets of the form

$$\{X \in \mathcal{SB} \mid X \cap U \neq \emptyset\},$$

respectively

$$\{X \in \mathcal{SB}(\ell_1) \mid X \cap U \neq \emptyset\},$$

where U runs over the open subsets of $C([0, 1])$, respectively of ℓ_1 . However, it is a fact that these two models are equivalent in the following precise sense: There is a Borel isomorphism $\phi: \mathcal{SB} \rightarrow \mathcal{SB}(\ell_1)$, i.e., an isomorphism of measurable spaces, such that any $X \in \mathcal{SB}$ is linearly isometric to $\ell_1/\phi(X)$. This is just one instance of the empirical fact that different, but natural, parametrizations of the same class of mathematical objects are equivalent. So it is not too important which specific parametrization one is working with, though, of course, certain computations might be more easily performed in one

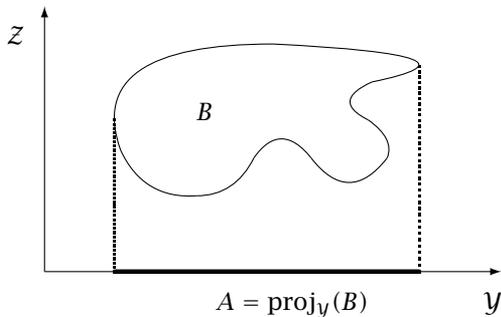


Figure 1. Projections.

model than in another. Therefore, we can think of \mathcal{G} and \mathcal{SB} as the standard Borel spaces of finitely generated groups, respectively separable Banach spaces, even though \mathcal{G} and \mathcal{SB} themselves are of a very different nature from groups or Banach spaces.

There are admittedly limitations to the classes of mathematical objects that admit standard Borel parametrizations. For, as the underlying Polish topology of a standard Borel space is Hausdorff and admits a countable basis for its topology, any standard Borel space has cardinality at most 2^{\aleph_0} . In fact, by a result of K. Kuratowski, all uncountable standard Borel spaces are isomorphic to \mathbb{R} equipped with its algebra of Borel sets. So we cannot model classes having too many objects. The ones that do admit standard Borel parametrizations are mostly either classes of countable algebraic and combinatorial objects (groups, rings, graphs, ...) or separable topological and analytical objects (algebraic subvarieties of \mathbb{C}^n , compact smooth manifolds, measure-preserving transformations, complete separable metric spaces, ...).

Once we have constructed our standard Borel space (X, \mathcal{B}) , we can go on to the isomorphism relation itself. For example, in the case of \mathcal{G} , we see that the relevant notion of isomorphism is not that of isomorphism \cong between $N, M \in \mathcal{G}$, but rather isomorphism between the quotients \mathbb{F}_∞/N and \mathbb{F}_∞/M . So let

$$NEM \Leftrightarrow \mathbb{F}_\infty/N \cong \mathbb{F}_\infty/M.$$

Then E is an equivalence relation on \mathcal{G} induced by an action of the countable group $\text{Aut}_f(\mathbb{F}_\infty)$ and hence has countable classes. Moreover, E is a Borel subset of the standard Borel space $\mathcal{G} \times \mathcal{G}$. However, in general, the corresponding isomorphism relation might not be Borel, though most often it is *analytic*.

Definition 2. Let $(\mathcal{Y}, \mathcal{B})$ be a standard Borel space. A subset $A \subseteq \mathcal{Y}$ is said to be *analytic* if there is a standard Borel space (Z, \mathcal{C}) and a Borel subset B

of $(\mathcal{Y} \times Z, \mathcal{B} \otimes \mathcal{C})$ such that

$$y \in A \Leftrightarrow \exists z \in Z (y, z) \in B.$$

In other words, a set is analytic if it is the projection of a Borel set (see Figure 1).

A very useful way of thinking of Borel and analytic sets, which is now known as the Kuratowski-Tarski algorithm, is in terms of the quantifier complexity of their definitions. Thus Borel sets are those that can be inductively defined from open sets in the underlying Polish topology by using only quantifiers over countable sets, while analytic sets are those that can be defined using quantifiers over countable sets and a single positive instance of an existential quantifier over a standard Borel space.

As an example, recall that two Banach spaces X and Y are said to be *isomorphic* if there is a bounded, bijective, linear operator $T: X \rightarrow Y$ (whereby T is a linear homeomorphism). Let F denote the relation of isomorphism between elements of \mathcal{SB} . We can construct a standard Borel space Z of isomorphisms $T: X \rightarrow Y$ between closed linear subspaces of $C([0, 1])$ such that the set

$$B = \{(T, X, Y) \in Z \times \mathcal{SB} \times \mathcal{SB} \mid T \text{ is an isomorphism between } X \text{ and } Y\}$$

is Borel. So as

$$XFY \Leftrightarrow \exists T \in Z (T, X, Y) \in B,$$

we see that F is analytic as a subset of $\mathcal{SB} \times \mathcal{SB}$.

While it is easy to see that any Borel set is analytic, not every analytic set is Borel. For example, the relation F above is not Borel (B. Bossard (1993)).

We now have the necessary framework to formulate the abstract concept of classification by complete invariants.

Definition 3. Let E and F be analytic equivalence relations on standard Borel spaces X and Y , respectively. We say that E is *Borel reducible* to F , in symbols $E \leq_B F$, if there is a Borel measurable function $\phi: X \rightarrow Y$ such that for all $x, x' \in X$,

$$xE x' \Leftrightarrow \phi(x) F \phi(x').$$

When

$$E \leq_B F \leq_B E,$$

E and F are said to be *Borel bireducible*, $E \sim_B F$, and when

$$F \not\leq_B E \leq_B F,$$

we write $E <_B F$.

The partial preorder \leq_B of Borel reducibility between analytic equivalence relations should be understood as a relative measure of complexity, so that if $E \leq_B F$, E is simpler than F .

In particular, a Borel reduction ϕ of the relation E of isomorphism defined on \mathcal{G} to the relation F of isomorphism on \mathcal{SB} can be seen as a Borel

assignment of separable Banach spaces to finitely generated groups as complete isomorphism invariants. While, as we shall see, there is such a reduction, there is no reduction the other way, i.e., $E <_B F$. So in terms of complexity, the isomorphism relation between separable Banach spaces is strictly more complex than that of isomorphism between finitely generated groups. And there is no way of using the latter as complete invariants (at least in a Borel manner) for isomorphism of separable Banach spaces.

The requirement that the reduction be Borel corresponds to a requirement that the assignment of invariants be somehow explicit. In particular, one sees that there are both 2^{\aleph_0} finitely generated groups and 2^{\aleph_0} separable Banach spaces up to isomorphism, so, by simple cardinality considerations, one easily gets non-Borel reductions in both directions. However, as assignments of invariants these are of little practical use, and indeed only one of the reductions can be made Borel.

Analytic Equivalence Relations

The notion of Borel reducibility was introduced independently by H. Friedman-L. Stanley (1989) and L. A. Harrington-A. S. Kechris-A. Louveau (1990) as a distillation of ideas originating in model theory and operator algebras. Since its inception, many prominent classification problems have been considered in this light in order to determine their relative complexity with respect to the Borel reducibility ordering. For example, in ergodic theory, two of the grand successes have been the classification by P. R. Halmos and J. von Neumann (1942) of the measure-preserving automorphisms with discrete spectrum and D. S. Ornstein's classification of Bernoulli shifts by Kolmogorov and Sinai's notion of entropy (1970).

Though certainly the deeper of the two, Ornstein's theorem is actually easier to understand, so let us consider this first. Suppose p_1, \dots, p_n are positive real numbers such that $\sum_{i=1}^n p_i = 1$ and give the set $\{1, \dots, n\}$ the distribution $\vec{p} = (p_1, \dots, p_n)$, which makes it into a probability space. We then equip $\Omega = \{1, \dots, n\}^{\mathbb{Z}}$ with the product probability measure and define a measure-preserving automorphism S of Ω as the bilateral shift

$$\begin{aligned} S(\dots, x_{-2}, x_{-1}, x_0, x_1, x_2, \dots) \\ = (\dots, x_{-1}, x_0, x_1, x_2, x_3, \dots). \end{aligned}$$

The system (Ω, S) is called a *Bernoulli shift*, and its *entropy* is defined to be the real number

$$h(\Omega, S) = - \sum_{i=1}^n p_i \log p_i.$$

We say that two Bernoulli shifts (Ω, S) and (Ω', S') given by distributions $\vec{p} = (p_1, \dots, p_n)$ and $\vec{q} = (q_1, \dots, q_m)$ are *measurably conjugate* if there is

an isomorphism of measure spaces, $T: \Omega \rightarrow \Omega'$, such that

$$S = T^{-1} \circ S' \circ T.$$

A. N. Kolmogorov and Ya. G. Sinai showed that entropy is an invariant for Bernoulli shifts, i.e., that measurably conjugate Bernoulli shifts have the same entropy. On the other hand, that entropy is a complete invariant was discovered by Ornstein, who showed that two Bernoulli shifts (Ω, S) and (Ω', S') with the same entropy, $h(\Omega, S) = h(\Omega', S')$, are measurably conjugate. Moreover, it is easy to see that the entropy function ϕ defined on the standard Borel space of Bernoulli shifts is Borel and so ϕ is a Borel reduction of conjugacy of Bernoulli shifts to the equivalence relation $=_{\mathbb{R}}$ of equality on the set of real numbers.

We say that an analytic equivalence relation E on a standard Borel space X is *smooth* if E is Borel reducible to the relation $=_{\mathbb{R}}$, i.e., if there is a Borel function $\phi: X \rightarrow \mathbb{R}$ such that

$$xEy \Leftrightarrow \phi(x) = \phi(y).$$

What makes the smooth equivalence relations particularly tangible is that, in this case, the quotient space, X/E , is Borel isomorphic with an analytic set, and hence the E -classes can be identified with points in a standard Borel space. For nonsmooth E , on the other hand, the space X/E has no reasonable measurable structure. So the smooth equivalence relations, such as conjugacy of Bernoulli shifts, are especially simple and, in the literature on operator algebras, are usually singled out as those that are *classifiable*. However, we shall avoid that terminology here, as some archetypical examples of classification are in fact of nonsmooth isomorphism relations.

An example of this is the Halmos-von Neumann theorem. A measure-preserving automorphism T of $[0, 1]$ has *discrete spectrum* if there is an orthonormal basis of eigenvectors for the associated unitary operator U_T on $L_2([0, 1])$ defined by $U_T(f) = f \circ T$. The Halmos-von Neumann theorem states that two discrete spectrum transformations are measurably conjugate if they have the same spectrum. So, in other words, the spectrum, which is a countable subset¹ of $S^1 = \{z \in \mathbb{C} \mid |z| = 1\}$, is a complete invariant for conjugacy of discrete spectrum measure-preserving automorphisms. However, there is no *canonical* way of enumerating a countable subset of S^1 (the reader is invited to try to construct such an enumeration of an arbitrary countable subset of \mathbb{R} and see why this fails). In fact, being able to uniformly choose an enumeration of each countable subset of S^1 relies essentially on a weak version of the Axiom of Choice. So it is impossible for this choice to

¹In fact, a countable subgroup.

be Borel. The best we can do is let E_{set} be the equivalence relation on $(S^1)^\mathbb{N}$ defined by

$$(x_n)E_{\text{set}}(y_n) \Leftrightarrow \{x_1, x_2, x_3, \dots\} = \{y_1, y_2, y_3, \dots\},$$

i.e., (x_n) and (y_n) are E_{set} -equivalent if they enumerate the same set. Then E_{set} is a Borel equivalence relation and is actually Borel bireducible with conjugacy of discrete spectrum measure-preserving automorphisms. However, $=_{\mathbb{R}} <_B E_{\text{set}}$ and so E_{set} is nonsmooth.

As we see from the above examples, it is useful to have a catalogue of various more combinatorial examples of analytic equivalence relations with which we can compare concrete classification problems. For example, E_{set} is much easier to handle directly than conjugacy of discrete spectrum measure-preserving automorphisms. One such combinatorial example that has long been considered in the literature on operator algebras is the relation E_0 of eventual agreement of infinite binary sequences, i.e., for $(x_n), (y_n) \in \{0, 1\}^\mathbb{N}$, we set

$$(x_n)E_0(y_n) \Leftrightarrow \exists N \forall n \geq N x_n = y_n.$$

While it is easy to Borel reduce $=_{\mathbb{R}}$ to E_0 , a simple measure-theoretic argument shows that there is no reduction in the other direction: First let μ be the product probability measure on $\{0, 1\}^\mathbb{N}$ given by the distribution $(\frac{1}{2}, \frac{1}{2})$ on $\{0, 1\}$. By Kolmogorov's zero-one law, any Borel subset of $\{0, 1\}^\mathbb{N}$ that depends only on the tail of its elements, i.e., which is E_0 -invariant, must either have μ -measure 0 or 1. So suppose toward a contradiction that

$$\phi: \{0, 1\}^\mathbb{N} \rightarrow \mathbb{R}$$

is a Borel function such that

$$(x_n)E_0(y_n) \Leftrightarrow \phi((x_n)) = \phi((y_n)).$$

Then if $\{I_n\}$ is a listing of all open intervals of \mathbb{R} with rational endpoints, we see that each $\phi^{-1}(I_n) \subseteq \{0, 1\}^\mathbb{N}$ only depends on the tail of its elements and hence has μ -measure 0 or 1. Letting A be the intersection of all $\phi^{-1}(I_n)$ and $\{0, 1\}^\mathbb{N} \setminus \phi^{-1}(I_n)$ of measure 1,

$$A = \left[\bigcap_{\mu(\phi^{-1}(I_n))=1} \phi^{-1}(I_n) \right] \setminus \left[\bigcup_{\mu(\phi^{-1}(I_n))=0} \phi^{-1}(I_n) \right],$$

we have $\mu(A) = 1$, while ϕ must be constant on A . But, as any E_0 -class is countable and hence of measure 0, there are $(x_n), (y_n) \in A$ that are E_0 -inequivalent, while $\phi((x_n)) = \phi((y_n))$. This contradicts the assumptions on ϕ , and so E_0 is nonsmooth.

Other examples are the relation E_1 defined on $\mathbb{R}^\mathbb{N}$ in a similar fashion by

$$(x_n)E_1(y_n) \Leftrightarrow \exists N \forall n \geq N x_n = y_n,$$

and the relation E_{ℓ_∞} also defined on $\mathbb{R}^\mathbb{N}$ by

$$(x_n)E_{\ell_\infty}(y_n) \Leftrightarrow \exists K \forall n |x_n - y_n| \leq K.$$

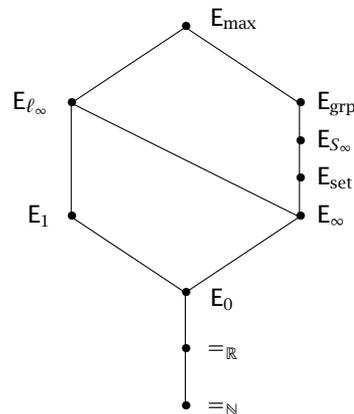


Figure 2. Significant examples of analytic equivalence relations under Borel reducibility.

As $=_{\mathbb{R}}$, we can of course also define $=_{\mathbb{N}}$, which is the equality relation on \mathbb{N} . The relationship between these and other equivalence relations is most easily visualized in a diagram with the simplest relations at the bottom (see Figure 2).

The remainder of the relations in Figure 2 have more complex descriptions, namely, E_∞ is the orbit equivalence relation induced by the shift action of \mathbb{F}_2 on the space $\{0, 1\}^{\mathbb{F}_2}$ of subsets of \mathbb{F}_2 , and E_{S_∞} is the \leq_B -maximum isomorphism relation between countable algebraic structures, which can, e.g., be realized as the isomorphism relation between countable groups. Similarly, E_{grp} is the equivalence relation \leq_B -maximum among all orbit equivalence relations induced by an action of a Polish topological group, while E_{max} is the analytic equivalence relation maximum in the Borel reducibility ordering.

Other examples of classification problems, or more precisely isomorphism relations, Borel bireducible with the relations of Figure 2 are the isomorphism relation between torsion-free Abelian groups of rank 1, which is bireducible with E_0 ; Lipschitz isomorphism of compact metric spaces, which is bireducible with E_{ℓ_∞} ; and isometry of separable, complete metric spaces, which is bireducible with E_{grp} . If one instead considers finitely generated algebraic structures, the complexity of the corresponding isomorphism relation decreases and will be Borel reducible to E_∞ . For example, isomorphism of finitely generated groups is bireducible with E_∞ .

Dichotomy Theorems for Borel Reducibility

The continuum hypothesis, as proposed by G. Cantor, is the statement that every infinite subset of the real line is in bijective correspondence with either \mathbb{N} or \mathbb{R} . In the first attempt at proving the hypothesis, Cantor showed that any closed subset

of \mathbb{R} is either countable or contains a homeomorphic copy of the Cantor space $2^{\mathbb{N}}$, which is itself of cardinality equal to that of the continuum. Somewhat later, P. S. Alexandrov and F. Hausdorff (1915) independently extended this result to include all Borel subsets of \mathbb{R} , and again this was extended by M. Y. Souslin (1917) to the class of analytic subsets of \mathbb{R} . However, after this, further development stalled for some time, due to the failure to prove a similar result even for sets that are complements of analytic sets, called *co-analytic sets*. Similarly, other regularity properties that had been established for analytic sets, such as Lebesgue measurability, could not be verified for more complex *projective* sets, i.e., those defined from the Borel sets by iterated complementations and projections.

N. Lusin (1925) made serious, but fruitless, attempts at deciding whether any uncountable coanalytic set is of the power of the continuum and showed enormous prescience by declaring

Les efforts que j'ai faits pour résoudre cette question m'ont conduit à ce résultat tout inattendu: *il existe une famille admettant une application sur le continu d'ensembles effectifs telle qu'on ne sait pas et l'on ne saura jamais si un ensemble quelconque de cette famille (supposé non dénombrable) a la puissance du continu, s'il est ou non de troisième catégorie, ni même s'il est mesurable.*

That is, "one does not know and one will never know [of the uncountable projective sets] whether or not they are all of the power of the continuum."

His bold contention was corroborated by K. Gödel's development of the *constructible universe* L (1938), a model of set theory in which the continuum hypothesis holds true, but in which there are non-Lebesgue measurable projective sets and so-called *thin* coanalytic sets, i.e., uncountable coanalytic sets not containing a homeomorphic copy of $2^{\mathbb{N}}$. With P. J. Cohen's introduction of the method of forcing (1963), it was realized that one can construct thin coanalytic sets of size \aleph_1 in models of set theory where $|\mathbb{R}| > \aleph_1$ and so even coanalytic sets can be counterexamples to the continuum hypothesis.²

In line with the feeling that the continuum hypothesis should hold for explicitly defined sets in analysis, R. L. Vaught conjectured (1961) that any first-order theory T in a countable language has either at most countably many countable non-isomorphic models or, alternatively, a continuum

of such. The conjecture remains open now after close to fifty years, but the strongest partial result was proved by M. Morley (1970), who showed that any first-order theory T in a countable language has either at most \aleph_1 countable nonisomorphic models or a continuum of these. Morley's theorem can be formulated in a stronger way once we notice that the set of models of T with underlying domain \mathbb{N} can be made into a standard Borel space \mathfrak{M}_T on which the relation of isomorphism \cong is an analytic equivalence relation. The theorem then states that either there are only $\aleph_1 \cong$ -classes on \mathfrak{M}_T or there is an uncountable Borel set $A \subseteq \mathfrak{M}_T$ of pairwise nonisomorphic models (and hence continuum many by the theorem of Alexandrov and Hausdorff).

In view of Vaught's conjecture and Souslin's result for analytic sets, it is natural to ask simply if for any analytic equivalence relation E on a standard Borel space X there are either countably many E -classes or an uncountable Borel set $A \subseteq X$ of E -inequivalent points. However, this is easily seen to be false by considering the following example: Let $X = \{0,1\}^{\mathbb{Q}}$ be the space of all subsets of \mathbb{Q} and define an analytic equivalence relation E on X by setting

$xEy \Leftrightarrow \langle \iota_x \text{ and } \iota_y \text{ are isomorphic well orderings, or neither } \langle \iota_x \text{ nor } \langle \iota_y \text{ is well ordered.}$

Then E has \aleph_1 equivalence classes: a class corresponding to the subsets of \mathbb{Q} of order type ξ for every countable ordinal $\xi < \aleph_1$, and a single class corresponding to the non-well-ordered subsets of \mathbb{Q} . Thus, if the continuum is larger than \aleph_1 , E cannot satisfy the stated conjecture, but, in fact, it can be shown that independently from any extra set theoretical assumptions, there cannot be an uncountable Borel set $A \subseteq X$ of E -inequivalent points.

Instead, in a technical tour de force involving a large arsenal of modern set theory, J. H. Silver proved the optimal conclusion for coanalytic equivalence relations.

Theorem 4 (J. H. Silver (1980)). *Let E be a coanalytic equivalence relation on a standard Borel space X . Then exactly one of the following holds:*

- *there are at most countably many E -classes,*
- *there is an uncountable Borel set $A \subseteq X$ of E -inequivalent points.*

Using Silver's dichotomy one can recuperate the result of Souslin: if $A \subseteq \mathbb{R}$ is an infinite analytic set, define a coanalytic equivalence relation E on \mathbb{R} by setting

$xEy \Leftrightarrow x, y \notin A \text{ or } x = y.$

Then $|X/E| = |A|$, and if there is an uncountable Borel set of E -inequivalent points, A contains an uncountable Borel set.

²For a thorough discussion of the current research on this, one can consult W. H. Woodin's article in this journal [12].

Unfortunately, coanalytic equivalence relations very rarely come up, unless they are actually Borel, while analytic equivalence relations abound and hence are the more important object of study. Deducing from Silver's dichotomy, J. P. Burgess showed that the above example is as bad as it can get.

Theorem 5 (J. P. Burgess (1978)). *Let E be an analytic equivalence relation on a standard Borel space X . Then exactly one of the following holds:*

- there are at most \aleph_1 E -classes,
- there is an uncountable Borel set $A \subseteq X$ of E -inequivalent points.

Silver's proof, which used substantial parts of modern set theory, was soon simplified by L. A. Harrington, who found a proof based on effective considerations, i.e., ultimately computability theory on the integers. Subsequently a number of dichotomies for various structures were proved using variations of this technique, but the theory would soon advance with deepening connections to other branches of mathematics.

Theorem 6 (L. A. Harrington, A. S. Kechris, A. Louveau (1990)). *Let E be a Borel equivalence relation on a standard Borel space X . Then exactly one of the following holds:*

- E is smooth, i.e., $E \leq_B =_{\mathbb{R}}$,
- $E_0 \leq_B E$.

This dichotomy extends previous work by J. G. Glimm (1961) and E. G. Effros (1965) on the representation theory of C^* -algebras. In his work on a conjecture of G. W. Mackey, Glimm originally proved the above dichotomy for orbit equivalence relations induced by the action of a second countable, locally compact group, and Effros subsequently generalized this to F_σ equivalence relations induced by actions of Polish topological groups.

The dichotomies of Silver and Harrington, Kechris and Louveau explain the linearity of the lower part of Figure 2. Indeed, for Borel equivalence relations E , either E is Borel reducible to $=_{\mathbb{N}}$, E is Borel bireducible with $=_{\mathbb{R}}$, or E_0 Borel reduces to E . For general analytic equivalence relations, this picture breaks down.

A number of other dichotomies for Borel equivalence relations are now known, most notably a dichotomy stating that E_1 is minimal (but not minimum) above E_0 among Borel equivalence relations (Kechris and Louveau (1997)). Even though the statements of these results involve nothing more than Borel sets and Borel measurable functions on standard Borel spaces, until recently the only known proofs of these results involved computability theory on the integers. However, recent proofs due to B. D. Miller (2009) have completely removed the need for such effective considerations.

Banach Spaces and Gowers's Classification Program

The two main classification problems for Banach spaces are arguably those of isomorphism and isometry. While the problem of isometrically distinguishing two Banach spaces is somewhat tangible, mainly due to a number of quantitative invariants at hand, e.g., moduli of smoothness and convexity, there are fewer general techniques for distinguishing the isomorphic structure of Banach spaces. One successful subcase is the isomorphic classification by A. A. Miljutin (1966) and C. Bessega and A. Pełczyński (1960) of the $C(K)$ spaces, for K compact metrizable, in terms of the cardinality and Cantor-Bendixson rank of K . However, with respect to isomorphic classification by complete invariants, there has otherwise only been limited progress. Though it has long been suspected that a complete classification of separable Banach spaces up to isomorphism would be too complicated to be of any practical value, the evidence was mostly circumstantial. However, based on work by S. A. Argyros and P. Dodos (2006) on amalgamations of analytic sets of Banach spaces, we now know the exact complexity of isomorphism.

Theorem 7 (V. Ferenczi, A. Louveau, C. Rosendal (2009)). *The relation of isomorphism between separable Banach spaces is maximum in the Borel reducibility ordering, i.e., is Borel bireducible with E_{\max} .*

By contrast, isometry is of substantially lower complexity, namely, J. Melleray (2007) showed that it is bireducible with the equivalence relation E_{grp} from Figure 2.

Partially motivated by the inherent complexity of the isomorphic structure of Banach spaces, W. T. Gowers (2002) proposed an alternative classification program by instead determining the irreducible components from which other spaces are built up. Now, as the finite-dimensional Banach spaces are fully determined up to isomorphism by their dimension, we should concentrate on the infinite-dimensional building blocks. So to avoid endless repetition, henceforth all Banach spaces will be assumed to be separable and infinite-dimensional. Concretely, Gowers proposed that one should determine a list $(C_i)_{i \in I}$ of isomorphism invariant classes of Banach spaces such that

- (1) if a space X belongs to a class C_i , then so do all of its subspaces,
- (2) the classes are disjoint for obvious reasons,
- (3) any space X has a subspace $Y \subseteq X$ belonging to some class C_i ,

- (4) knowing that a space X belongs to some class C_i should yield substantial knowledge about its structure and about the operators that may be defined on it.

Gowers's classification program can be thought of as a prototypical example of the third type of classification, but it has one distinguishing feature, namely, it makes no promise that we should be able to reconstruct a space X from those of its subspaces belonging to the various classes C_i . This is in contrast with, for example, the theory of unitary representations, where one seeks to write representations as direct integrals of their irreducible subrepresentations.

Another feature that sets it apart from the first two types of classification is that *embedding*, i.e., isomorphism with a subspace, rather than isomorphism, is the focal point (we shall write $X \sqsubseteq Y$ to denote that X embeds into Y). Thus, for example, properties (1) and (2) together imply that spaces X and Y belonging to different classes are totally incomparable. Here X and Y are *incomparable* if neither $X \sqsubseteq Y$ nor $Y \sqsubseteq X$ and are *totally incomparable* if there is no other space Z such that both $Z \sqsubseteq X$ and $Z \sqsubseteq Y$.

For many years (long before Gowers formulated his program), it was conjectured that any Banach space contains a copy of some ℓ_p or c_0 , whereby if C_p and C_0 denote the set of subspaces of ℓ_p , respectively of c_0 , then $(C_p)_{p \in \{0\} \cup [1, \infty[}$ would provide a list, as above. This was refuted by B. S. Tsirelson (1974), who constructed a space, now known as the *Tsirelson space*, not containing any ℓ_p or c_0 . Nevertheless, Tsirelson's space in many ways resembled the classical sequence spaces c_0 and ℓ_p , and it was not clear just how far the structure of a space could diverge from these.

Schauder Bases

In order to manipulate the subspaces of a Banach space, we need a way of representing these efficiently, namely via bases. A sequence $(e_n)_{n=1}^\infty$ of vectors in a Banach space X is said to be a *Schauder basis* for X if any vector $x \in X$ can be uniquely represented as a norm convergent series

$$x = \sum_{n=1}^{\infty} a_n e_n,$$

where the a_n are scalars. So, for example, if e_n denotes the sequence

$$(0, 0, \dots, 0, 1, 0, 0 \dots),$$

where the 1 occurs in the n th place, then $(e_n)_{n=1}^\infty$ is a Schauder basis for the space

$$\ell_1 = \{(a_1, a_2, a_3, \dots) \in \mathbb{R}^\mathbb{N} \mid \sum_{i=1}^{\infty} |a_i| < \infty\}$$

of absolutely summable sequences (and similarly for c_0 and ℓ_p , $1 \leq p < \infty$). For the combinatorial

analysis of bases, however, another equivalent formulation is more useful: a sequence $(e_n)_{n=1}^\infty$ of nonzero vectors is a Schauder basis for X if its linear span is dense in X and there is a constant K such that

$$(*) \quad \left\| \sum_{n=1}^k a_n e_n \right\| \leq K \left\| \sum_{n=1}^{\infty} a_n e_n \right\|,$$

whenever a_n are scalars and $k \in \mathbb{N}$.

Obviously, as in linear algebra, it can be extremely useful to represent a Banach space via a basis, as, for example, operators then can be written as matrices with respect to this basis. However, P. Enflo (1973) showed that not every Banach space has a Schauder basis. Actually, Enflo did more by constructing a space X without Grothendieck's approximation property, i.e., such that the identity operator on X cannot be approximated uniformly on compact sets by finite rank operators. Nevertheless, a classical result due to S. Banach states that any space has a subspace with a Schauder basis.

A distinguishing feature of the bases of c_0 and ℓ_p is that not only do we have uniformly bounded projections onto initial segments of the basis as in (*), but we also have uniformly bounded projections onto any subset. That is, for some constant K (actually $K = 1$ works for c_0 and ℓ_p) and all sets $A \subseteq \mathbb{N}$, we have

$$\left\| \sum_{n \in A} a_n e_n \right\| \leq K \left\| \sum_{n \in \mathbb{N}} a_n e_n \right\|,$$

for all scalars a_n . Bases satisfying this stronger property are said to be *unconditional*. Now if X is a Banach space with an unconditional basis (e_n) , then X has a multitude of complemented subspaces. For if $A \subseteq \mathbb{N}$, then the closed linear span $[e_n]_{n \in A}$ of the subsequence $(e_n)_{n \in A}$ will be the image of the bounded projection P_A on X defined by

$$P_A \left(\sum_{n \in \mathbb{N}} a_n e_n \right) = \sum_{n \in A} a_n e_n,$$

and hence is complemented by the subspace $[e_n]_{n \notin A}$.

The existence of a Schauder basis allows us to largely replace the analytical theory of Banach spaces with combinatorics in vector spaces. To set this up, suppose X is a Banach space with a Schauder basis (e_n) and let E denote the set of finitely supported vectors

$$E = \left\{ \sum_{n=1}^k a_n e_n \mid a_n \in \mathbb{R} \text{ \& } k \in \mathbb{N} \right\}.$$

Then E is a countable-dimensional normed vector space with basis (e_n) . A *block sequence* of (e_i) is an infinite sequence (y_i) of nonzero vectors in E such that

$$\max \text{support}(y_n) < \min \text{support}(y_{n+1})$$

for all $n \in \mathbb{N}$ (see Figure 3).

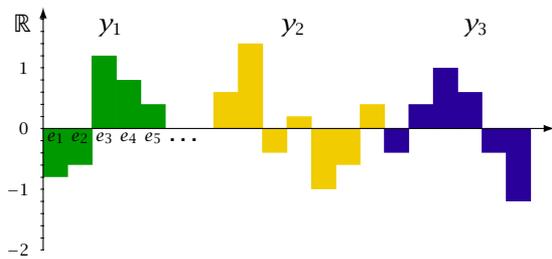


Figure 3. A block basis (y_n) of (e_n) .

Any such block sequence will be a Schauder basis for its closed linear span $[y_i]$, which is an infinite-dimensional subspace of X called a *block subspace*. Also, a classical result implies that, modulo a small isomorphic perturbation, any subspace of X contains a block sequence and hence, up to embeddability, the block sequences of (e_n) parametrize the closed subspaces of X .

These considerations allow us to replace the notions of Banach space theory with combinatorial properties of block sequences in the normed vector space E . The goal of Gowers's classification program is then to isolate mutually exclusive and hereditary classes $(C_i)_{i \in I}$ of block subspaces, such that any Schauder basis (e_n) has a block subspace $Y = [y_n]$ belonging to some C_i . Of course, the import of such a classification largely depends on how informative membership in the classes C_i is and on the "logical gap" or conceptual distance between them. For example, no information is gained by splitting into the classes

$$C_1 = \{\text{reflexive spaces}\}$$

and

$$C_2 = \{\text{spaces without reflexive subspaces}\}.$$

Ramsey Theory for Block Sequences

If one attempts to apply Ramsey theoretical methods to Banach spaces, it is natural to first review the classical Ramsey theory for integers to look for principles that might transfer to the new context. So for any $n = 1, 2, \dots, \infty$ and infinite subset $A \subseteq \mathbb{N}$, we let $[A]^n$ denote the set of all strictly increasing n -tuples of numbers in A . Then whenever

$$c: [\mathbb{N}]^n \rightarrow \{\text{green, blue}\}$$

is a coloring with two colors, we can ask if there is an infinite subset $A \subseteq \mathbb{N}$ such that $[A]^n$ is monochromatic. In other words, is there an infinite set $A \subseteq \mathbb{N}$ such that all increasing n -tuples from A get the same color?

In the case $n = 1$, c is really just a coloring of the natural numbers themselves, so of course there is such a monochromatic subset A (this is just the Dirichlet or pigeonhole principle). For $1 < n < \infty$, though any such coloring c still admits a monochromatic set $[A]^n$, this is certainly less trivial and is just the statement of the infinite

version of Ramsey's theorem (from which the usual finite version follows by a simple compactness argument).

On the other hand, when coloring infinite increasing sequences of natural numbers new phenomena occur, and one has to restrict the allowable colorings. However, a result due to F. Galvin and K. Prikry (1973) states that if the coloring c is a Borel function, where $[\mathbb{N}]^\infty$ has the topology induced from $\mathbb{N}^\mathbb{N}$, then one can still find a monochromatic set $[A]^\infty$.

Now, when transferring these concepts to Banach spaces, our base set \mathbb{N} should be replaced with the unit sphere of a Banach space X (recall that all spaces are assumed infinite-dimensional), the infinite subsets of \mathbb{N} with unit spheres of subspaces $Y \subseteq X$ and the natural numbers with vectors of norm 1 in X . So if

$$c: S_X \rightarrow [0, 1]$$

is a Lipschitz function defined on the unit sphere of a Banach space X and $\epsilon > 0$, does there exist a subspace $Y \subseteq X$ such that

$$\text{diam}(c[S_Y]) < \epsilon ?$$

Well, at least for one space we do have such a result.

Theorem 8 (W. T. Gowers (1992)). *Suppose*

$$c: S_{c_0} \rightarrow [0, 1]$$

is a Lipschitz function and $\epsilon > 0$. Then there is a subspace $Y \subseteq c_0$ such that

$$\text{diam}(c[S_Y]) < \epsilon.$$

Unfortunately, for the classification of Banach spaces, c_0 is essentially the only space for which this holds.

Theorem 9 (E. Odell, Th. Schlumprecht (1994)). *Suppose X is a Banach space not containing an isomorphic copy of c_0 as a subspace. Then there is a subspace $Y \subseteq X$ and a Lipschitz function*

$$c: S_Y \rightarrow [0, 1]$$

such that for any subspace $Z \subseteq Y$, we have

$$c[S_Z] = [0, 1].$$

So even the simplest of the Ramsey principles for \mathbb{N} , i.e., the Dirichlet principle, has no direct analogue for Banach spaces. However, Gowers overcame this predicament by taking a more dynamical perspective that led to a general Ramsey principle for Banach spaces. We now introduce such a principle in the context of pure vector spaces.

Suppose E is a countable-dimensional \mathbb{Q} -vector space with basis $(e_n)_{n=1}^\infty$. We let \mathcal{B} be the set of

all block sequences³ of the basis (e_n) and equip \mathcal{B} with a separable, complete metric d given by

$$d((x_n), (y_n)) = 2^{-\min(m \mid x_m \neq y_m)}.$$

So with the d -topology \mathcal{B} is a Polish space.

We consider a pair of infinite games between two players I and II that will produce block sequences of (e_n) . The *Gowers game* G_X below a block subspace $X \subseteq E$ is played by letting I and II alternate in choosing, respectively, block subspaces $Y_i \subseteq X$ and nonzero vectors $x_i \in Y_i$ subject to the constraint that

$$\max \text{support}(x_n) < \min \text{support}(x_{n+1}).$$

Diagrammatically:

I	Y_0	Y_1	Y_2	Y_3	\dots
II	x_0	x_1	x_2	x_3	\dots

The *infinite asymptotic game* F_X below the block subspace $X \subseteq E$ is defined as the Gowers game, except that we now additionally demand that the block subspaces $Y_i \subseteq X$ played by I should have *finite codimension* in X . In both games, the *outcome* of an infinite run of the game is defined to be the infinite block sequence $(x_i)_{i=0}^\infty$ produced by player II.

In both G_X and F_X , II is thus the only player that is directly contributing to the outcome of the game, while player I only indirectly influences the play of II by determining in which block subspaces II has to choose her vectors. Clearly, I has greater powers in Gowers's game G_X than in the infinite asymptotic game F_X , since in G_X he is not restricted to choosing subspaces of finite codimension in X .

Definition 10. A subset $A \subseteq \mathcal{B}$ is said to be *strategically Ramsey*⁴ if there is a block subspace $X \subseteq E$ such that one of the following two properties holds

- II has a strategy in G_X to play in A ,
- I has a strategy in F_X to play in $\sim A$.

We note that this is stronger than requiring that the games G_X and F_X to play in A are determined. For, in general, it is much stronger for I to have a strategy in F_X to play in $\sim A$ than to have a strategy in G_X to play in $\sim A$. On the other hand, the notion of strategically Ramsey does involve passing to a block subspace $X \subseteq E$ and so is really both a Ramsey theoretical and a game theoretical concept.

The basic fact about strategically Ramsey sets is then

Theorem 11. *Analytic sets are strategically Ramsey.*

³We import the relevant concepts from Schauder bases wholesale.

⁴The actual definition of strategically Ramsey that one needs is slightly more complicated and involves quantification over block spaces and finite block sequences.

This principle can be further strengthened in the context of Banach spaces. For suppose X is a Banach space with a Schauder basis (e_n) , $B \subseteq (S_X)^\mathbb{N}$, and let E be the \mathbb{Q} -vector subspace of X with basis (e_n) . Assume that for some block subspace $Y \subseteq E$, player I has a strategy in the infinite asymptotic game F_Y to play in B . Then for any sequence $\Delta = (\delta_n)$ of positive real numbers there is a further block subspace $Z \subseteq Y$ such that any block sequence in S_Z belongs to

$$B_\Delta = \{(z_n) \mid \exists (v_n) \in B \ \forall n \ \|v_n - z_n\| < \delta_n\}.$$

From this follows

Theorem 12 (W. T. Gowers (2002)). *Suppose X is a Banach space with a basis (e_n) and A is an analytic set of block sequences. Assume moreover that for any Δ and any block subspace $Y \subseteq X$ there is a block sequence in S_Y not belonging to $(\sim A)_\Delta$. Then there is a block subspace $Y \subseteq X$ such that II has a strategy in G_Y to play in A .*

So, up to small perturbations, if an analytic set of normalized block sequences cannot be avoided by passing to a block subspace, then, for some block subspace Y , II has a strategy in G_Y to play into this set.

Dichotomies for Banach Spaces

Up till the beginning of the 1990s, perhaps the major unsolved problem of Banach space theory was the *unconditional basic sequence problem*, i.e., the question of whether any Banach space contains a subspace with an unconditional basis and thus to some extent resembling the classical sequence spaces ℓ_p and c_0 . This was solved negatively by Gowers and B. Maurey (1993) by the construction of a so-called *hereditarily indecomposable* space, i.e., a space in which no two infinite-dimensional subspaces form a direct sum and so admitting no nontrivial projections.

The construction of the Gowers-Maurey space spurred significant activity, most notably the recent construction by Argyros and R. G. Haydon (2009) of a Banach space on which every operator is of the form $\lambda I + K$, where K is a compact operator. But, surprisingly, despite the extreme intricacy of its construction, any counterexample to the unconditional basic sequence problem must resemble the Gowers-Maurey space. This was proved by Gowers as the first application of his Ramsey theorem of the preceding section.

Theorem 13 (Gowers's first dichotomy (1996)). *Any Banach space contains either a hereditarily indecomposable subspace or a subspace having an unconditional Schauder basis.*

Since being hereditarily indecomposable or having an unconditional basis are hereditary properties, i.e., are inherited by block subspaces, and are contradictory, this provides an initial step in

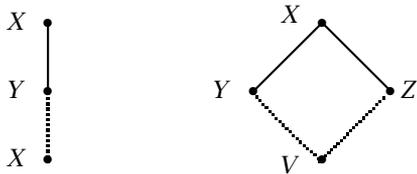


Figure 4. Minimality and quasi-minimality.

Gowers's classification program by splitting into two classes of spaces, namely the hereditarily indecomposable and those with unconditional basis. However, this division can be further refined by another application of the Ramsey theorem. First, a space X is said to be *minimal* in case it embeds into all of its subspaces, and X is *quasi-minimal* if whenever $Y, Z \subseteq X$ there is some V such that $V \subseteq Y, Z$, i.e., X has no pair of totally incomparable subspaces (see Figure 4).

Theorem 14 (Gowers's second dichotomy (1996)). *Any Banach space contains either a quasi-minimal subspace or a subspace with an unconditional basis such that disjointly supported block subspaces are totally incomparable.*

In other words, the hereditary failure to quasi-minimality can be explicitly witnessed on a subspace with an unconditional basis. Moreover, this latter property can be conveniently reformulated as follows. Suppose X is a space with a Schauder basis (e_n) . Saying that disjointly supported block subspaces are totally incomparable is just requiring that whenever $Y = [y_n]$ is a block subspace, $I_n = \text{support}(y_n)$ and $T: Y \rightarrow X$ is an isomorphic embedding, then

$$\liminf_{n \rightarrow \infty} \|P_{I_n} T\| > 0$$

(recall that P_{I_n} denotes the projection of X onto the subspace $[e_i]_{i \in I_n}$). So any isomorphic copy of Y inside of X has essential support on the sequence of finite-dimensional subspaces $[e_i]_{i \in I_n}$.

Since Gowers's two dichotomies are logically dependent, putting them together only gives us a decomposition into three classes: hereditarily indecomposable, quasi-minimal with unconditional basis, and spaces with an unconditional basis such that disjointly supported subspaces are totally incomparable. However, it is natural to look for a dichotomy distinguishing the minimal spaces (a property characteristic of the classical sequence spaces ℓ_p and c_0) among the more general quasi-minimal spaces. For this, a Banach space X with a basis (e_n) is said to be *tight* if whenever $Y = [y_n]$ is a block subspace, there are finite sets

$$I_0 < I_1 < I_2 < \dots \subseteq \mathbb{N}$$

such that any isomorphic embedding $T: Y \rightarrow X$ satisfies

$$\liminf_{n \rightarrow \infty} \|P_{I_n} T\| > 0.$$

Thus, for example, the spaces occurring above are seen to be tight by using the support of the vectors y_n . Tight spaces are easily seen to have no minimal subspaces.

Theorem 15 (V. Ferenczi, C. Rosendal (2009)). *Any Banach space contains either a tight or a minimal subspace.*

Of course, the bare existence of the finite sets I_n can be somewhat unsatisfactory, and in concrete cases one would like to know how these are computed from the block subspace $Y = [y_n]$. And, indeed, there are other dichotomies for weakened types of minimality in terms of the choice of sets I_n (involving constants of embeddability by the range of vectors, or, as in Gowers's second dichotomy, by their support).

The dichotomies obtained hitherto give a pretty detailed picture of the nonclassical Banach spaces, i.e., those not containing minimal subspaces, but our knowledge of the minimal spaces is still very far from being complete. In particular, one would like to have a truly informative dichotomy detecting the presence of c_0 or ℓ_p inside a Banach space. There are such dichotomies for ℓ_1 or c_0 due to H. P. Rosenthal (1974) and (1994), but none as informative exist for $\ell_p, p \neq 1$.

On a somewhat different note, the following question still remains open.

Question 16. Let X be a Banach space. What is the number of nonisomorphic subspaces of X ?

Since Hilbert space ℓ_2 is outright isometric to its subspaces, any space isomorphic to ℓ_2 is *homogeneous*, i.e., isomorphic to all of its subspaces. That the converse holds, i.e., that any homogeneous space is isomorphic to Hilbert space, is a consequence of Gowers's first dichotomy together with a result of R. Komorowski and N. Tomczak-Jaegermann (1995). But this leaves a huge gap of possible cardinalities for the number of nonisomorphic subspaces of a Banach space. Since it can be shown with the aid of tightness that any space without minimal subspaces contains a continuum of nonisomorphic subspaces, the main problem lies in understanding the minimal spaces. A perhaps optimistic guess is that any Banach space into which ℓ_2 does not embed contains a continuum of nonisomorphic subspaces.

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About the Cover

Old North Church, Boston

The cover shows a watercolor sketch of Old North Church in Boston, site of the annual Joint Mathematics Meetings in January 2012. It was done by Karl Hofmann. We don't mean to deceive you about Boston weather in January, so we show below a more typical winter scene, the Great Spirit statue next to the Boston Museum of Fine Arts, also by Karl.



This is the third cover we have had from Karl Hofmann. He is a member of the mathematics faculties of both Tulane University and Universität Darmstadt. He still works at mathematics, but his most unusual accomplishment is an extraordinarily long series of poster designs in tempera colors and felt pen calligraphy accompanying colloquium talks in Darmstadt, which you can see at

<http://www3.mathematik.tu-darmstadt.de/galerie-der-kolloquiumsposter.html>

He has also provided illustrations for mathematics books, most notably the very popular *Proofs from the Book* by Martin Aigner and Günter Ziegler.

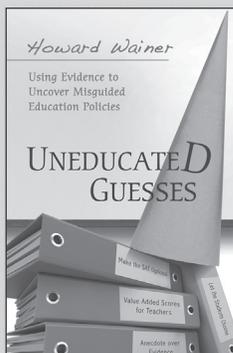
The photograph below shows him at work in his "studio" at the university in Darmstadt.



—Bill Casselman
Graphics editor
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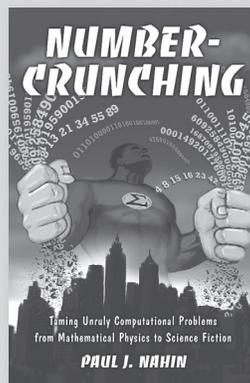
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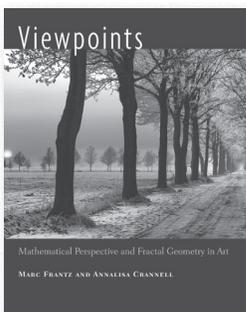
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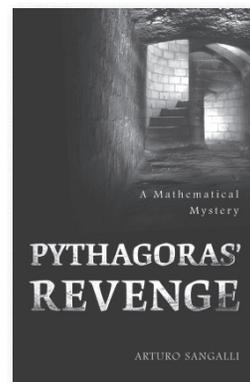
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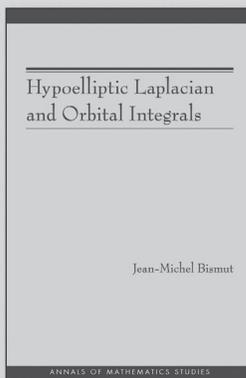
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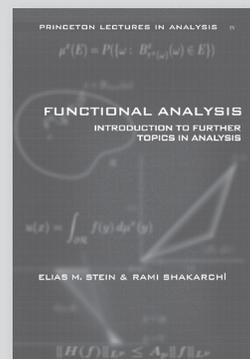
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A Science-of-Learning Approach to Mathematics Education

Frank Quinn

The focus in this approach is directly on individual, mathematics-specific learning. It is “science” in the sense that it developed bottom-up from micro-scale observations. It addresses long-term needs for abilities and skills because these impose strong constraints on elementary education. Our eventual goal is to produce competent citizens and capable scientists and engineers. To do this, college faculty need certain skills from high school; to develop these skills, high-school teachers need certain outcomes from middle school; and so on down. Finally the account draws on, and is consistent with, modern professional practice. These features are described a bit more in the next section and in detail in [4], from which this material was drawn.

Much of the output from this approach is also micro-scale: highly effective ways to treat fractions, polynomial multiplication, word problems, and so forth, but with little indication as to how these might be put together in a course or curriculum—in other words, a toolkit without much assembly instruction, in contrast to educational-philosophy approaches that provide assembly instructions (pedagogy and content-independent methodology) without much toolkit. There are, however, strategies to make the tools work, and we invert the logical progression and begin with these in the section on Mathematics and Teaching. The section on Examples provides examples, mostly from [4]. Topics in the first four subsections are fractions, multiplication of polynomials, and partial fractions in both integers and polynomials. The goal is to indicate how topics might develop over time and

to suggest that a cognitively adapted and logically clear development might be more ambitious. Word problems are the last topic in the section. The final section concerns teacher preparation relevant to this approach. Among other things, it throws light on why study of advanced topics does not seem to improve K-12 teaching.

This article was developed as a response to articles in the AMS *Notices* special issue on education in March 2011 [1]. The supplement [5] includes comparisons to these articles.

Background

The most significant background for this material is over a thousand hours of one-on-one diagnostic work with students.¹ The procedure is that I go to students when they need help. I review their work, diagnose the specific problem, and show them how to fix it to avoid a recurrence. This is not tutoring. The students do most of the talking and most of the work, and I leave them to finish on their own as soon as they are past the specific difficulty. The focus on diagnosis also helps students see how to diagnose and correct their own errors.

The context for the diagnostic work is a computer-tested engineering calculus course I developed. The courseware is designed to emphasize structure and encourage work habits that avoid problems. The material is also designed so that pre-existing learning errors will cause serious difficulty. The goal is to expose these errors so they can be diagnosed and repaired.

A final ingredient is an extensive bottom-up analysis of contemporary mathematical practice [3]. This draws on my own research experience,

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¹*In the Math Emporium at Virginia Tech.*

editorial work, work on publication policy, cognitive neuroscience, history of mathematics, the work with students mentioned above, and many other sources. It is well known that modern professional practice is quite different from that in the nineteenth century and from models used in education and most philosophical accounts. It was no surprise to find that contemporary practice is better adapted to the subject. It was a surprise to find that, within the subject constraints, it is much better adapted to human cognitive facilities. It seems that contemporary practice is not just for freaks: carefully understood, it can be a powerful resource for education.

These experiences have given a fine-grained perspective on mathematical learning and its difficulties. Moreover, the perspective directly concerns individual learning: not teaching, and not learning mediated by teachers. It has become uncomfortably clear that teaching is not nearly as closely connected with learning as educators like to think.

Mathematics and Teaching

Mathematics offers insights into the world and its own realms to explore, but it is not a spectator sport. Current educational approaches do not provide enough functionality to bring it to life. Current introductions to numbers and fractions, for instance, have rather passive “understanding” as goals rather than *doing* things with them. The difference for fractions is illustrated in the examples.

The goal here is to suggest that a more active approach could be successful in real-life settings, but there are very strong constraints. First, weak goals permit relaxed attitudes toward educational philosophy and individual practice. Achieving strong goals is delicately dependent on approach and provides a criterion that identifies many approaches as “wrong”. To achieve success one must first avoid failure. Second, there are guidelines for “right” approaches, but no easy formula. Successful practice is a delicate negotiation between mathematical structure and the complex oddities of human cognition. This has to be done on a case-by-case (micro-scale) basis, but in ways that fit into the long-term development.

This section provides an overview of structure and practice of mathematics, extracted from a detailed account in [3] and formulated for use in elementary education. However, it is an after-the-fact description of the methodological constraints found in the micro-scale material, *not* a philosophical foundation from which methodology can be deduced. Again these are—at best—guidelines that help avoid failure, not formulas that guarantee success.

Precision and Functionality

Mathematics has evolved a set of explicit rules of reasoning with the following astounding property: arguments without rule violations have completely reliable conclusions!² People often have trouble learning to use these rules effectively because rules in most other systems are sufficiently vague and ineffective that precision is a waste of time, while in mathematics anything less than *full* precision (*no* rule violations) is a waste of time. However, mathematical rules are simple compared to those of the tax code, religion, politics, physical science, and so on. Most people can master the basics.

Precision. Precision is particularly important for functionality in elementary mathematics: sloppy thinking that is harmless to experienced users can seriously confuse beginners. Confusion about fractions, for instance, results from failing to distinguish between things and names for them; between representatives of an equivalence class and the equivalence class; and from common ambiguity in the use of “=”. This is acceptable if the goal is passive “understanding”, but ambitious goals require much more clarity. The following subsections suggest ways to avoid these and other problems.

Potential Proofs. For users the key enabling concept ([3] §4, [4](c)) is *potential proof*: a record of reasoning, using methods of established reliability, and detailed enough to check for errors. Potential proofs in this sense are very common. The scratch work done by a child multiplying multidigit integers by hand provides a record of reasoning that can be checked for errors. When teachers tell students to “show your work”, they mean “provide a record of reasoning...”. The basic method is already in wide use, and the potential-proof description mainly clarifies the features and activities needed to make it fully effective.

In these terms a “real” proof is a potential proof that has been checked (and repaired if necessary) and found to be error-free. However, the benefits come from reasoning and checking. Errors happen. A flawed first attempt with sufficient detail can provide a framework for diagnosis and improvement. A flawed first attempt with insufficient detail is useless, and the user must start again from scratch. Focusing on the formal and error-free aspects of completed proofs actually distracts from the features that provide power to users.

²For all practical purposes; see [3], §2 for nuances.

Work Templates. To exploit the power of potential proofs, students should be taught to record their reasoning in a way that can be checked for errors. Criteria for good work formats are:

- (1) record enough detail so reasoning can be reconstructed and checked for errors;
- (2) be compact and straightforward; and
- (3) help organize the work in ways consistent with human cognitive constraints.

Designing such a format is hard for professionals and cannot be expected of students, so they must be provided with *templates*. These can range from literal fill-in-the-blank forms (cf. the Solution subsection of Multiplying Polynomials) to routinely recording crucial intermediate steps (cf. the section Word Problems).

The standard formats for multidigit multiplication and long division are well-known examples of templates, though they are not fully satisfactory. They satisfy the first two conditions but are less successful with (3) because they have been optimized for production arithmetic by experienced users rather than to provide support for beginners. A less efficient but potentially more supportive template for multiplication is explored in [4](a).

Accuracy and Diagnosis. Mathematical methods enable near 100 percent accuracy, and extended arguments depend on this. If a single operation can be done with 70 percent accuracy, then the likelihood of getting the right answer in problems with ten operations is under 3 percent. If one wants 70 percent accuracy in the ten-operation problem, then individual operations must be done with 97 percent accuracy. Elementary teachers who accept 70 percent success rates are not only wasting the unique potential of mathematics but also setting their students up for failure in later courses. The proposal, then, is that the goal should be quality, not quantity, and not speed; fewer problems, but expected to be 100 percent right. Is this reasonable in education? Maybe not, but I sketch strategies that should make it possible to get close. One is described above: carefully designed work templates for students to emulate.

The most important strategy is teacher diagnosis of errors that students can't find themselves. Ideally, *every* wrong answer should be corrected. For diagnosis, the student should explain his or her reasoning following his or her written work record. If the record is illegible, steps were skipped, or appropriate templates were not used, then the work should be redone before being diagnosed for specific errors; it is remarkable how often this resolves the problem, and it is valuable for students to see this. If the work record is appropriate, then it can be reviewed efficiently and mistakes quickly pinpointed. Premature guesses about the difficulty are often wrong and will make confusion worse, so the teacher should wait until the student has

come to the error before doing anything. Further, the student learns more if he or she spots the error him- or herself; wait and see if he or she says, "oh, now I see what went wrong." In such cases the teacher can ask what happened, to see if the insight is right, but if so then the teacher should leave well enough alone and *not* explain further, even if a clearer description can be given. If this approach is used systematically, then errors will become remarkably uncommon. Confusions don't accumulate and students learn to diagnose their own work.

Definitions and Key Statements

Precise reasoning requires precise descriptions: vague or intuitive things are inaccessible to mathematics. I discuss four aspects: when explicit descriptions are necessary; how things are described precisely; where good descriptions come from; and how they support the intuitive processes that usually precede precise reasoning.

When Statements Are Needed. There are no hard-and-fast rules about when things should be formalized because it depends more on how our brains work than on mathematical structure. Professional practice gives clues: mathematicians have essentially the same neural equipment as everyone else and are very ambitious about exploiting it to the fullest.

For instance, addition seems to be internalized as a kind of behavior, and work habits learned in the integers transfer relatively easily to much more general contexts that behave in the same way. This is formalized as: any binary operation that is commutative, associative, and has a neutral element and inverses is entitled to be called "addition" and denoted by "+". Similarly, a second operation that distributes over + is entitled to be denoted as "multiplication". This enables transparent transfer of work habits. That this is a cognitive strategy rather than just mathematical structure becomes clear when people move out of their comfort zone. Technical examples: homology is written additively, and the bar construction multiplicatively, and it is rather awkward to translate these to the other notation. It can be amusing to watch mathematicians encountering tropical arithmetic in the integers for the first time. This has two operations, and one distributes over the other just as multiplication does over addition. However, the operation that distributes like multiplication is ordinary addition. This means it cannot be rewritten as multiplication, so distributivity looks backward. The operation analogous to addition is the max function, which does not have inverses and also does not follow familiar patterns.

The point is that while it is a good idea to have the associative and commutative axioms available for reference, well-internalized work

habits make it unnecessary and distracting to require students to work with them explicitly. See [4](b) for an elaboration. In contrast, making explicit the definition of fractions and the quadratic formula has significant cognitive benefits.

Formats. Contemporary practice uses axiomatic definitions to provide precision, but the format is not forced by the job to be done. In fact, the definition format seems to have won out over the alternatives because it is more effective for human use; see [3], §5. In other words, precise definitions can be an enabling technology for people. Similarly for concise theorems.

Definitions and theorems provide precision, but, as with any format, they do not turn junk into gold. *Effective* definitions usually result from long and painful searches. Mathematicians will have some intuitive goal, make a precise description that they hope will realize their intuition, work with it for a while, and most of the time it doesn't do what they hope for. They junk the attempt and try again. In some areas these false starts probably account for 50 percent of all mathematical effort. A really good definition is therefore a treasure, and because it can efficiently guide newcomers around years of confusion, a powerful legacy. Really sharp and effective theorem statements are similarly precious.

Suggestion. Important objects, terminology, and properties (fraction, prime, relatively prime, proper fraction, quadratic formula, ...) should be given brief and genuinely precise formulations.

- Formulations should be constructed primarily by professional mathematicians, with education feedback. Professionals habitually hone and fine-tune them to be brief and effective and can ensure that they are compatible with later material.
- Ideally, students should memorize them so they can be reproduced exactly. Definitions provide anchor points, and genuinely functional understanding nucleates and deepens around the definition. This is particularly true for weaker students.
- Explanation of what a definition “means” is best given after the definition, not before. Putting too much explanation first almost guarantees confusion.

Compared with current educational practice, this is very rigid, but it is a baby version of the way mathematicians approach unfamiliar material, and it works. More precisely, less rigid approaches take longer, are less effective, and were abandoned when this approach became available about a century ago.

Is this approach reasonable in education? Well-crafted definitions evoke mathematical objects with the economy and grace of poetry. Asking

students to memorize them is like asking them to memorize unusually powerful poems. There are not so many that this is burdensome, and if it is done consistently it will become routine. Students will also see quick payoffs because good definitions are immediately functional.

Intuition. The final point concerns the role of intuition. A great deal of mathematical activity is at least guided by intuition, but this makes precise definitions *more* important. Intuitions developed by working with a good definition are often effective. Intuitions based on sloppy “definitions”, or naive intuitions “refined” by exposure to definitions, tend to be unreliable. Intuitions based on “meaning” or physical analogues are almost never satisfactory. This is acceptable if passive understanding is the goal, but it strongly limits long-term outcomes.

Limits of Mathematics

The need for complete precision provides power but also limits the scope of mathematics. In particular, nothing in the physical world can be described with mathematical precision, so mathematical methods do not apply directly. People applying mathematics accommodate this with an intermediate step: a symbolic *mathematical model* is developed to represent the physical situation, and it is the model that is analyzed mathematically. Mathematical conclusions about the model are reliable in a way that the connection between the physical situation and the model cannot be (see Example 1: Buying Pencils and [5] for examples), and working without a model confuses this structural difference.

Historically, systematic use of modeling developed in the seventeenth century as an essential part of the “scientific revolution”.

There are additional reasons that the mixing of modeling and analysis has been obsolete for four centuries: they are quite different cognitively, and mixing causes cognitive interference. In fact, cognitive interference in word problems may be the most serious single difficulty I have seen in students. For weaker students “crippling” may not be too strong a word. Examples are given here in the section Word Problems, and there are many more in [4].

Most contemporary educators are philosophically committed to word problems as a different *format* rather than a different activity. They encourage a holistic approach with reasoning “in context” and discourage modeling. In other words, they follow sixteenth-century practice and, naturally, get sixteenth-century outcomes.

Technology

A great deal of [4] is concerned with educational use (or misuse) of technology. The issue is too

complex to be addressed here, but I make one comment.

The traditional classroom was a tightly bound package, and technology is making it come apart. In particular, it is loosening the link between teaching and learning. For instance, calculators appear to make teaching easier and improve student performance on traditional test problem types. However, these problem types no longer have the learning correlates they once did. Easier teaching and better test performance are, in some cases, masking learning declines. A genuinely learning-oriented approach reveals this.

Examples

Explicit problem-oriented methods for student use are the main products of the science-of-learning approach and are the bases for generalities described in the previous section. Space constraints do not permit really illuminating the generalities, but we give enough to illustrate how they fit together. The first section gives a precise but unconventional approach to fractions. It does not immediately give the usual passive “parts-of-a-whole” picture, though that could be given as an application of *integer* fractions. However, it does immediately give effective contexts for partial fractions in both the integers and the polynomials (both in the subsection Integer Partial Fractions). An unconventional procedure for multiplying polynomials in the subsection Multiplying Polynomials carefully exploits structure to give access to much more complex problems than usual and is adapted to find coefficients in the Integer Partial Fractions subsection. Many more examples and interconnections are given in [4]. The polynomial multiplication procedure, for instance, is adapted to give an algorithm for multiplying multidigit integers in [4](a, c).

The subsection Word Problems illustrates the earlier discussion of word problems in Limits of Mathematics.

Fractions

These are a perennial source of trouble, and there seem to be two reasons. First, a fraction is a name for, or description of, something, not the thing itself. The expression $\frac{9}{4} = 2.25$ really means “2.25 can be written as (is a name for) $\frac{9}{4}$ ”. The different names encode different properties, and we want to work with both because we want to exploit the different information they encode. Of course all our symbols are names, not things. This point is too subtle for explicit use in elementary education, but students learn a great deal subliminally from the way things are presented, so confusion can be avoided if teachers are aware of it and accommodate it in their phrasing (see the later subsection Caution).

The second point about fractions is that they specify things implicitly. The name 2.25 encodes an explicit procedure for assembling a number from single-digit integers and powers of 10. Fractions and names such as $\sqrt{2}$ encode properties that determine the thing but do not encode a procedure. See [5] for a completely analogous description of square roots.

Definition. “ \square can be expressed as $\frac{a}{b}$ ” means $b\square = a$.

Notes.

- Examples in the rest of this section demonstrate that this is an effective approach for high and middle school. It is not yet clear whether it can be used directly in elementary grades, but it should be clear that whatever approach *is* used should be carefully upward-compatible with this.
- The structure of the definition implies that the default way to work with fractions is to clear denominators. The usual rules are shortcuts that sometimes avoid this, but these shortcuts are verified by clearing denominators, and if you cannot see how to use shortcuts, then clear denominators.
- Note that $0\square = 0$, so if $a \neq 0$, then *nothing* can be expressed as $\frac{a}{0}$. It is a useless notation, and we avoid it by requiring denominators to be nonzero.

Examples.

- (1) The decimal 2.25 can be expressed as $\frac{9}{4}$ because it satisfies $4 \times 2.25 = 9$.
- (2) Show that if $c \neq 0$, then $\frac{ca}{cb}$ can be expressed as $\frac{a}{b}$. To check, set $\frac{ca}{cb} = \square$ and clear denominators. This gives $ca = cb\square$. If $c \neq 0$, then c can be canceled to give $a = b\square$, and this means $\square = \frac{a}{b}$.
- (3) Is $a - 2 \stackrel{?}{=} \frac{a^2 - 4}{a + 2}$? To find out, clear denominators:

$$(a + 2) \times (a - 2) = a^2 - a^2 + 2a - 4 = a^2 - 4;$$

this is true, so the answer is “yes” (but see the subsection Caution).

- (4) Is $\frac{a}{x} + \frac{b}{y} \stackrel{?}{=} \frac{a+b}{x+y}$? Clear denominators (multiply by $xy(x+y)$) to get $a(y(x+y)) + b(x(x+y)) \stackrel{?}{=} (a+b)(xy)$. Expanding and canceling gives $ay^2 + bx^2 \stackrel{?}{=} 0$. This hardly ever works, so the answer in general is “no”.
- (5) Express $\frac{a}{x} + \frac{b}{y}$ as a fraction. First give it a neutral name, $\square = \frac{a}{x} + \frac{b}{y}$, and clear denominators by multiplying by x and y : $xy\square = ya + xb$. But this means \square can be written as $\square = \frac{ya+xb}{xy}$.

Comments and Cautions. First, I explain the notations \square and $\stackrel{?}{=}$.

\square . If we are trying to express something as a fraction, then we need another name for it to use during the process. The thing is usually given with a compound name (e.g., $\frac{2}{a} + 7 \times \frac{2}{b}$), but it is hard to work with this and still think of it as a single object. It helps to use a temporary name, e.g., “let $A = \frac{2}{a} + 7 \times \frac{2}{b}$ ”. But using a symbol means we have *three* symbolic names in play, and recycling a symbol (for instance using “A” in both Examples (2) and (5)) invites confusion. The neutral placeholder, \square , encodes no structure and has no hidden or lasting significance.

$\stackrel{?}{=}$. This addresses problems with sloppy use of “=”. In common use this can mean “define x by...”; “it is *always* true that...”; “is it always true that...?”, or “determine *when* it is true that...”. The equation alone is incomplete, and the intended meaning is to be inferred from context. This ambiguity becomes invisible to experienced users, but students—and many teachers—do not understand it and it is a constant source of confusion (see question 2, p. 390, in [2]). Computers do not understand it either, and the programming language of *Mathematica* provides at least six different symbols for different meanings of “=”. In the example here we want to begin with an equality posed as a question and end with the same expression as an assertion. Confusion is inevitable if the notation does not display the difference between the two.

Caution. There is an additional ambiguity in the use of $\square = \frac{a}{b}$ as short for “ \square can be written as $\frac{a}{b}$ ”. The difficulty can be seen by rephrasing Example (2) as “show that $\frac{ca}{cb} = \frac{a}{b}$ ”. The typical response is “clear denominators by multiplying by cb and b to get $b(ca) \stackrel{?}{=} cb(a)$. This is true so the original expression is true.” But this logic must be flawed because it does not require c to be nonzero.

The source of the flaw is that fractions (as names) encode a property as well as an underlying object. The symbol “=” only concerns underlying objects, while “can be expressed as” includes the additional information. Technically this leads people to overlook one of the two implications in the “if and only if” aspect of the definition. This error is essentially harmless, especially after “don’t divide by 0” is firmly internalized, and I think trying to fix or explain it would cause more problems than it would solve. I suggest teachers should be aware of it and use the more precise phrasing to evoke correct reasoning when appropriate—especially when verifying rules—and to answer questions about meaning. In ordinary practice the flawed version should be accepted.

More about Names. Using care about the difference between things and names resolves a lot of confusion. Again, this is too subtle for explicit use in elementary education, but teachers should be aware of it and terminology should be consistent with it. Examples:

- “Express $1.23 + 45.6$ as a decimal” rather than “find $1.23 + 45.6$ ”. The expression specifies a number, so it is already “found”. The decimal name encodes a particular construction of the number in addition to the number itself, and the objective is to find the construction-describing name.
- “Express $\frac{1}{2} + \frac{2}{3}$ as a fraction” rather than either “find” or “simplify”. As above, the expression already specifies a number, so it is not “lost”. We could convert the fractions to decimals and “find” it by adding these, but this does not give the desired form. Finally, “simplify” is ambiguous: the sum is the partial-fraction form of the rational number, so is already “simplified” in this sense.

Integer Partial Fractions

One objective is to foreshadow a standard rational-function topic in the Polynomial Partial Fractions subsection. This might also illustrate that there are lots of interesting problems within mathematics.

First, a theorem. Theorems are great labor-savers: they explain what you can do with complete confidence, and what the limits are. In this case, for instance, you should expect that attempts to separate nonrelatively prime factors will fail in some way.

Theorem 1. *If b and c are relatively prime, then fractions with denominator bc can be expanded as $\frac{a}{bc} = \frac{x}{b} + \frac{y}{c}$, for some x, y .*

This is true essentially whenever the terms make sense (any commutative ring) and is an immediate consequence of the definition of relatively prime: a, b are *relatively prime* if there are m, n so that $am + bn = 1$. This is the correct general definition, but it is cumbersome to use, and in practice (integers here, and real polynomials in the Polynomial Partial Fractions subsection) one uses refinements of both “relatively prime” and the expansion.

Theorem 2 (Refinements for integers).

- (1) *For integers, “relatively prime” is the same as “have no common factor” (except 1, of course).*
- (2) *if b_1, b_2, \dots, b_n are pairwise relatively prime, then there is a unique expansion*

$$\frac{a}{b_1 \times \dots \times b_n} = \frac{r_1}{b_1} + \frac{r_2}{b_2} + \dots + \frac{r_n}{b_n} + q$$

with all the $\frac{r_i}{b_i}$ proper fractions and q an integer.

For integer fractions, $\frac{a}{b}$ *proper* means that $b > a \geq 0$; see the section Polynomial Partial Fractions for the polynomial version. Note that the version for a single factor, $\frac{a}{b} = \frac{r}{b} + q$ with $\frac{r}{b}$ proper, is the usual quotient-with-remainder expression for $a \div b$.

This refinement is true because the Euclidean algorithm works in the integers. In fact, there is an algorithm for the numerators in the expansion, see the Wikipedia entry on the extended Euclidean algorithm. The algorithm is cumbersome and obscure, so modular arithmetic is used here.

Problem. Express $47/180$ as a sum of an integer and proper fractions with prime-power denominators.

Solution. $180 = 2^2 3^2 5$ so the maximal partial fraction expansion is of the form $\frac{a}{4} + \frac{b}{9} + \frac{c}{5} + d$.

The first step must be to clear denominators: fractions are defined implicitly, and we must convert to an explicit form to work with them (see the earlier subsection Fractions). This gives

$$\begin{aligned} 47 &= (4 \cdot 9 \cdot 5) \left(\frac{a}{4} + \frac{b}{9} + \frac{c}{5} + d \right) \\ &= 9 \cdot 5a + 4 \cdot 5b + 4 \cdot 9c + 4 \cdot 9 \cdot 5d. \end{aligned}$$

Reduce mod 4 to get $47 \equiv 3 \equiv 45a \equiv a$. This means $a = 3 + 4r$, and the numerator that gives a proper fraction is 3. Next reduce mod 9 to get $2 \equiv 2b$, so $b \equiv 1$. Finally reduce mod 5 to get $2 \equiv 2c$.

We now know that $47/180 = \frac{3}{4} + \frac{1}{9} + \frac{2}{5} + d$, with d an integer. We can find d by converting the partial fractions back to a common denominator, but we could also use a calculator. The left side is approximately 0.2611, while the fractions on the right add up to about 1.2611. Since d is an integer it must be -1 , and

$$47/180 = \frac{3}{4} + \frac{1}{9} + \frac{2}{5} - 1.$$

Multiplying Polynomials

This section illustrates how careful attention to cognitive issues and mathematical structure can significantly extend the problem types students can do. The main cognitive concern is that different activities (here organization, addition, and multiplication) should be separated as much as possible. Structure is used to make the procedure flexible; see the next section for a variation. See [4](a) for detailed discussion.

Problem. Write the product $(2y^3 + y^2 - 9)(-y^2 + 5y - 1)$ as a polynomial in y , in standard form.

“Standard form” here means coefficients times powers of the variable, with exponents in descending order. The factors are given in this standard form. Sometimes ascending order is used.

Solution. The first step is purely organizational. We see that the outcome will be a polynomial of degree 5, so set up a template for this:

$$y^5[\quad] + y^4[\quad] + y^3[\quad] + \cdots$$

(with enough space between brackets for the next step).

Next scan through the factors and put coefficient products in the right places. To get the y^3 coefficient, for example, begin with the leftmost term in the first factor. Record the coefficient, (2). The exponent is 3, so the complementary exponent is 0. Beginning at the right in the second factor, we see that the coefficient on y^0 is -1 , so we record this as a product $(2)(-1)$. Now move one place to the right in the first factor and record coefficient (1). The exponent is 2, so look for complementary exponent 1 in the second factor. The coefficient on this is 5, so record this as $(1)(5)$. Again move one place to the right in the first factor and record coefficient (-9) . The exponent is 0, so we look for complementary exponent 3 in the second factor. There is none, so we record coefficient 0 as $(-9)(0)$. The template will now look like

$$\cdots + y^3[(2)(-1) + (1)(5) + (-9)(0)] \cdots$$

It is quite important that *no arithmetic* be done in the organizational phase, not even $(1)(5) = 5$. Also, we usually quit scanning the first factor when complementary exponents are above the degree of the second, but it is better to record overruns such as $(-9)(0)$ than to worry about this. The reason is that even trivial on-the-fly arithmetic requires a momentary break in focus that significantly increases error rates in both organization and arithmetic. For the same reason, every coefficient is automatically enclosed in parentheses whether they are needed or not.

The first arithmetic step is to do the multiplications:

$$\begin{aligned} &y^5 \left[\underbrace{(2)(-1)}_{-2} \right] + y^4 \left[\underbrace{(2)(5)}_{10} + \underbrace{(1)(-1)}_{-1} \right] \\ &+ y^3 \left[\underbrace{(2)(-1)}_{-2} + \underbrace{(1)(5)}_5 + \underbrace{(-9)(0)}_0 \right] + \cdots \end{aligned}$$

The second arithmetic step is to do additions:

$$\begin{aligned} &y^5 \left(\underbrace{(2)(-1)}_{-2} \right) + y^4 \left(\underbrace{(2)(5)}_{10} + \underbrace{(1)(-1)}_{-1} \right) \\ &+ y^3 \left(\underbrace{(2)(-1)}_{-2} + \underbrace{(1)(5)}_5 + \underbrace{(-9)(0)}_0 \right) + \cdots \end{aligned}$$

Additions and multiplications are separated because, again, switching back and forth invites errors. Note also that this pattern requires essentially no organizational activity during the arithmetic steps: everything is in standard places, and outcomes are written just below inputs.

The final result is

$$y^5(-2) + y^4(9) + y^3(3) + y^2(8) + y^1(-45) + 9.$$

Discussion. Standard high-school practice is to restrict to product of binomials and use the intelligence-free algorithm with acronym “FOIL”. This is so ingrained that many students say “FOIL it” rather than “expand”, even when the factors are not binomials. However, this algorithm mixes organization and arithmetic enough that some students have trouble even with this simple case, and since the expansion step is not adapted to the eventual goal, a second sorting step is needed. Finally, the near-exclusive focus on binomials makes larger expressions foreign territory. Some students are at a loss about how to deal with them, others generalize incorrectly from the pattern, and almost all are anxious and hesitant. A better algorithm fixes all this and opens up a much wider world.

Polynomial Partial Fractions

The final example brings together fractions, partial fractions, and polynomial multiplication. The analogue of modular arithmetic is included in the supplement [5]. Theorem (1) in the earlier subsection Integer Partial Fractions applies, but, as in that section, we need a refinement.

Theorem 3 (Refinement for polynomials).

- (1) For polynomials “relatively prime” is the same as “have no common factor” and the same as “have no common roots” (including complex roots).
- (2) If b_1, b_2, \dots, b_n are pairwise relatively prime real-coefficient polynomials, then there is a unique expansion

$$\frac{a}{b_1 \times \dots \times b_n} = \frac{r_1}{b_1} + \frac{r_2}{b_2} + \dots + \frac{r_n}{b_n} + q$$

with r_i, q polynomials and each $\frac{r_i}{b_i}$ a proper fraction.

A polynomial fraction is called proper if the degree of the numerator is strictly smaller than the degree of the denominator. The term has the same significance as the integer version even though the definitions are different. As with integers, q is the result of division (the “quotient”) and the r_i are remainders.

This statement is almost identical to the integer statement. This emphasizes commonality of the underlying structure, but the main reason is efficiency: since the underlying structures *are* the same, a maximally efficient statement for one context will also be maximally efficient for the other.

Problem. Find the real partial-fraction expansion of the polynomial fraction

$$\frac{3x^3 + 2x + 9}{(4x^2 - 4x + 1)(x^2 - 2x + 3)}.$$

Solution, Setup. The first quadratic in the denominator factors as $(2x - 1)^2$, but these factors cannot be separated because they are not relatively prime. The second quadratic has complex roots, so it can be factored over the complexes as a product of linear terms. These could be separated in a partial-fraction expansion over \mathbb{C} , but not over \mathbb{R} . The denominators in the partial fractions are therefore the two quadratics. Finally, the input fraction is proper, so the expansion cannot have a (nonfraction) polynomial term (note this conclusion is special to polynomials: it does not work for integers).

Both pieces in the expansion have denominators of degree 2, and we know that the numerators have smaller degree. The expansion is therefore of the form

$$\frac{3x^3 + 2x + 9}{(4x^2 - 4x + 1)(x^2 - 2x + 3)} = \frac{ax + b}{4x^2 - 4x + 1} + \frac{cx + d}{x^2 - 2x + 3}.$$

As usual, to work with fractions we have to clear denominators. This gives

$$(1) \quad \begin{aligned} 3x^3 + 2x + 9 &= (ax + b)(x^2 - 2x + 3) \\ &+ (cx + d)(4x^2 - 4x + 1). \end{aligned}$$

Solution, Linear-Algebra Approach. Here we illustrate the use of linear algebra to find the coefficients in the expansion above. The supplement [5] also includes a modular-arithmetic approach analogous to the integer procedure. Equation (1) is an equality of polynomials, so the coefficients must be equal. The coefficient equations give the linear system that determines $a-d$.

The plan is as follows: for each exponent n scan through the products above and pick out coefficients on x^n , exactly as in the section on polynomial products. Recording coefficients gives

$$\begin{aligned} x^3 : & \quad 3 = a(1) + c(4) \\ x^2 : & \quad 0 = a(-2) + b(1) + c(-4) + d(4) \\ x^1 : & \quad 2 = a(3) + b(-2) + c(1) + d(-4) \\ x^0 : & \quad 9 = b(3) + d(1). \end{aligned}$$

Writing this linear system in matrix form gives

$$\begin{pmatrix} 1 & 0 & 4 & 0 \\ -2 & 1 & -4 & 4 \\ 3 & -2 & 1 & -4 \\ 0 & 3 & 0 & 1 \end{pmatrix} \begin{pmatrix} a \\ b \\ c \\ d \end{pmatrix} = \begin{pmatrix} 3 \\ 0 \\ 2 \\ 9 \end{pmatrix}.$$

Problems this involved are necessary to illustrate some of the phenomena, but full solutions are not always necessary. A possibility is to ask “find a linear system that determines the coefficients...” to avoid the linear algebra. Setting up the system is

an important goal in any case because in the long run they would enter

```
LinearSolve[{{1, 0, 4, 0}, {-2, 1, -4, 4},  
{3, -2, 1, -4}, {0, 3, 0, 1}}, {3, 0, 2, 9}]
```

in a computer-algebra system,³ and obtain $(\frac{319}{81}, \frac{214}{81}, -\frac{19}{81}, \frac{29}{27})$. Even if a full solution is required, then the problem statement should be “find a linear system that determines the coefficients, and then solve to find the expansion.” Requiring explicit display of the intermediate step has two functions: first, if the final answer is wrong, then the intermediate step can be used to locate errors. The second reason is to ensure that students carefully formulate the intermediate step, especially if the system is to be solved by hand. Many will try to save writing (and thinking) by solving on the fly as coefficients are found (e.g., for the x^3 coefficient writing $a = 3 - 4c$ and using this to eliminate a). They could use this strategy to solve the system after it is set up, but mixing the steps increases the error rate and in the long term will limit the problems they can handle.

As a final note, if the input fraction were not proper, then the q term in Theorem 3 would be nonzero. It can be included in the cleared-denominator form (1) and handled the same way. Most approaches recommend first using long division to get q (the quotient) and a proper fraction (with remainder as numerator), and then expanding the proper fraction. The division algorithm gives the coefficients in the quotient, so the remaining coefficients give a smaller linear system. But division takes a lot more work. The extra part of the larger linear system has lower triangular coefficient matrix so does not add much to the difficulty.

Word Problems

This is a crucial topic because contemporary educators put great emphasis on word problems, but they use a problematic approach. There is an abstract discussion in the earlier subsection Limits of Mathematics; here I illustrate the use of modeling to avoid the problem.

A *mathematical model* is a translation of a real-world or word problem to a symbolic form suitable for mathematical analysis. The key feature is that little or no analysis is done during modeling, and no modeling is done during analysis of the model. Three examples are given. The first and second are typical number-and-word problems with little or no mathematical content. The third illustrates the use of algebra to explore a problem about statistics. The supplement [5] has additional examples and illustrates difficulties with “trick problems”.

³This is Mathematica syntax.

Example 1: Buying Pencils. This was suggested to me as representative of a common and important problem type. Educational goals are discussed below.

Frank bought 8 pencils at 32 cents apiece.
How much did he pay?

Mathematical Model. This is a rate problem, with model:

$$\begin{aligned} &(\text{number of pencils, items}) \times (\text{cost rate, cents/item}) \\ &= (\text{total cost, cents}). \end{aligned}$$

Plugging in values gives $8 \times 32 = 256$ cents, or \$2.56.

Rate equations and the format that includes units (here items and cents) are discussed in the next problem.

Problems with the Model. As a reality check, Frank actually did buy some pencils.

- Pencils are now sold in blister packs. I got one pack of 8 for \$2.57. Math was unnecessary.
- I paid \$2.70, including \$0.13 Virginia sales tax.

No one really expects problems like this to have much relation to reality, but this illustrates a point made in the subsection Limits of Mathematics. If this is a math problem, then, evidently, math does not connect well with reality. Separating modeling and analysis gives a better picture: it is the model that is faulty, and the mathematical analysis of the model is perfectly correct.

Problems with Educational Goals. There are two points of view on such problems. One is that they bring math to life. Teachers reading them can almost smell the pencils. The other is that they are a “thinly disguised invitation to multiply”, with some unpackaging activity that does not qualify as modeling.

The students I have asked about this almost unanimously despise these problems and ignore the charming context. They parse it as “...8...32...apiece”: two numbers, multiply. Some educators even teach a “keyword” approach to determine the operation. So the bring-to-life idea fails, but pencils no longer smell good anyway.

I have serious concerns with the second view. First, why are large numbers of thinly disguised trivial arithmetic problems a good thing? They improve grades and test scores, but do they contribute in any real way to learning? Second, it is not a good idea to encourage “unpackaging” without modeling. The carefully formulated model uses a rate equation, and making it explicit connects with more complicated work (see the next problem). Conversely, hiding rate equations will cause confusion later. More generally, “reasoning

in context” with intuitive “unpackaging” is a hard-to-break habit that seriously limits outcomes in later courses.

Example 2: Leaky Fuel Tank.

A car begins a trip with 40 liters of fuel and drives at a constant speed 70 km/hr. At this speed the car gets 12 km/liter, but it runs out of fuel after 360 km. Apparently the fuel tank is leaking. If it leaks at a constant rate, what is the rate (liter/hr)?⁴

Model. The rate of loss is (fuel Lost)/(Time); denote this by L/T . There are two rate equations, and the relation of (fuel Lost) to (fuel Used):

- (1) (speed, km/hr)×(Time, hr) = (distance, km)
- (2) (distance rate, km/liter)×(Used, liter) = (distance, km)
- (3) (Lost, liter) = (total, liter) - (Used, liter).

Now put in the numbers from the problem statement:

- (1) $70 T = 360$
- (2) $12 U = 360$
- (3) $L = 40 - U$.

Solve to get $T = 36/7, U = 30, L = 10$, and therefore $L/T = 70/36 = 35/18 \approx 1.94$ liters/hour.

Discussion. The first step was to write the rate equations in a symbolic form designed to be easily and reliably remembered. Neither numerical values nor *any* analytic reasoning are done in this step. Trying to look ahead, for instance “I need to know the time, so write the speed rate equation as (time)=(distance)/(speed)...” invites errors. This problem is significantly more difficult without modeling because there are so many opportunities for such errors. Note also that the rate equations are written with units, so dimensional analysis can be used as a check that they are correct. In particular, the rate in the fuel use equation is given as a *distance* rate (km/liter) rather than a *fuel* rate (liter/km). The latter seems more logical (see the next problem), and confusion on this point is likely to be a source of error.

The last step is to substitute numbers into the symbolic forms, and then solve. This is routine, and easy because the analysis is protected from cognitive interference with modeling.

As an aside, it is a common criticism of such problems that “constant rate” cannot be made precise without derivatives (cf. [6]). This is not correct: “constant rate” means a rate equation applies, and this makes perfect sense if it is made explicit. Variable rates need derivatives.

⁴Adapted from a Massachusetts high school problem via a “puzzler” from the National Public Radio program Car Talk.

Example 3: Fuel Efficiency. This illustrates a common way to misuse statistics. Comparison with the degraded version illustrates the benefits of symbols rather than the usual inert numbers.

A regulatory agency wants to promote development of fuel-efficient cars. The regulations require a certain *average* efficiency to provide automakers flexibility and incentive: they can offer inefficient models if these are balanced by super-efficient ones. However, an environmental group claims that if the regulators use the traditional km/liter measure of automotive efficiency, then more efficient models will actually lead to *increased* fuel use. Are they right? Which measure should be used to avoid this?

Symbolic Specific Problem. Suppose there is a target efficiency T km/liter. A manufacturer sells two models: an efficient one that gets rT km/liter for some efficiency multiplier $r > 1$, and an inefficient one that gets b km/liter so that the average of rT and b is T .

- (1) Find the average of the fuel required by the two models to go distance d . Express this as the product of the fuel required by a car with average efficiency T and a function $h(r)$.
- (2) Evaluate $h(r)$ for $r = 4/5$ and $5/3$. Plot $h(r)$ (by calculator or computer) on the interval $[1, 1.8]$. For which efficiency multipliers r does the two-model fleet use more fuel than average-efficiency cars?
- (3) Find r so that the two-model fleet uses twice as much fuel as a fleet of average-efficiency cars.
- (4) Explain what could theoretically happen if the automakers developed a car with efficiency *twice* the target (i.e., $r = 2$).

Discussion. The previous problem provides an appropriate template for the modeling step, so an explicit solution is not given here.

Is there a better measure? Here we are interested in total fuel use. The km/liter measure has rate equation

$$(\text{fuel, liter}) = \frac{(\text{distance, km})}{(\text{distance rate, km/liter})}$$

so it is *inversely* related to fuel use. But standard statistical methods are additive: they work well if the data have a linear structure, poorly otherwise. This explains why the km/liter measure works poorly. The *linearly* related efficiency measure is the inverse, the fuel rate in liter/km with rate equation

$$(\text{fuel, liter}) = (\text{distance, km})(\text{fuel rate, liter/km}).$$

It would therefore be more honest to use the fuel rate in the statistical analysis.

Degraded Specific Problem. The regulatory agency sets 12 km/liter as the target efficiency. A manufacturer sells two models: an efficient one that gets 18 km/liter and an inefficient one that gets b km/liter so that the average of 18 and b is 12.

- (1) Find the average of the fuel required by the two models to go 100 km. Compare with the fuel required by a car with average efficiency 12.
- (2) Repeat for high-efficiency rates 20 and 22. Describe the pattern you see as the better efficiency increases.

The use of specific numbers is typical of contemporary practice. This makes it easier to do without modeling and more accessible to direct evaluation on a calculator. On the other hand, a great deal of mathematical structure has been lost. The average fuel use as a function of the upper efficiency is now represented by a few numerical values. These suggest part of the pattern but do not make obvious the infinite limit at upper efficiency 24. Further, the use of a specific numerical target hides the fact that the controlling parameter is the quotient (max efficiency)/(target efficiency), called r in the first version. All this structure emerges from essentially the same work done symbolically.

The use of numerical values is also a favorite tactic of test designers. The first version is a single problem. Plugging in numbers gives a large number of seemingly different problems. But don't we *want* students to see structure and patterns? Destroying it for the convenience of test design and calculator evaluation seems inappropriate.

Teacher Preparation

Outcomes from K-12 education are unsatisfactory and not improving. Angst about this has mainly focused on teacher preparation, implicitly assuming that educational methodology is effective and the problem is incompetent teachers. The discussion here suggests an alternative: it is the methodology that is incompetent, and worse outcomes might actually reflect *better* teaching of the methodology. If this is the case, then the methodology has to be straightened out before there is much point in discussing teacher preparation.

The issue is approached through analysis of two common but conflicting viewpoints about advanced study.

Advanced Study *Not* Necessary?

The school-of-education argument is essentially "our students have trouble with advanced courses and don't get much from them. Pedagogy is more important than content anyway."

Wu [6] tries to give this point of view more substance by citing an article of Begle that found no correlation between advanced coursework and better student outcomes. Wu concludes that advanced

viewpoints are irrelevant to elementary education and uses fractions to illustrate the reasons. However, his description of fractions is inaccurate (see the supplement [5] for discussion), and what this actually shows is that imprecision and sloppy notation that are harmless at advanced levels can render the presentation irrelevant to elementary teaching. More care can give more relevance: see [4](b) for a relatively painless extension of the fraction material in the subsection Fractions to commutative rings. This includes dealing with zero-divisors; not K-12 classroom material, but it certainly clarifies why having 0 in the denominator is a bad idea. It also connects with modern themes by observing that Grothendieck groups are just a fancy name for fractions when they are approached this way. On the other hand, I agree that courses such as real and complex analysis are unnecessary: they have little to do with K-12 topics and benefits to survivors are unlikely to justify the severe attrition among potential teachers.

Examples such as the above suggest that modern advanced courses with appropriate topics and precision could connect nicely with K-12 *topics*, but the next discussion reveals a problem with *methodology*.

Advanced Study *Is* Necessary?

Most people with technical backgrounds feel teachers need more mathematics but cannot clearly articulate why. It seems to me the essence is "my background leads me to feel that educators are doing bad things. If they had stronger backgrounds they would feel the same way, and do better." Roughly, the need is for more sophistication and mathematically disciplined thinking. The standard way to get these is subliminally from the material during extensive study, so more study seems to be the solution. According to Begle, however, the teachers who did have enough advanced study to internalize the mindset do not do any better as teachers.

There is a disturbing explanation for this. Advanced study leads to internalization of *modern* methodology. Education is modeled on a philosophical description of mathematical practice in the nineteenth century and before,⁵ centered around romanticized ideas about the power of intuition. In professional practice this was abandoned as ineffective in the early twentieth century. However, educators reject contemporary professional methods as inappropriate for normal humans. This bias makes internalization from advanced courses useless. In fact, the conviction that the nineteenth century was a better time for children is so strong that mathematicians working in education tend to

⁵For extensive historical and technical background on this see [3].

buy into it and suspend their professional skills and sensibilities.

Conclusions

Genuinely productive discussion of teacher preparation must wait for resolution of deeper problems:

- (1) Core methodology for mathematics education is stuck in the nineteenth century.
- (2) The approach to applications (word problems) is stuck in the sixteenth century, and much of geometry is stuck in the third century BCE.
- (3) Until this changes, we should not expect outcomes better than those of antiquity.
- (4) Until this changes, advanced coursework with twentieth-century methodology will be irrelevant.

On a brighter note, the science-of-learning methodology described here is compatible with modern mathematics, and advanced coursework would be relevant to teaching based on this approach. Moreover, students trained this way would not find modern mathematics so totally alien, and the calculus/proof transition would not be the killer that it is today.

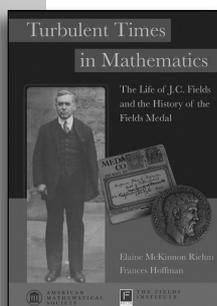
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Turbulent Times in Mathematics

The Life of J.C. Fields and the History of the Fields Medal

Elaine McKinnon Riehm and Frances Hoffman

One of the little-known effects of World War I was the collapse of international scientific cooperation. In mathematics, the discord continued after the war's end and after the Treaty of Versailles had been signed in 1919. Many distinguished scientists were involved in the war and its aftermath, and from their letters and papers, now almost a hundred years old, we learn of their anguished wartime views and their struggles afterwards either to prolong the schism in mathematics or to end it.

J.C. Fields, the foremost Canadian mathematician of his time, championed an international spirit of cooperation to further the frontiers of mathematics. It was during the awkward post-war period that J.C. Fields established the Fields Medal, an international prize for outstanding research, which soon became the highest award in mathematics.

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... This work is a triumph of persistence with far-flung archival and documentary sources, and provides a rich non-mathematical portrait of the man in all aspects of his life and career. Highly readable and replete with period detail, the book sheds useful light on the mathematical and scientific world of Fields' time, and is sure to remain the definitive biographical study.

—Tom Archibald

Simon Fraser University, Burnaby, BC, Canada

... Riehm and Hoffman provide a vivid account of Fields' life and his part in the founding of the highest award in mathematics. Filled with intriguing detail ... it is a richly textured story engagingly and sympathetically told. Read this book and you will understand why Fields never wanted the medal to bear his name and yet why, quite rightly, it does.

—June Barrow-Green

Open University, Milton Keynes, United Kingdom



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WHAT IS . . .

a Stationary Measure?

Alex Furman

The concept of a stationary measure appears in probability, dynamics of group actions, and foliations of manifolds. But it can also be related to such real-life experiences as card shuffling and searching the Internet.

Markov Chains and Markov Operators

Let $P = (p_{ij})$ be a $k \times k$ stochastic matrix, i.e., a matrix with nonnegative entries satisfying $p_{i1} + \dots + p_{ik} = 1$ for each $1 \leq i \leq k$. We view p_{ij} as the probability of moving from state i to state j . Given P and some distribution ν_0 on $\{1, \dots, k\}$, the corresponding *Markov chain* is a sequence $\{X_n\}_{n \geq 0}$ of random variables with values in $\{1, \dots, k\}$, where X_0 is chosen according to ν_0 , and for each $n \geq 0$ the value of X_{n+1} given X_0, \dots, X_n depends only on the value of X_n , and $X_{n+1} = j$ with probability p_{ij} provided $X_n = i$. Then the distribution ν_n of X_n is $\nu_n = P^* \nu_{n-1} = \dots = (P^*)^n \nu_0$, where $P_{ij}^* = p_{ji}$. A *P-stationary measure* is a solution to the equation: $\nu = P^* \nu$.

Observe that the distribution ν_n of the n th step X_n of the Markov chain defined by a stationary measure ν remains stable: $\nu_n = \nu$. Any finite Markov chain is guaranteed to have a stationary measure. Indeed, any stochastic P satisfies $P1 = 1$. Thus 1 is an eigenvalue for P and therefore also for P^* . Writing a P^* invariant ν as $\nu = \nu^+ - \nu^-$ with $\nu^+, \nu^- \in (\mathbb{R}_+)^k$, we obtain $P^* \nu^\pm = \nu^\pm$ because P^* preserves the positive cone; if $\nu^+ \neq 0$ take $\nu = (\sum \nu_i^+)^{-1} \cdot \nu^+$, otherwise normalize ν^- . Another argument for the existence of stationary measures is by Brouwer's fixed point theorem applied to the P^* -invariant simplex of probability measures $\Delta = \{q_i \geq 0, \sum q_i = 1\}$.

Often (e.g., if $P_{ij}^{n_0} > 0$ for some n_0 and all i, j) there is only one stationary measure ν , and given any initial distribution ν_0 the distributions $\nu_n = (P^*)^n \nu_0$ converge to ν exponentially fast (Perron-Frobenius theorem).

Apparently Google uses this phenomenon in its page-ranking algorithm, where thousands of

sites containing the searched-for words have to be ranked by their "relevance". Imagine a graph whose vertices are the sites found in a particular search and interconnected by links between them. One assumes that sites that are better connected (linked to or from) within this graph are most relevant and that the stationary measure for this graph can be used to determine the ranking of the search results. Since the convergence to the stationary measure is very fast, it can be approximated by the n th step of the random walk, rather than by a calculation of the eigenfunctions of the potentially huge matrix.

Card shuffling is another, much older, example. Performing a number of shuffles, say cutting the deck at random places, is implicitly assumed to produce permutations of the deck with an approximately uniform distribution. From a mathematical standpoint, a finite group (S_{52}) acts transitively on a set (fifty-two cards), and some probability measure μ is given on a generating set (cut-shuffles) of the group. This defines a Markov chain $p_{ij} = \mu\{g : gi = j\}$, and one can show that the uniform measure is the unique stationary one on this set. This example appears already in Poincaré's *Calcul des probabilités* (1912).

Markov chains are generalized by *Markov operators* on, say, a compact space X . Let $\{\mu_x\}_{x \in X}$ be a family of Borel probability measures on X , so that $x \mapsto \mu_x$ is continuous in the weak-* topology. This defines a (positive, normalized) operator on $C(X)$ by $Pf(x) = \int_X f(y) d\mu_x(y)$. The dual operator P^* acting on $C(X)^* = \mathcal{M}(X)$ preserves the convex weak-* compact subset $\text{Prob}(X)$ of probability measures. In this setting, stationary measures are solutions in $\text{Prob}(X)$ to $\nu = P^* \nu$. Existence of stationary measures is now guaranteed by the Markov-Kakutani fixed point theorem.

μ -Stationary Measures

Next consider a continuous action $G \curvearrowright X$ of some locally compact group G on a compact space X . We say that X is a compact G -space. Fix a probability measure μ on G and define a Markov operator $\{\mu_x\}$ on X by pushing μ forward via $g \mapsto g.x$.

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This Markov operator on $\text{Prob}(X)$ is given by the convolution $\mu * \nu = \int g_* \nu d\mu(g)$. Stationary (or rather μ -stationary) measures are solutions to

$$(1) \quad \nu = \mu * \nu.$$

Note that any G -invariant measure on X is μ -stationary for any μ on G ; however, many important actions of large groups (precisely the nonamenable ones) leave no probability measure invariant. Yet any compact G -space X is entitled to a μ -stationary measure ν .

Here is a beautiful application of this fact (observed by Deroin-Kleptsyn-Navas): *any countable subgroup $G < \text{Homeo}(S^1)$ of the group of homeomorphisms of the circle is conjugate to the subgroup of bi-Lipschitz homeomorphisms.* Indeed, fix a measure μ of full support on G and let ν be a μ -stationary measure on the circle. Then it follows from (1) that $\frac{dg_* \nu}{d\nu} \leq \mu(g)^{-1}$, and the required conjugation can be realized by any circle homeomorphism mapping ν to the Lebesgue measure.

Poisson-Furstenberg Boundaries

Now let us very briefly discuss the notions of μ -stationary measures, μ -harmonic functions, and Poisson (or rather Poisson-Furstenberg) boundaries that were developed by Furstenberg in his study of random walks on groups [2] and that continue to play an important role in rigidity, dynamics, and geometry.

Let ν be a μ -stationary measure on some G -space X . If μ is sufficiently nice, say absolutely continuous with respect to the Haar measure on G and not supported on a proper closed subgroup, then ν is G -quasi-invariant. Consider the transform $\Pi : L^\infty(X, \nu) \rightarrow L^\infty(G)$ given by

$$(2) \quad \Pi f(g) = \int_X f(x) dg_* \nu(x) = \int_X \frac{dg_* \nu}{d\nu}(x) f(x) d\nu(x).$$

Equation (1) implies that $u = \Pi f$ satisfies a μ -mean value property

$$u(g) = \int_G u(gh) d\mu(h).$$

Such functions are called *bounded μ -harmonic*. In the case of $G = \text{PSL}_2(\mathbb{R})$ acting on the circle $X = \mathbb{R} \cup \{\infty\}$ and μ being a bi- $\text{SO}(2)$ -invariant measure, bounded μ -harmonic functions u on G are lifts of the classical harmonic functions on the Poincaré disc $\text{PSL}_2(\mathbb{R})/\text{SO}(2)$, and (2) is the classical Poisson transform.

This construction has an analogue in the completely general setting of an arbitrary locally compact group G and a nice probability measure μ on it. Namely, there exists a G -space X with a μ -stationary measure ν , so that transform (2) is an isometric isomorphism between $L^\infty(X, \nu)$ and the subspace of bounded μ -harmonic functions in $L^\infty(G)$. Such an (X, ν) is defined uniquely as a

measurable G -space; it is called the *Poisson* or the *Poisson-Furstenberg* boundary $\text{PF}_\mu(G)$ of (G, μ) .

Such boundaries have been identified explicitly in many examples, including semisimple Lie groups and their lattices, where PF_μ is a compact homogeneous space of the Lie group ([2]); Gromov hyperbolic groups Γ , where PF_μ is realized on the Gromov boundary $\partial\Gamma$; and many other situations (see [3]).

The G -action on PF_μ has important dynamical properties—the action is *amenable* and *ergodic* in a very strong sense. The dynamics of $G \curvearrowright \text{PF}_\mu$ and, in particular, the structure of their equivariant quotients play a crucial role in proofs of many remarkable rigidity results for representations of lattices, group actions on manifolds, computations of bounded cohomology, and more.

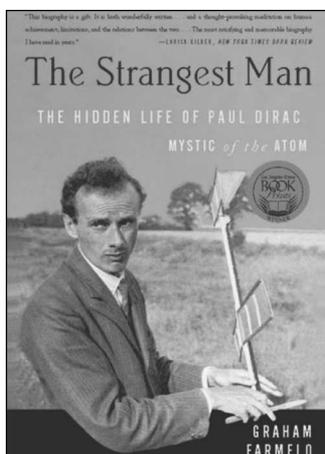
Stiff Actions

Studying dynamics of a single transformation $T : X \rightarrow X$, one is interested in closed invariant sets, invariant measures, and limiting distributions for orbits of individual points. Famously, Ratner's theorems provide a complete classification of these objects for unipotent flows on homogeneous spaces.

Recently, significant progress has been made on analogous problems for algebraic actions of large groups Γ , such as $\Gamma < \text{SL}_d(\mathbb{Z})$ acting on the torus $X = \mathbb{R}^d/\mathbb{Z}^d$ ([1]), or $\Gamma < \text{SL}_d(\mathbb{R})$ acting on $X = \text{SL}_d(\mathbb{R})/\text{SL}_d(\mathbb{Z})$ ([4]). In this context, any Γ not contained in a proper algebraic subgroup $L \leq \text{SL}_d(\mathbb{R})$ is “large” enough. The acting group Γ is nonamenable; thus the role played by invariant probability measures in Ratner's theorems is taken here by stationary ones. For example, classification of closed invariant sets is deduced from the classification of stationary measures. These turn out to be invariant (such actions are called *stiff*): either atomic on a finite Γ -orbit, or uniform, or convex combinations of these. Hence using a few matrices from $\text{SL}_d(\mathbb{Z})$ at random, one can very effectively shuffle the deck of torus points to get a uniform distribution.

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The Strangest Man: The Hidden Life of Paul Dirac, Mystic of the Atom

Reviewed by Brian E. Blank

The Strangest Man: The Hidden Life of Paul Dirac, Mystic of the Atom

Graham Farmelo

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In September 1926 Paul Dirac began a five-month visit with Niels Bohr at the Institute for Theoretical Physics in Copenhagen. Dirac, then barely twenty-four years old, had been in possession of his Ph.D. since only May of that year. Bohr was middle aged and already a Nobel laureate, but he was accustomed to working with junior colleagues. Nevertheless, collaboration between the two physicists proved to be impossible. Whereas Dirac was taciturn, Bohr was voluble: his habit of thinking out loud produced a constant stream of sentences in need of revision or retraction. By bouncing half-baked ideas off Dirac, Bohr elicited little more than the response, “At school I was always taught not to start a sentence until I knew how to finish it.” When Bohr bemoaned to Ernest Rutherford, “Dirac never says anything,” Rutherford replied with a story about a shop owner assuaging a dissatisfied customer who had purchased a parrot that would not speak. “Please forgive me. You wanted a parrot that talks, and I gave you the parrot that *thinks*.”

Dirac departed Copenhagen in January 1927 to stay with Max Born in Göttingen. In doing so, he joined the steady flow of promising young physicists who traveled between those two centers of quantum physics in the 1920s. According to Max Delbrück, one of Born’s students and a future Nobelist, these peripatetics were “highly

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bizarre, genially mad, unworldly, and completely, decidedly difficult in their behavior toward their fellow man.” Even in that eccentric company, Dirac stood out. In a conversation with Kurt Gottfried in 1959, Bohr remarked that, of all the visitors to his institute, “Dirac was the strangest man.”

Graham Farmelo, Senior Research Fellow at London’s Science Museum and Adjunct Professor of Physics at Northeastern University, has cleverly co-opted Bohr’s characterization of Dirac for the title of his recently published biography. With a sparseness that would meet Dirac’s approval, *The Strangest Man* does double duty as a title: it intrigues the reader who is only moderately interested in Farmelo’s subject, and it announces a trait of Dirac that the reader will find relentlessly stressed. Farmelo’s subtitle, *The Hidden Life of Paul Dirac, Mystic of the Atom*, may also be an effective hook, but it is a deceptive one: the phrase “hidden life” suggests a kinky, shady, or salacious side of Dirac that did not exist. He did not deal in nuclear secrets, he abstained entirely from alcohol and tobacco, and he accepted only the weakest doses of caffeine. His love life was conventionally proper. When an incredulous physicist asked Dirac if he had any vices, the reply was, “No obvious ones.” Nothing in Farmelo’s book contradicts that.

Of course, Dirac did keep many aspects of his life private, and, as a conscientious biographer, Farmelo has made every effort to ferret them out. Dirac could, for example, spend a day at the cinema watching Mickey Mouse films, a vice he kept secret from his Cambridge colleagues. He also concealed his romance with Margit Balázs (née Wigner), Eugene Wigner’s younger sister. When anyone knocked at his door, the thirty-three-year-old bachelor took down a picture of Margit and hid it in a drawer. For Dirac, keeping a photograph of his swimsuited

future wife on the mantelpiece was as lurid as it got.

Paul Adrien Maurice Dirac was born in Bristol on August 8, 1902, to a Cornish mother and francophone Swiss father. Paul's childhood was not a happy one. In interviews he gave late in his life, Paul portrayed his father, Charles, as a cold tyrant who psychologically abused him and his older brother. It is this family dynamic that Farmelo highlights in the prologue with which he begins his work. The setting for the prologue is an evening in 1980 when Margit and Paul entertained a friend in their home. In the course of this social occasion, an innocuous detail Margit mentioned triggered a two-hour monologue during which Paul unburdened himself before his startled guest. "I never knew love or affection when I was a child," Paul volunteered. He also spoke of the tragedy of his brother, who, in 1925, bullied and frustrated by Charles at every turn, took his own life. Paul's visitor, aware of his host's reputation for equability and pathological reticence, was shocked to hear him angrily unleash the demons that had haunted him for seventy years.

Farmelo precedes his prologue with a brief extract from Samuel Butler's novel, *The Way of All Flesh*: "Unkindness and selfishness on the parts of parents towards children...may cast a gloom over their children's lives for many years." This self-evident observation, expressed without the wit or elegance usually found in a quotation, is actually an ingenious reference. Butler's semi-autobiographical story of Ernest Pontifex happened to be published a few months after Paul Dirac's birth. Charles Dirac might as well have used Ernest's father, Theobald, as a model for becoming a cruel, miserly, domineering paterfamilias. Whereas Ernest was forced to sing hymns before Theobald, Paul was forced to speak French to Charles. Just as Ernest was beaten when he mispronounced a word of a hymn, so was Paul punished for every error he made speaking French. When such slips occurred at dinner, Paul was refused permission to leave the table, even if he was sick. Time and again, Paul, who suffered from digestive problems all his life, was forced to stay put and vomit. In Paul's mind, this treatment was the basis of one of his trademark idiosyncrasies: to avoid punishment, he learned to say nothing.

After graduating with a first-class honors degree in electrical engineering from the Merchant Venturers' Technical College, an antecedent institution of the University of Bristol, Dirac won a small scholarship to Cambridge. Because Charles was unwilling to provide the remaining funds necessary for attendance, Dirac searched for a job instead. At the time, England was suffering from its worst economic slump since the Industrial Revolution, and Dirac joined the ranks of the two million unemployed. His luck turned when

the University of Bristol arranged for him to pursue a mathematics degree free of charge. On the completion of those studies, Dirac was awarded a more substantial scholarship to Cambridge, which he entered in October 1923.

By 1923 the atom had been actively studied for over a quarter century. Two constituents of the atom were then known: the electron, discovered in 1897, and the proton, discovered in 1919. For more than two decades, beginning with Max Planck's derivation of blackbody radiation in 1900 and Einstein's explanation of the photoelectric effect in 1905, quantum theory had been used to elucidate atomic phenomena. An important confirmation of quantum physics was provided by Arthur Holly Compton when, in 1923, he published his observations of collisions between the photons of incident electromagnetic radiation and the free electrons of an irradiated target, thereby demonstrating the particle nature of light. And yet, when Dirac arrived in Cambridge, he considered atoms to be "very hypothetical things". It was his research supervisor, Ralph H. Fowler, a rising theoretical physicist in close contact with both Bohr and Born, who introduced atomic theory to Dirac.

Despite its successes, quantum theory was then in an unsatisfactory state: the Bohr-Sommerfeld quantization rules for the spectroscopy of the hydrogen atom were puzzling, and the theory was completely inadequate for the treatment of complex atoms. A radically new approach was needed, and Werner Heisenberg, then a Privatdozent at Göttingen, hesitantly supplied it. On July 9, 1925, he completed the final draft of the paper that would introduce quantum mechanics. Among his innovations was a multiplication of atomic quantities, the noncommutativity of which he considered to be "a significant difficulty". Before departing Göttingen for visits in Leiden and Cambridge, Heisenberg, worried that his paper was "crazy", deposited the manuscript with Born, who was to determine whether it was publication worthy.

On July 28 Heisenberg, still uncertain of the value of his recent work, lectured about the old quantum theory in Cambridge. He did, however, discuss his new approach with Fowler in private and, a few weeks later, mailed his English host the proofs of his article, which Born had, in the meantime, submitted. Fowler scribbled "What do you think of this?" on the first page and forwarded Heisenberg's paper to Dirac, who received it in Bristol early in September. Dirac's initial impression was that Heisenberg's work was "of no interest". It was in October, when he was back in Cambridge, that Dirac recognized the similarity between the Poisson bracket he remembered from classical dynamics and the commutator of two of Heisenberg's variables. Very quickly, Dirac

reformulated Heisenberg's quantum mechanics, simplified the mathematics, clarified the break with classical theory, and significantly extended Heisenberg's results. The paper resulting from this work, "The fundamental equations of quantum mechanics", was received by the *Proceedings of the Royal Society* on November 7 and rushed to press. No amount of speed, however, could have overcome Born's head start.

As has been mentioned, Born was in possession of Heisenberg's manuscript within a few days of its completion. On July 15 he wrote Einstein that Heisenberg's latest work was "very mysterious, but certainly correct and profound." By July 19 Born had simplified Heisenberg's presentation so that the noncommutative multiplication formula could be expressed as the product of matrices. In particular, he conjectured that Heisenberg's quantum conditions could be written in terms of the position and momentum matrices as $qp - pq = i\hbar I$, where \hbar is the reduced Planck constant and I is the unit matrix. Born recruited his former student, Pascual Jordan, to collaborate on the project; their joint paper, "Zur Quantenmechanik", was received by *Zeitschrift für Physik* on September 27, 1925. Nowadays we are well aware of the impetuses quantum mechanics imparted to Hilbert space theory and the theory of group representations. Less well known is that matrix algebra was not in the physicist's toolkit before the Born-Jordan paper, which defined matrix operations *ab initio*.

In September and continuing through October, Heisenberg joined Born and Jordan in writing a substantial extension, "Zur Quantenmechanik II", that treated systems with several degrees of freedom. It was received by *Zeitschrift für Physik* on November 16. Einstein described this paper as "extremely ingenious and, thanks to its complexity, sufficiently protected from disproof." It is therefore noteworthy that Dirac's short, direct paper not only contained all the essential results of both "Zur Quantenmechanik" and "Zur Quantenmechanik II" but also nipped the latter at the finish line. In a letter to Dirac dated November 20, Heisenberg acknowledged that, in some particulars, "Your results...go considerably further" than those of the Göttingen group. Heisenberg continued, "Your paper is also written really better and more concisely than our formulations."

By November 3, Pauli, who was brought into the loop through his correspondence with Heisenberg, was able to use the "Göttingen theory", also known as *matrix mechanics*, to derive Bohr's formulas for the Balmer series of the hydrogen atom. For many physicists, it would be the publication of Pauli's work that confirmed Heisenberg's quantum mechanics. Heisenberg himself seems to have maintained his reservations a bit longer. In his November 20 letter to Dirac that has already been quoted, he apprised Dirac of Pauli's success and

yet allowed that there was still room to doubt the foundations on which Dirac and Pauli were building. In the few days that followed that letter, Heisenberg must have digested Dirac's work more completely, because on November 24 he informed Pauli, "An Englishman working with Fowler, Dirac, has independently re-done the mathematics for my work. ...Now we really know that the theory is correct."

To reach readers not versed in classical mechanics and the old quantum theory, Farmelo employs simplifications that sometimes reduce the precision of his discussions. Farmelo asserts that, instead of using an electron's position as a variable, Heisenberg substituted a matrix with each entry representing the likelihood of the electron jumping between a pair of energy levels. The choice of "related to the likelihood" rather than "representing the likelihood" would have allowed Farmelo to avoid technical jargon and remain factual. (Or he might have added an endnote, as he would later do for Born's probabilistic interpretation of Erwin Schrödinger's wave function.) With regard to the attribution of matrices to Heisenberg, Farmelo has followed a common practice among physicists who consider Born's matrix reformulation to be comparatively unimportant. Having availed himself of this traditional fiction, Farmelo should have maintained it for consistency. Instead, on page 96, he (accurately) writes, "Heisenberg had never heard of matrices when he discovered the theory [of quantum mechanics]."

The onslaught of closely spaced discoveries did not abate in the immediate aftermath of the creation of quantum mechanics. Electron spin was announced by Samuel Goudsmit and George Uhlenbeck in November 1925. The first of the sequence of papers with which Schrödinger introduced *wave mechanics*, an alternative to matrix mechanics, appeared in March 1926. In April 1926 Dirac used his own quantum algebra to obtain a theoretical demonstration of Compton scattering. Because the formula he derived for the intensity of the scattered radiation yielded values that differed from the experimental data Compton had observed in 1922, Dirac was able to assert, "This is the first physical result obtained from the new mechanics that had not been previously known." Differentially but unequivocally, he concluded, "The theory gives the correct law of variation of intensity with angle, and suggests that in absolute magnitude Compton's values are 25 per cent too small." Four months later, Compton wrote a letter to Mr. P. A. M. Dirac—nobody then knew the names represented by the initials—to inform him that measurements taken at the University of Chicago confirmed the new theory.

Given that Dirac had not yet written his Ph.D. thesis when he published his theory of Compton scattering, the effect for which Compton would

receive Nobel recognition within a year, one might think this episode would interest a biographer. However, 1926 was a productive year for Dirac, and Farmelo confines his discussion to two other important papers from that year: Dirac's independent rediscovery of *Fermi-Dirac statistics* and Dirac's *transformation theory*, which introduced the Dirac δ -function and provided a formalism for passing between matrix mechanics and wave mechanics. When Farmelo first mentions "transformation theory" (page 114), he makes it seem to be a technique from classical mechanics. Because of this awkward handling, the indexer did not cite this page. It seems likely that the three subsequent references to transformation theory will be obscure to most of Farmelo's readers.

From the summer of 1926 through October 1927, the set of physicists who struggled to integrate special relativity and quantum theory included Heisenberg, Jordan, Pauli, Schrödinger, Wigner, Oskar Klein, Walter Gordon, Hendrik Kramers, Vladimir Fock, Yakov Frenkel, and Lev Landau. Some tried incorporating relativistic effects as perturbations of the nonrelativistic theory. Others sought a relativistic extension of Pauli's spin theory. Most concentrated on finding a relativistic wave equation. Schrödinger found such a candidate, the Klein-Gordon equation (as it would be called after its rediscovery) but left it unpublished because it conflicted with Sommerfeld's fine structure formula. In October 1927, at the Fifth Solvay Conference in Brussels, Dirac was dismayed to hear Bohr say that the Klein-Gordon equation did in fact describe the relativistic electron. Dirac thought otherwise: he inferred from his transformation theory that the desired relativistic wave equation would be *first* order in time. On his return to Cambridge after the conference, he devoted himself to the problem and solved it in about six weeks. By rediscovering Clifford algebras, he factored the second-order Klein-Gordon equation, thereby obtaining a relativistic first-order equation—the Dirac equation—for the electron.

The resulting paper, "The quantum theory of the electron", received by the *Proceedings of the Royal Society* on January 2, 1928, is Dirac's most celebrated work. His contemporaries considered his derivation of electron spin from nothing more than Lorentz invariance and transformation theory "a miracle". The ingenuity, originality, and beauty of Dirac's theory of the electron has impressed physicists of the highest rank ever since. Sin-Itiro Tomonaga, for example, after sketching the main steps [5], remarked, "We mortals are left reeling by this staggering outpouring of ideas from Dirac." "The quantum theory of the electron" was more than a watershed for physics: it also stimulated Richard Brauer, Hermann Weyl, John von Neumann, Oswald Veblen, Bartel van der Waerden, Valentine Bargmann, and Wigner to

revive and develop the theory of spinors, which had received scant attention since its introduction in 1913 by Élie Cartan.

A feature of Dirac's theory that profoundly troubled physicists, Dirac included, is that it allowed for a positively charged electron. No such thing was expected in 1928. In fact, the proton and the electron were still the only known subatomic particles in May 1931 when Dirac predicted "a new kind of particle, unknown to experimental physics, having the same mass and opposite charge to an electron." He continued, "We may call such a particle an anti-electron." In the same remarkable paper, "Quantised singularities in the electromagnetic field", Dirac observed that a (magnetic) monopole, the magnetic analogue of an electron, is consistent with quantum mechanics. Moreover, he demonstrated that the existence of a single monopole anywhere in the universe would account for the quantization of electric charge. Dirac did not explicitly predict the monopole but noted, "One would be surprised if Nature had made no use of it."

In August 1932, six days before Dirac turned thirty, Carl Anderson announced the discovery at Caltech of an "easily deflectable positive". By March 1933 Anderson was confident that the particle he had detected was a positively charged electron, which he named the *positron*. Experiments at Cambridge demonstrated that Anderson's positron and Dirac's anti-electron were the same. These developments brought respectability to quantum mechanics in the eyes of the Nobel committee, which previously had regarded the theory as an abstraction with no substantiated utility. In November 1933 Heisenberg was awarded the delayed 1932 Nobel Prize, and Dirac and Schrödinger shared the 1933 prize. Hoping to avoid publicity, Dirac considered declining, but Rutherford convinced him that doing so would attract even more attention. Years later Dirac *did* refuse a knighthood, at least in part because he preferred the appellation "Mr. Dirac" to "Sir Paul".

The end of Dirac's bachelorhood began with a chance encounter he had with Margit Wigner Balázs in a Princeton restaurant in September 1934; she spotted him entering and had her brother Eugene, whom she was visiting, invite him to their table. From then until the successful conclusion of her campaign in December 1936, Margit pursued Dirac with the inexorability of a target-tracking missile. Or, as Farmelo states it, Margit "knew that she would have to take the initiative if she were to stir in him the first quantum of romance." With Dirac based in Cambridge and Margit in Budapest, the relationship was prosecuted in large part by correspondence. Farmelo was granted access to these letters and has quoted from them freely. Near the beginning of their postal exchanges, Dirac protested, "I am afraid I cannot write such

nice letters to you—perhaps because my feelings are so weak and my life is mainly concerned with facts and not feelings.” When the letters continued, Dirac advised, “You ought to think less of me.” In response to Margit’s complaint that he was not answering all her questions, Dirac constructed a three-column table with the headings: Letter number, Question, and Answer. His tabulated reply to the question “You know that I would like to see you very much?” was “Yes, but I cannot help it.”

Even though Margit suggested that Dirac deserved “a second Nobel Prize, in cruelty”, she persisted. When Dirac fully understood he was in the crosshairs of a determined woman, he warned, “You should know that I am not in love with you.” Undeterred, Margit tried the telephone, a gambit that angered Dirac. Communication by letter surely ought to suffice, he wrote her. Margit resumed her courtship of Dirac with the methods allowed her. Dirac parried for some time but was outmatched. In December 1936 Dirac wrote to a mother figure in whom he sometimes confided, “I have felt very favourably inclined to [Margit] for several months, with occasional relapses, which get less and less as time goes on.” He proposed a few days later and, in January 1937, married “his anti-particle, a woman almost opposite to him in character and temperament.” Sometimes Farmelo’s cute turns of phrase can be too cute.

In his first publication as a married man, Dirac announced his Large Numbers Hypothesis (LNH), which he stated as, “All very large dimensionless numbers which can be constructed from the important natural constants of cosmology and atomic theory are connected by simple mathematical relations involving coefficients of the order of magnitude unity.” Dirac based this hypothesis on the approximate equalities $N_1 \approx N_2 \approx \sqrt{N_p} \approx 10^{40}$ that involve three large dimensionless numbers: N_1 , the ratio of the radii of the observable universe and the electron; N_2 , the electromagnetic-to-gravitational force ratio between the proton and electron; and N_p , the number of protons in the observable universe. Given the relationships $N_1 \propto t$ and $N_2 = e^2 / (Gm_e m_p)$, where m_p and m_e are the masses of the proton and electron, e is the electron charge, and t is the age of the universe, Dirac proposed that Newton’s gravitational constant satisfies $G \propto 1/t$. “Look at what happens to people when they get married,” Bohr exclaimed when he first heard Dirac’s idea.

The consensus is that LNH is wrong. Farmelo seems to assert the opposite when he writes, “Robert Dicke demonstrated that the large numbers hypothesis is a consequence of the fact that human life occurs after stars were formed and before they die. If the hypothesis were wrong, astronomers, and all other life forms, would not exist.” The error in each of these sentences is

that Farmelo has confused the apparently coincidental approximation $N_1 \approx N_2$ with LNH, Dirac’s postulated explanation for the coincidence. What Dicke demonstrated was that the approximation $N_1 \approx N_2$ must hold in an epoch in which there is intelligent life capable of measuring N_1 and N_2 . Given that we are here, at a time in cosmic history when heavy elements have formed, intelligent life has evolved, and the stars have not all died, we can deduce that t lies in a sufficiently narrow interval for the approximation $N_1 \approx N_2$ to hold.

Even though LNH did not pan out, it was a daring, innovative idea that prompted Dicke and others to conceive the anthropic arguments that were used for its refutation. In the late 1930s Dirac was no longer coming up with comparably original ideas in atomic physics, which was then in the doldrums. Comparing the years 1925–33, which he called his “exciting era”, with the frustrating time into which he and other atomic physicists had fallen, Dirac noted, “It was very easy in those days for any second-rate physicist to do first-rate work; it is very difficult now for a first-rate physicist to do second-rate work.” Inevitably, Dirac entered a final period during which he suffered from, as Farmelo puts it, “the fate of all aging theoretical physicists: his spirit was outliving his imagination.” Dirac had pioneered quantum electrodynamics in 1927 but was unwilling to accept the renormalization program introduced by Richard Feynman, Julian Schwinger, and Tomonaga in the 1940s to overcome the impasse the subject had reached. Until his death, Dirac believed that renormalization theory was ugly, artificially contrived, and most likely wrong. At a conference in Princeton in 1946, Feynman served as leader of the discussion that followed Dirac’s lecture. Feynman’s criticism was blunt: Dirac was “on the wrong track”. More than thirty-five years later Dirac was still on the same track when he wrote what would become his last paper, “The inadequacies of quantum field theory”, which was published posthumously in 1987.

Dirac held the Lucasian Professorship of Mathematics at the University of Cambridge from September 1932 until he reached the statutory retirement age in September 1969. In 1971 he accepted a position at Florida State University, where he remained until his death. In his final years, depression seems to have darkened his outlook. The foundational work with which he introduced monopoles should have been a source of pride when, after 1974, Gerard ’t Hooft and, independently, Alexander Polyakov showed that certain gauge theories also predict monopoles. Instead, Dirac described his theory as “just a disappointment”. According to Big Bang cosmology, a very large number of monopoles were produced in the early universe. And yet, in the 1980s, in a letter to Abdus Salam, Dirac wrote, “I am inclined

now to believe that monopoles do not exist.”¹ This pessimism extended to his entire oeuvre. In 1983 Dirac declined an invitation to give a lecture at the University of Florida, stating, “I have nothing to talk about. My life has been a failure!”

Dirac’s health began to wane in July 1984; he passed away on October 20, 1984. At Margit’s prompting, the *Tallahassee Democrat* dispatched a young reporter to cover his funeral. Following the service, the journalist approached one of the lingering mourners, a Florida State physicist, and asked, *Who was this guy?* There are now several books that help answer his question. Two tribute volumes, [3] and [4], were published in 1987, and another, [1], was issued in 1998 on the occasion of Dirac’s commemoration at Westminster Abbey. Kragh’s superb scientific biography, [2], came out in 1990 and remains indispensable for its focus on Dirac’s most important contributions to physics. Farmelo’s well-written, engaging book, the first standard biography of Dirac, is a welcome alternative that can be recommended to readers who find the technical prerequisites of Kragh’s work too forbidding.

As a biography, *The Strangest Man* is excellent; had its author’s background not been disclosed, one might have guessed he was experienced in this genre. Everything has been done right. Pages have been given running heads, such as “October 1923–November 1924”, that allow the reader to easily follow the timeline. Pages for the endnotes have heads, such as “Notes to Pages 25–28”, that eliminate much of the usual fumbling associated with end-of-book searches. The index was surely compiled by an expert professional. Every lead has been run to ground. For example, when Dirac was a visiting professor at the University of Wisconsin in April and May 1929, he was interviewed by a popular sports columnist, Joseph “Roundy” Coughlin, for the *Wisconsin State Journal*. Or so it was believed. Copies of the article, which Kragh reproduced *in extenso*, are in the archives at Cambridge and Tallahassee. However, by examining the extant microfilm records for the two months Dirac spent in Madison, Farmelo concludes that the frequently anthologized interview “is an example of a probably apocryphal Dirac story that captures his behaviour so accurately that it somehow ought to be true.” It is a pity that the following question and answer are not the genuine article:

¹As of this writing, monopoles have not yet been detected. However, a new search (MoEDAL) has been under way at CERN’s Large Hadron Collider since January 2011. A test array is currently taking data at the center-of-mass energy of 7 TeV. Preliminary results are expected to be analyzed beginning in 2012. The MoEDAL detector should start its official run with the full array deployed and the collider operating at its full design energy of 14 TeV in the spring of 2014.

They tell me that you and Einstein are the only two real sure-enough high-brows and the only ones who can really understand each other. I won’t ask you if this is straight stuff for I know you are too modest to admit it. But I want to know this— Do you ever run across a fellow that even you can’t understand? “Weyl,” says he.

It was Weyl who, along with Wigner, introduced group theory into quantum mechanics between 1926 and 1929. In a letter to Igor Tamm written in January 1929, Dirac acknowledged that Weyl’s *Gruppentheorie und Quantenmechanik* was “not very easy”, but only after he praised it as “[by] far the most connected account of quantum mechanics that has yet appeared.” Perhaps further scrutiny of Dirac’s perspective on group theory is warranted. Based on some remarks Dirac made later in 1929, Kragh concluded that Dirac held group theory to be not particularly appealing and “largely unnecessary for physical applications”. Kragh added, more emphatically, “He always preferred to do without group theoretical methods.” These statements are debatable. As early as 1928 Dirac suggested to Wigner the subject of the latter’s 1939 paper concerning the unitary representations of the inhomogeneous Lorentz group. During Dirac’s stay in Princeton in 1931, he studied “a good deal” of group theory with the intention of applying it to physics, as he wrote to Tamm in January 1932. Dirac discussed representation theory with Wigner in 1934 and 1935 and wrote a paper on the representations of the Lorentz group in 1945. More importantly for the subject, Dirac pointed one of his research students, Harish-Chandra, in that direction. Late in his life, Dirac apparently thought that “pathological” representations of the Lorentz group might provide a clue for the reformulation of quantum mechanics [3, p. 32]. It is not surprising that there is no discussion of group theory in Farmelo’s nontechnical biography, but it is disappointing that nothing is said about Harish-Chandra other than that he was a bright student of Dirac. This passing mention is actually indexed under Lily Harish-Chandra, who is referenced more prominently than her husband due to her frank assessment of the mysterious union of Paul and Margit: “He gave her status and she gave him a life.”

Here is a puzzle: Dirac and Wigner were both born in 1902, they were both experts in quantum theory at the highest level, and they were together in Princeton, Wigner’s home base, for extended periods. Was there no interaction between them after 1937 when they became brothers-in-law? Farmelo’s biography, like Kragh’s, does not address this natural question. From Farmelo we



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learn that Wigner remarked, "Feynman is a second Dirac, only this time human." We are also told that Margit's reaction to her brother's death was "Thank God the monster is dead." Some clues to the strained relationship between the Wigner siblings are offered, but Farmelo's readers will inevitably wonder, What went on in this tormented clan?

For those who have already been persuaded to read *The Strangest Man*, the time has come to put aside this review: there is a spoiler ahead.

Much of Farmelo's account contains tiresome family drama involving Dirac's despotic father and suffocating mother. The excessive detail seems to have been included to bolster the hypothesis that Dirac was doomed to strangeness by nurture rather than by nature. There is even a prologue that has no other purpose than to establish this behavioral theory. It is only after 420 pages that Farmelo comes clean: he does not subscribe to the rationale he previously seemed to have been documenting so thoroughly—it was nature, not nurture, after all. "Dirac was born to be a child of few words and was pitifully unable to empathise with others," he announces. Dirac, Farmelo finally reveals, had autism.

Ho-hum. Farmelo reached his conclusion by consulting with Simon Baron-Cohen, one of Cambridge's leading researchers into autism and Asperger's syndrome. In Marcus du Sautoy's *Symmetry*, reviewed in February's *Notices*, Baron-Cohen arrived at the same diagnosis for a living Fields Medalist. Mathematicians supposedly form a rich pool of subjects for such psychologists—according to a report discussed in du Sautoy's book, mathematics departments have a higher proportion of faculty members with Asperger's syndrome than any other university department. I do not know about that, but I do believe we have a high threshold for calling an individual strange. After reading Farmelo's biography, you will likely find Dirac's personality amiable and his character admirable. Chances are, you will not need to know whether Dirac was neurotypical. The strangest man might not even redline your strangeness meter.

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Learning by Reading Original Mathematics

Ranjan Roy

In spite of the large number of good textbooks available today, our undergraduate and graduate students can greatly benefit by regarding the corpus of received original mathematical works as accessible, fascinating, relevant reading material with direct bearing on their coursework. When mathematicians such as Landen, Daniel Bernoulli, or Newton discussed summation of series, difference equations, or areas under curves, they wrote with the passion and enthusiasm that accompanies the discovery of new insights and relationships. By reading these original works, our students may more clearly see mathematics as dynamic and evolving. They can better understand theorems and formulas as arising out of real and significant mathematical questions, with connections to other problems. Moreover, many older works present their results in simple form, without the elaborate techniques developed later. Also, the results in older works may be incomplete or lacking in rigor; this apparent deficiency gives students an opportunity to provide that rigor, or to understand the need for further refinement.

Reflecting a sense of excitement and the new prospects revealed by his discovery of infinite series, in 1670–71 Newton wrote in his *De Methodis* [5]

I am amazed that it has occurred to no one (if you except N. Mercator with his quadrature of the hyperbola) to fit the doctrine recently established for decimal numbers in similar fashion to variables, especially since the way is then open to more striking consequences. For since this doctrine in species has the

same relationship to Algebra that the doctrine in decimal numbers has to common Arithmetic, its operations of Addition, Subtraction, Multiplication, Division and Root-extraction may easily be learnt from the latter's provided the reader be skilled in each, both Arithmetic and Algebra, and appreciate the correspondence between decimal numbers and algebraic terms continued to infinity ...

Using Newton's analogy between arithmetic and algebra, just as $1/3$ or $\sqrt{3}$ could be written as infinite decimals, $1/(1+x^2)$ and $\sqrt{1+x^2}$ could be expanded in infinite series. As one of the "more striking consequences", he applied the method of successive approximation for solving an algebraic equation $f(y) = 0$, gleaned from his study of Viète, to solve a polynomial equation $f(x, y) = 0$, but using infinite series. Newton showed that such a solution had to be of the form $y = x^\alpha g(x)$, with α rational and $g(x)$ a power series. He thereby obtained the first statement of the implicit function theorem. The factor α was determined by the method called Newton's polygon; interestingly, in his *De Analysisi* of 1669, Newton had not yet taken this factor into account, though a simple example shows the need for it. Against the backdrop of Descartes's geometry, Newton's results appear in a meaningful context, motivated by his effort to find the area under a curve defined by $f(x, y) = 0$, a problem he solved by integrating $y = x^\alpha g(x)$ term by term.

Students may be concerned that Newton did not consider convergence questions, and this itself provides ample food for thought. Indeed, the algebraic geometer Abhyankar [1] wrote, "...Newton's proof, being algorithmic, applies equally well to power

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series, whether they converge or not. Moreover, and that is the main point, Newton's algorithmic proof leads to numerous other existence theorems, while Puiseux's existential proof does not do so." In his *Adventures of a Mathematician*, Ulam recalls Banach's remark, "Good mathematicians see analogies between theorems or theories, the very best ones see analogies between analogies." In Newton, one finds analogy being employed by a master.

In the work of Daniel Bernoulli, students may perceive the dynamic development of mathematical ideas, as well as the intellectual growth and joy of discovery within Bernoulli himself. In 1724 Daniel Bernoulli wrote in his *Exercitationes* that there was no formula for the general term of the sequence 1, 3, 4, 7, 11, 18, ..., a sequence satisfying the second-order difference equation $a_n + a_{n-1} = a_{n+1}$. His cousin Niklaus I Bernoulli informed him that, in fact, the general term could be expressed as $[(1 + \sqrt{5})/2]^n + [(1 - \sqrt{5})/2]^n$. On rethinking, Daniel Bernoulli discovered the method for solving linear difference equations usually presented in textbooks. He explained in a 1728 paper [2] that if x_1, x_2, \dots, x_m were the solutions of the algebraic equation $\sum_{k=0}^m \beta_k x^k = 0$, then the general solution of the difference equation

$$\sum_{k=0}^m \beta_k a_{n+k} = 0 \quad \text{would be} \quad a_n = \sum_{k=1}^m A_k x_k^n$$

where A_1, A_2, \dots, A_m were arbitrary constants determined by the m initial values. In 1717 de Moivre had published the method of generating functions, or, in his words, recurrent series, to solve difference equations. Bernoulli's novel idea was the construction of the general solution as a linear combination of special solutions, a method so original that it took a decade to extend it to linear differential equations. In fact, Euler wrote to Johann Bernoulli in September 1739 that he was astonished to discover that the solution of a linear differential equation with constant coefficients was determined by an algebraic equation.

Daniel Bernoulli applied his discovery to find the numerically largest solution of an algebraic equation. From the general solution, he easily determined the numerically largest value to be approximately a_{n+1}/a_n , for n sufficiently large. Bernoulli commented that his result, even if not useful, was beautiful. But, in fact, he applied it to obtain the zeros of some Laguerre polynomials arising in his work on the frequencies of oscillation of hanging chains. At the end of his 1728 paper, he solved the difference equation

$$a_{n+1} - 2 \cos \theta a_n + a_{n-1} = 0.$$

Surprisingly, this gave him a new derivation of de Moivre's 1707 formula

$$2 \cos(n\theta) = (\cos \theta + i \sin \theta)^n + (\cos \theta - i \sin \theta)^n,$$

from which de Moivre [4], in a few lines, had obtained the important and useful formula

$$\begin{aligned} x^{2n} - 2a^n x^n \cos(n\theta) + a^{2n} \\ = \prod_{k=0}^{n-1} \left(x^2 - 2ax \cos \left(\theta + \frac{2k\pi}{n} \right) + a^2 \right). \end{aligned}$$

It would be a fascinating experience for a student to work through the derivation of this factorization formula from a difference equation.

Landen's efforts to sum $\sum_{n=1}^{\infty} 1/n^2$ produced a brilliant and essentially correct idea. But, since complex analysis had not been developed, his solution was incomplete, with many loose ends. Students may study Landen's insights with great benefit, as they attempt to fill in the gaps and render his work more coherent; they may observe that routine calculations can yield results of tremendous significance.

In 1729 Euler discussed the dilogarithm function

$$\text{Li}_2(x) = - \int_0^x \frac{\log(1-t)}{t} dt = \sum_{n=1}^{\infty} \frac{x^n}{n^2},$$

where the last equality would hold for $|x| \leq 1$; though he found some interesting results, he was unable to evaluate $\text{Li}_2(1)$ from the integral representation. In a paper of 1760 in the *Philosophical Transactions*, Landen [3] showed that this evaluation required the use of $\log(-1)$. Unaware of Euler's work on logarithms, Landen set out to determine $\log(-1)$ by first differentiating $x = \sin z$ to obtain $dz/\sqrt{-1} = dx/\sqrt{x^2-1}$. Integrating this, he got

$$\frac{z}{\sqrt{-1}} = \log \left(\frac{x + \sqrt{x^2-1}}{\sqrt{-1}} \right).$$

He set $z = \pi/2$ and $x = 1$ so that $\log \sqrt{-1} = -\pi/(2\sqrt{-1})$. Since a square root must have two values, he concluded

$$(1) \quad \log(-1) = \pm \frac{\pi}{\sqrt{-1}}.$$

To evaluate $\text{Li}_2(1)$, he started with the calculation

(2)

$$\begin{aligned} x^{-1} + \frac{x^{-2}}{2} + \frac{x^{-3}}{3} + \dots \\ = \log \frac{1}{1-1/x} = \log x + \log \frac{1}{1-x} - \frac{\pi}{\sqrt{-1}}, \end{aligned}$$

where he chose the negative sign from equation (1). Next, Landen divided (2) by x to obtain

(3)

$$-\text{Li}_2(1/x) = -\frac{\pi}{\sqrt{-1}} \log x + \frac{1}{2} (\log x)^2 + \text{Li}_2(x) + C.$$

To find C , he first took $x = 1$ to get $C = -2 \sum_{n=1}^{\infty} 1/n^2$ and to evaluate this series, he set $x = -1$ in (3). But this time, he pragmatically chose the positive sign in (1) and arrived at

$$\sum_{n=1}^{\infty} \frac{1}{n^2} = \frac{\pi^2}{6}.$$

As his computations indicate, formula (3) is correct only for $x \geq 1$. Landen proceeded to divide (3) by x and then integrate; he repeated the process indefinitely. The resulting formulas gave him the values of

$$\sum_{n=1}^{\infty} \frac{1}{n^{2k}} \quad \text{and} \quad \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{(2n-1)^{2k+1}}.$$

Observe that the series $\text{Li}_2(x)$ and $\text{Li}_2(1/x)$ converge when $x = e^{i\theta}$, with $0 < \theta \leq 2\pi$. When this value of x is substituted in (3), the resulting formula is incorrect; choosing the plus sign in (3) makes the formula valid, yielding the Fourier series expansion of the second Bernoulli polynomial! Clearly, a student of complex analysis could learn a great deal by delving into Landen's remarkable summations.

An ever-increasing number of old mathematics papers and books are easily available online and in print, making it very convenient to use such material in class discussions, assignments, or math club activities. For example, Newton's basic analogy may be presented in a calculus lecture, and Newton's polygon assigned as a project. The wealth of old mathematics applicable in our courses is astonishing, including both circumscribed and open-ended problems, and this treasure trove is a wonderful teaching resource.

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The Mathematical Work of Daniel Spielman

Michel X. Goemans and Jonathan A. Kelner

The *Notices* solicited the following article describing the work of Daniel Spielman, recipient of the 2010 Nevanlinna Prize. The International Mathematical Union also issued a news release about the prize, which appeared in the December 2010 issue of the *Notices*.

The Rolf Nevanlinna Prize is awarded once every four years at the International Congress of Mathematicians by the International Mathematical Union for outstanding contributions in mathematical aspects of information sciences. The 2010 recipient was Daniel Spielman, who was cited for “smoothed analysis of Linear Programming, algorithms for graph-based codes, and applications of graph theory to Numerical Computing”.

In this article, we summarize some of Spielman’s seminal contributions in these areas. Unfortunately, because of space constraints, we can barely scratch the surface and have to leave out many of his impressive results (and their interconnections) over the last two decades.

Error-Correcting Codes

Several of Spielman’s important early contributions were in the design of error-correcting codes. Error-correcting codes are fundamental in our increasingly digital lives, and they are important mathematical tools in the theory of computing.

In a code of block length n and rate $r < 1$ over the alphabet $\{0, 1\}$, a message in $\{0, 1\}^{rn}$ is encoded into a codeword in $\{0, 1\}^n$. To be able to correct errors in the transmission of a codeword, one would like the minimum distance d between two codewords to be large. A code is said to be *asymptotically good* if both the rate r and the relative distance d/n are bounded below by

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positive constants as n grows. The goal is to get not only asymptotically good codes with the best possible trade-off between the rate and the relative minimum distance but also codes for which both the encoding and the decoding can be done as fast as possible, ideally in linear time. In his Ph.D. work, Spielman and his advisor Michael Sipser proposed the first asymptotically good codes that allow linear-time decoding (for a survey, see [6] and references therein). Their codes are low-density parity check (LDPC) codes, introduced by Gallager half a century ago, in which a sparse bipartite graph links the bits of the codeword on one side to *parity checks* on the other side that constrain sets of bits to sum to 0 over $GF(2)$; these are *linear* codes. The Sipser and Spielman codes use a bipartite expander graph as the parity check graph. The expansion property not only implies a good bound on the minimum distance but also allows a simple decoding algorithm, in which one repeatedly flips codeword bits with more than half of their neighboring constraints violated. The Sipser and Spielman codes require quadratic time for encoding, as in any linear code. Subsequently, Spielman (see also [6]) provided a more intricate construction, still based on expanders, that yielded the first asymptotically good codes with linear-time encoding *and* decoding.

In later work, Spielman and collaborators designed highly practical LDPC codes for the erasure channel model, in which some of the bits are simply lost. Their codes [4] approach the maximum capacity possible according to Shannon’s theory, and they can be encoded and decoded in linear time. The decoding is based on belief propagation, which sets a missing bit whenever it can be recovered unambiguously. Despite the simplicity of these

algorithms, the design and analysis of these codes are mathematically quite involved. Some of this work has had considerable practical impact.

Smoothed Analysis of Algorithms

One of Daniel Spielman's most celebrated contributions is his introduction of a new notion for analyzing the efficiency of algorithms, the concept of smoothed analysis, and its powerful and highly technical illustration on the simplex algorithm for linear programming. This was done in joint work with Shang-Hua Teng, his longtime collaborator.

The traditional way to measure the efficiency of an algorithm for a computational problem (such as inverting a matrix, factoring a number, or computing a shortest path in a graph) is to measure its worst-case running time over all possible instances of a given input size. Efficient algorithms are considered to be those whose worst-case running times grow polynomially with the size of the input. But this worst-case, pessimistic measure does not always reflect the behavior of algorithms on typical instances that arise in practice.

A compelling example of this is the case of linear programming, in which one aims to maximize a linear function subject to linear constraints: $\max\{ \langle c, x \rangle : Ax \leq b, x \in \mathbb{R}^d \}$ with the inputs $c \in \mathbb{R}^d$, $A \in \mathbb{R}^{m \times d}$, and $b \in \mathbb{R}^m$. This problem has numerous industrial applications. In the late 1940s, George Dantzig proposed the simplex algorithm for linear programming, which has been cited as one of the "top ten algorithms of the 20th century" (Dongarra and Sullivan). In the nondegenerate case, the simplex algorithm can be viewed as starting from a vertex of the polyhedron $P = \{x \in \mathbb{R}^d : Ax \leq b\}$ and repeatedly moving to an adjacent vertex (connected by an edge, or face of dimension 1) while improving the value $\langle c, x \rangle$. However, no pivot rule (dictating which adjacent vertex is chosen next) is known for which the worst-case number of operations is polynomial in the size of the input. Even worse, for almost every known pivot rule, there exist instances for which the number of steps grows exponentially. Whether there exist polynomial-time algorithms for linear programming was a long-standing open question until the discovery of the ellipsoid algorithm (by Nemirovski and Shor, and Khachian) in the late 1970s and interior-point algorithms (first by Karmarkar) in the mid-1980s. Still, the simplex algorithm is the most often used algorithm for linear programming, as it performs extremely well on typical instances that arise in practice. This almost paradoxical disparity between its exponential worst-case behavior and its fast typical behavior called for an explanation. In the 1980s, researchers considered probabilistic analyses of the simplex method under various probabilistic

models, but results in one model do not necessarily carry over to other probabilistic models and do not necessarily shed any light on instances that occur in practice.

Spielman and Teng [7] instead proposed *smoothed analysis*, a blend of worst-case and probabilistic analyses, which marvelously explains the typical behavior of the simplex algorithm. In smoothed analysis, one measures the maximum over all instances of a certain size of the expected running time of an algorithm under small random perturbations of the input. In the setting of the simplex algorithm for linear programming, Spielman and Teng consider any linear program given by $c \in \mathbb{R}^d$, $A \in \mathbb{R}^{m \times d}$, and $b \in \mathbb{R}^m$ and randomly perturb A and b by independently adding to each entry a Gaussian random variable of variance σ^2 times the maximum entry of A and b . Using an intricate technical argument, they prove that the *expected* number of steps of the simplex algorithm with the so-called shadow-vertex pivot rule is polynomial in the dimensions of A and $1/\sigma$. The shadow-vertex pivot rule essentially corresponds to walking along the projection of the polyhedron onto a 2-dimensional linear subspace containing c . One step of the proof is to bound the expected number of vertices along a random 2-dimensional projection by a polynomial in n , d , and $1/\sigma$. For this purpose, they prove that the angle at a vertex of the projection is unlikely to be too flat, and this is formalized and proved by showing that a random Gaussian perturbation of any given matrix is sufficiently well conditioned, a fundamental notion in numerical linear algebra. Their work has motivated further developments, including better estimates on the condition number of randomly perturbed matrices, other probabilistic models for the perturbations, and smoothed analyses for other algorithms and problems (see the Smoothed Analysis page in [5]). Smoothed analysis also suggested the first randomized polynomial-time simplex algorithm for linear programming by Daniel Spielman and the second author [3]. This could be a step toward finding a strongly (not depending on the size of the numbers involved) polynomial-time algorithm for linear programming.

Fast Algorithms for Numerical Linear Algebra and for Graph Problems

In recent years, Spielman and his collaborators have ignited what appears to be an incipient revolution in the theory of graph algorithms. By developing and exploiting deep connections between graph theory and computational linear algebra, they have introduced a new set of tools that have the potential to transform both fields. This work has already resulted in faster algorithms for several

fundamental problems in both linear algebra and graph theory.

Fast Algorithms for Laplacian Linear Systems

With any graph G , one can associate a matrix L_G known as the *graph Laplacian*. Much of Spielman's recent work has been in the realm of spectral graph theory, which studies the rich interplay between the combinatorial properties of G and the linear algebraic properties of L_G .

Motivated by scientific computing, Spielman's work in this field began with the search for a faster algorithm to solve linear systems of the form $L_G x = b$. While the best known algorithms for solving general $n \times n$ linear systems require time $O(n^{2.378})$, Spielman and Teng showed that this class of linear systems can be solved much more quickly. In a technical tour de force, they gave an algorithm [8] that approximately solves such linear systems to any given accuracy in an amount of time that is *nearly linear* in the number of edges of G . This allows one to solve sparse diagonally dominant linear systems, which are ubiquitous in scientific computing.

However, its impact has extended far beyond solving linear systems. Their algorithm works by finding simpler graphs whose Laplacians are algebraically similar to L_G and using the solutions to linear systems involving them to speed up an iterative solver. To find these graphs, they introduce two algorithmic tools that have found broader applicability and led to substantial follow-up work: spectral sparsification and local clustering.

Spectral Sparsification

The goal of sparsification is to approximate a dense graph G by a sparser graph H . In a landmark paper, Benczur and Karger showed that any graph G can be approximated in nearly linear time by a weighted graph H with $O(n \log n / \epsilon^2)$ so that the weight of every cut in H is preserved up to a factor of at most $1 + \epsilon$. This allows one to approximately solve any problem whose solution depends only on the weights of cuts by operating on H instead of G . Since H has many fewer edges when G is dense, this is usually much faster.

For their solver, Spielman and Teng introduced the notion of spectral sparsification, which requires that L_G and L_H be approximately the same as quadratic forms. This is a strictly stronger requirement that implies that H approximately preserves the weights of cuts as well. They then showed how to compute such sparsifiers with $O(n \log^{O(1)} n / \epsilon^2)$ edges in nearly linear time [9].

In later work, Batson, Spielman, and Srivastava [1] have shown that one can eliminate the polylogarithmic factors and compute spectral sparsifiers with just $O(n / \epsilon^2)$ edges. This was not previously known even for the weaker cut-based notion of

sparsification. In addition to being a surprising result in graph theory, their techniques have led to a new simpler proof of an important theorem by Bourgain and Tzafriri in functional analysis and a new approach to the long-open Kadison-Singer conjecture.

Local Clustering

A key part of Spielman and Teng's construction of sparsifiers was an algorithm for *local clustering* [10]. The goal is to find a well-connected cluster of vertices that contains a given vertex v in some graph G so that the running time grows with the size of the cluster and depends only very weakly on the size of G . This can be a vast improvement over global algorithms when one is looking for a small cluster inside a huge ambient graph.

Assuming that v is sufficiently well contained in a cluster, Spielman and Teng provide an algorithm for finding this cluster using the connection between graph conductance and random walks. This has sparked an active area of research into improving and applying these techniques.

Electrical Flows and Graph Algorithms

In constructing their solver, Spielman and Teng use graph theory to speed up linear algebra. In more recent work, Spielman and his collaborators have shown how to exploit this connection in the other direction, using the linear system solver to obtain faster algorithms for several fundamental graph problems, most notably for approximating maximum flows in undirected graphs [2]. To do this, they model the edges of a graph as resistors, and they study the electrical currents and potentials that result when one imposes voltages or injects current into various parts of the graph. It turns out that this can be computed by solving a Laplacian linear system, so it can be done using the Spielman-Teng solver in nearly linear time. Since electrical flows encode complex global information about a circuit, this provides a powerful new tool to probe the structure of a graph.

Summary

We were able to give only a glimpse of Daniel Spielman's mathematical work in the theory of computing, but we hope we were able to convey that his numerous mathematical insights have led to groundbreaking results in the design and analysis of algorithms for error-correcting codes, linear programming, graph algorithms, and numerical linear algebra. We refer the interested reader to his website [5] for additional results, pointers, references, and mathematical gems.

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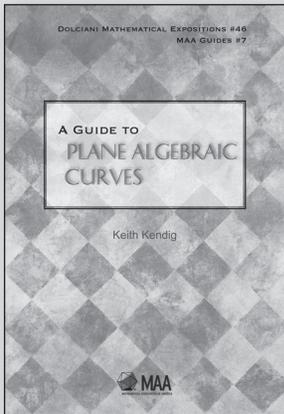


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Christodoulou and Hamilton Awarded Shaw Prize

On June 7, 2011, the Shaw Foundation announced the awarding of its annual Shaw Prize in Mathematical Sciences to DEMETRIOS CHRISTODOULOU and RICHARD S. HAMILTON “for their highly innovative works on nonlinear partial differential equations in Lorentzian and Riemannian geometry and their applications to general relativity and topology.” The prize carries a cash award of US\$1 million.

The Shaw Prize in Mathematical Sciences committee made the following statement:

“Since Riemann’s invention of a geometry to describe higher dimensional curved spaces and Einstein’s introduction of his equations to describe gravity, the theory of the associated nonlinear partial differential equations has been a central one. These equations are elegant, but in general they are notoriously difficult to study. One of the key issues is whether the solutions develop singularities.

“Demetrios Christodoulou has made fundamental contributions to mathematical physics and especially in general relativity. His recent striking dynamical proof of the existence of trapped surfaces in the setting of Einstein’s equations in a vacuum demonstrates that black holes can be formed solely by the interaction of gravitational waves. Prior to that he made a deep study of this phenomenon in symmetrically reduced cases showing that unexpected naked singularities can occur but that they are unstable. In joint work with Klainerman he established the nonlinear stability of the Minkowski spacetime. His work is characterized by a profound understanding of the physics connected with these equations and brilliant mathematical technique.

“Richard S. Hamilton introduced the Ricci flow in Riemannian geometry. This is a differential equation which evolves the geometry of a space according to how it is curved. He used it to establish striking results about the shape (topology) of positively curved three- and four-dimensional spaces. During the last three decades he has developed a host of original and powerful techniques to study his flow—for example, a technique called surgery allowing for the continuation of the evolution should singularities form. A primary goal of his theory was to classify all shapes in dimension three and in particular to resolve the Poincaré conjecture. Hamilton’s program was completed in the brilliant work of Grigory Perelman. With his Ricci flow, Hamilton has provided one of the most powerful tools in modern geometry.”

Demetrios Christodoulou was born in 1951 in Athens, Greece. He is currently professor of mathematics and physics at the ETH Zürich in Switzerland. He received his Ph.D. in physics in 1971 from Princeton University. He was professor of mathematics at Syracuse University from 1985 to 1987, at the Courant Institute of Mathematical Sciences from 1988 to 1992, and at Princeton University from 1992 to 2001. He received the Bôcher Memorial Prize of the AMS in 1999. He is a member of the American Academy of Arts and Sciences and the European Academy of Sciences.

Richard S. Hamilton was born in Cincinnati, Ohio, in 1943 and is currently Davies Professor of Mathematics at Columbia University. He received his Ph.D. in 1966 from Princeton University. He has held positions at the University of California Irvine, the University of California San Diego, and Cornell University. He received the Oswald Veblen Prize in Geometry of the AMS in 1996. He is a member of the U.S. National Academy of Sciences and the American Academy of Arts and Sciences.

The Shaw Prize is an international award established to honor individuals who are currently active in their respective fields and who have achieved distinguished and significant advances, who have made outstanding contributions in culture and the arts, or who have achieved excellence in other domains. The award is dedicated to furthering societal progress, enhancing quality of life, and enriching humanity’s spiritual civilization. Preference is given to individuals whose significant work was recently achieved.

The Shaw Prize consists of three annual awards: the Prize in Astronomy, the Prize in Science and Medicine, and the Prize in Mathematical Sciences. Established under the auspices of Run Run Shaw in November 2002, the prize is managed and administered by the Shaw Prize Foundation based in Hong Kong.

Previous recipients of the Shaw Prize in Mathematical Sciences are Jean Bourgain (2010), Simon K. Donaldson and Clifford H. Taubes (2009), Vladimir Arnold and Ludwig Faddeev (2008), Robert Langlands and Richard Taylor (2007), David Mumford and Wen-Tsun Wu (2006), Andrew Wiles (2005), and Shiing-Shen Chern (2004).

— *From Shaw Foundation announcements*

The Dangers of the “Author Pays” Model in Mathematical Publishing

Ilya Kapovich

Open-access publishing is widely touted as making scientific knowledge quickly and freely available to scholars around the world, particularly in poor and developing countries. There is considerable validity to this argument. It also *feels* good and noble to participate in the global drive toward the free spread of knowledge.

The problem is that the “author pays” model for open-access publishing, usually put forward as the solution to the lack of free access, is, in many respects, a cure that is worse than the disease, particularly for mathematics.

The first issue here concerns editorial integrity. When the financial bottom line of a journal depends directly on the number of articles published, the pressure to accept and publish papers faster and in greater quantities can easily compromise the integrity of the editorial and peer review processes, even at good journals. Recently, “author pays” open-access journals, which charge significant author fees (often a few thousand dollars per article) and promise fast refereeing and publication speeds, have significantly proliferated. In my observation, most of such mathematical journals are essentially “paper mills” and “vanity outlets”, publishing low-quality research with pro-

forma peer review. Hardly a week goes by that I don’t receive another email from such a journal inviting me to submit a paper there or to join their editorial board. This is not a healthy development. The “author pays” model, even if implemented with rigorous editorial standards, still significantly blurs the line between reputable journals and “vanity press” outlets.

The bigger problem concerns the effect of the “author pays” system on the open and egalitarian nature of mathematical research. While being able to access mathematical papers is crucial for conducting research, being able to publish the results of one’s research is even more important. Are we doing any great favors to mathematicians in developing countries by “pricing them out” of being able to publish their work? What about graduate students? Retirees? Unaffiliated researchers? And what about the majority of the faculty members in the U.S. mathematics departments who are not supported by NSF grants? Even those of us, like myself, who currently receive NSF support do not have grants that contain a substantial publication fee component. Even if publication fees become a standard budget item of NSF grants, the grant sizes are not likely to increase—rather, the budget portions will be decreased for other activities.

The research enterprise is organized rather differently in mathematics as opposed to experimental sciences. For the latter, it is relatively

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rare for graduate students to publish solo author papers, since most publications are based on research conducted at large labs (and most papers have many coauthors, starting with the lab director). These labs are usually supported by large external grants that can easily cover significant publication fees, even if they are \$1,000 or more per paper. By contrast, in mathematics, research is still mostly conducted by individuals working alone or in ad hoc groups, and such research is not dependent on using the equipment and resources of some huge lab. Should the “author pays” model of mathematical journals become prevalent, colleges, universities, and mathematics departments would be expected to cover publication fees. With the higher education funding in the United States being squeezed on all fronts, it is unlikely that they would come up with significant amounts of institutional funding for that purpose. Forcing U.S. mathematics departments to use their modest resources to ration funding of publication fees by their faculty, graduate students, and retirees could not lead to a positive outcome. Even if the standard publication fee were to stabilize at a relatively modest amount of around \$500 per paper, most U.S. mathematics departments could still afford covering only a fraction of them, and much (probably most) of the publication expenses would have to be paid by individual mathematicians, from their own pockets. Such a system will particularly penalize graduate students, young Ph.D.s, and the faculty members without external grants. In mathematics, such a change would lead to a greater concentration of research funding toward a small number of well-established researchers.

In my opinion, moving to the prevalence of the “author pays” model for mathematical journals would not be beneficial for the mathematical research enterprise as a whole, and for U.S. mathematicians in particular. The AMS needs to be much more proactive on this issue; we can ill afford to sit on the sidelines, waiting for the events to overtake us. This need is made more urgent by the building up of administrative and legislative pressure toward the use of open-access journals. The NIH already has a formal policy of requiring that all research supported by NIH grants be published in open-access journals, and the NSF may well come under Congressional pressure to do the same. Yet, in my observations, most U.S. mathematicians are only dimly aware of these developments.

In my opinion, a key point in the AMS strategy should be to stress the already available open-access alternatives not involving author fees. A substantial portion of new mathematical papers are posted to the `arXiv.org` preprint server, where they are freely available to everyone, well before being published. In this regard mathematics is far more open than most experimental sciences, in which getting credit for a particular advance is

closely tied to a paper’s publication date and in which prepublication release of the results of scientific research is relatively uncommon. We need to build on our unique advantage. The copyright transfer agreements of many (perhaps most) math journals expressly allow the authors to post their accepted papers to preprint servers, provided the journal publication info is included. Some mathematical journals already require the authors of accepted papers to post their final versions to `arXiv`. We should encourage wider use of such admirable practices.

The `arXiv` approach achieves the goals of open access without imposing new financial burdens on the authors of mathematical papers. We need to trumpet the extended usage of `arXiv` to legislators and university administrators, who are largely unaware of its existence. We should work on making the practices of `arXiv` posting more uniform and on convincing those U.S. mathematicians who do not yet post their papers to `arXiv` to start doing so. Currently the rates of participation in `arXiv` vary widely among various areas of math, and there are also significant generational differences. However, we do have a solid and naturally developed base from which to expand.

I believe that we should adopt a policy of expressly discouraging AMS members from participating, as authors, referees, or editors, in the activities of those journals that impose significant author fees without providing an alternative to publish a paper in a fee-free format. Finally, we need to develop tools for encouraging low-cost subscription journals.

Of course, as was noted by the reviewers, there are many nuanced and complex aspects of open access that cannot be covered in the short space of this column. But it is high time to have a broad and organized discussion within the AMS on these issues, followed by adoption of specific policies and implementation measures.

Mathematical Sciences in the FY 2012 Budget

Samuel M. Rankin III

Highlights

- Federal support for the mathematical sciences is estimated to increase by 12.1 percent over fiscal year (FY) 2010¹ to US\$593.4 million.
- The National Science Foundation's (NSF) Division of Mathematical Sciences (DMS) is estimated to increase by 6.3 percent over FY 2010 to US\$260.4 million.
- Department of Defense (DOD) funding for the mathematical sciences is estimated to grow by 29.4 percent over FY 2010 to US\$132.0 million.
- The aggregate funding for the mathematical sciences in the Department of Energy (DOE) is estimated to increase by 16.9 percent.

Introduction

Research in the mathematical sciences is funded primarily through the National Science Foundation, the Department of Defense (including the National Security Agency), the Department of Energy, and the National Institutes of Health (NIH). As in previous years, the majority of federal support for the mathematical sciences in FY 2012 would come from the Division of Mathematical Sciences (DMS) of NSF. NSF accounts for 65 percent of the federal support for academic research in the mathematical sciences and is the only agency that supports mathematics research broadly across all fields. Most research in the mathematical sciences in the United States is performed by academic researchers. The DOD, DOE, and NIH support research in the mathematical sciences that contributes to the missions of these agencies. DOD supports math-

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¹*At the time of this writing, the agencies discussed in this article were operating on a continuing resolution for FY 2011, meaning that their FY 2011 budgets were the same as their FY 2010 budgets. Therefore, throughout the article, the FY 2012 budget estimates are compared with the FY 2010 appropriated budgets. The FY 2012 budget estimates are based on the FY 2012 Budget Request.*

ematical sciences research and related activities in several programs: the Directorate of Mathematics, Information, and Life Sciences and the Directorate of Physics and Electronics within the Air Force Office of Scientific Research (AFOSR); the Information Sciences Division within the Army Research Office (ARO); the Mathematics, Computers, and Information Sciences Research Division within the Office of Naval Research (ONR); the Defense Sciences Office and the Microsystems Technology Office within the Defense Advanced Research Projects Agency (DARPA); and the Mathematical Sciences Program within the National Security Agency (NSA). DOE funds mathematics through its Applied Mathematics and Scientific Discovery through Advanced Computing (SciDAC) programs within the office of Advanced Scientific Computing Research. The National Institutes of Health funds mathematical sciences research primarily through the National Institute of General Medical Sciences (NIGMS) and through the National Institute of Biomedical Imaging and Bioengineering (NIBIB).

Trends in Federal Support for the Mathematical Sciences

The FY 2012 aggregate spending for mathematical sciences research and related activities is estimated to be US\$593.4 million, a potential increase of 12.1 percent over FY 2010 funding. Given the current budget-cutting atmosphere, it is unlikely that this estimate can make it through the upcoming appropriations cycle. In particular, NSF will likely not receive the level of funding proposed in the FY 2012 Budget Request. This is unfortunate because in FY 2009, NSF/DMS, with American Recovery and Reinvestment Act (ARRA) money, provided support for deserving investigators who in the past were not supported because of a lack of funds. Many of the grants funded with ARRA money will be ending in FY 2012, and the investigators will, very probably, be reapplying in extremely competitive circumstances.

The mathematical sciences make major contributions to the country's intellectual capacity and provide the tools, insight, and capability needed for innovation and technological progress. Many disciplines depend on research in the mathematical sciences to open up new frontiers and advance discovery. Mathematical sciences research contributes

to advances in many areas, such as: medicine, cyber security, weather prediction, digital data compression and mining, aeronautics, and computing.

National Science Foundation (NSF). The Division of Mathematical Sciences (DMS) is housed in the NSF Directorate of the Mathematical and Physical Sciences (MPS). DMS has essentially two modes of support: (1) research and education grants and (2) institutes. Grants include individual-investigator awards; awards for groups of researchers, including multidisciplinary; and educational and training awards aimed at increasing the number of U.S. students choosing careers in the mathematical sciences. Each year, typically 59 percent of the DMS budget is available for new research grants, and the remaining 41 percent is used primarily to fund continuing grants made in previous years. The Division supports core research programs in algebra and number theory, analysis, applied mathematics, computational mathematics, geometry and topology, mathematical biology, probability, combinatorics and foundations, and various areas within statistics. Additionally, DMS will participate in the new NSF-wide initiatives, Cyber-Infrastructure Framework for the 21st Century (CIF21) and Advanced Manufacturing, as well as in the new Research at the Interface of Biological, Mathematical, and Physical Sciences (BioMaPS) program.

The Division will continue to invest in the Science, Engineering, and Education for Sustainability

Portfolio (SEES) and Science Beyond Moore's Law (SEBML). The DMS FY 2012 budget is estimated to increase by 6.3 percent over FY 2010.

Air Force Office of Scientific Research (AFOSR). Portfolios for the mathematical sciences at AFOSR are found in the Directorate of Mathematics, Information, and Life Sciences and the Directorate of Physics and Electronics. The AFOSR mathematics program includes specific portfolios in dynamics and control, multiscale modeling, computational mathematics, optimization and discrete mathematics, electromagnetics, and sensing, surveillance, and navigation. For additional information on the focus areas within each of these portfolios, refer to the Broad Area Announcement 2010-1 (see the website <http://www.afosr.af.mil>). The AFOSR FY 2012 budget estimate for mathematical sciences reflects an increase of 17.2 percent over FY 2010.

Army Research Office (ARO). The Mathematics Program, housed in the Information Sciences Division, manages the following programs: modeling of complex systems, numerical analysis, probability and statistics, and biomathematics. The Mathematical Sciences Division plays an essential role in the modeling, analysis, and control of complex phenomena and large-scale systems that are of critical interest to the Army. The areas of application include communication networks, image analysis, pattern recognition, test and

Table 1. Federal Funding for the Mathematical Sciences (millions of dollars)

	FY 2010 Actual	FY 2012 Budget	Change Amount	FY 10-12 Percent
National Science Foundation				
Mathematical Sciences	245	260	16	6.3%
Department of Defense	102	132	30	29.4%
Air Force Off. of Sci. Res.	52	61	9	17.2%
Army Research Office	12	12	0	0.0%
Def. Adv. Res. Proj. Agency	12	28	16	129.2%
Natl. Security Admin	7	6	-1	-7.7%
Office of Naval Research	20	26	6	30.0%
Department of Energy	93	109	16	16.9%
Applied Mathematics	44	49	5	12.1%
SciDAC ¹	50	60	11	21.2%
National Institutes of Health	89	92	3	3.4%
General Medical Sciences	50	52	2	4.0%
Imaging & Bioengineering	39	40	1	2.6%
Total Mathematical Sciences	529	593	64	12.1%

Source: Agency budget justifications and other agency communication.

All figures rounded to the nearest million.

Changes calculated from unrounded figures.

¹ Scientific Discovery through Advanced Computing

evaluation of new systems, sensor networks, network science, autonomous systems, analysis of very large or very small data sets, and mathematics of biological systems. The division also works closely with the Computing Sciences Division and Network Science Division of ARO to develop mathematical theory for systems control, information processing, information assurance, network design, and data fusion. The Mathematics Program FY 2012 budget is estimated to be unchanged from FY 2010.

Defense Advanced Research Projects Agency (DARPA). The Defense Sciences Office (DSO) and the Microsystems Technology Office (MTO) inside DARPA both have mathematics programs cutting across mathematics and its applications. Current programs include Focus Areas in Theoretical Mathematics, Mathematics of the Brain, Foundational Computer Science, Mathematical Challenges, and Nanostructure in Biology. The aggregate FY 2012 DARPA mathematics budget is estimated to increase by 129.2 percent over 2010.

National Security Agency (NSA). The Mathematical Sciences Program of the NSA administers a Grants Program that supports fundamental research in the areas of algebra, number theory, discrete mathematics, probability, and statistics. The Grants Program accepts proposals for conferences and workshops in these research areas. NSA does not fund grant proposals in cryptography in order to avoid direct conflict of interest with the Agency's mission. In addition to grants, the Mathematical Sciences Program supports an in-house faculty Sabbatical Program. The program administrators are especially interested in funding initiatives that encourage the participation of underrepresented groups in mathematics (such as women, African-Americans, and other minorities). As the largest employer of mathematicians in the United States, NSA has a vested interest in maintaining a healthy academic mathematics community in the United States. The NSA mathematics FY 2012 budget is estimated to decrease by 7.7 percent from FY 2010.

Office of Naval Research (ONR). The ONR Mathematics, Computers, and Information Research Division's scientific objective is to establish rigorous mathematical foundations and analytical and computational methods that enhance understanding of complex phenomena and enable prediction and control for Naval applications in the future. Basic research in the mathematical sciences is focused on analysis and computation for multiphase, multimaterial, and multiphysics problems; predictability of models for nonlinear dynamics; electromagnetic and acoustic wave propagation; mathematical foundation for quantum information sciences; and signal and image analysis and understanding. Also of interest are modeling pathological behaviors of large, dynamic

complex networks and exploiting hybrid control to achieve reliability and security; optimization; formal methods for verifiably correct software construction; and computational foundations for machine reasoning and intelligence to support integrated sensing, computing, communication/networking, and control of cyber-physical systems. The Mathematical, Computer, and Information Sciences Division's FY 2012 budget would increase by 30.0 percent over FY 2010.

Department of Energy (DOE). Mathematics at DOE is funded through the Office of Advanced Scientific Computing Research (ASCR), one of the interdisciplinary research offices within DOE's Office of Science. Research supported by ASCR underpins computational science throughout DOE. ASCR funding for the mathematical sciences is found primarily in the Applied Mathematics program and the Scientific Discovery through Advanced Computing (SciDAC) program. The Applied Mathematics activity supports the research, development, and application of applied mathematical models, methods, and algorithms to understand complex physical, chemical, biological, and engineered systems related to the department's mission. SciDAC investments in FY 2012 will include addressing challenges from emerging hardware to ensure continued progress in computational science in support of the department's missions. Aggregate funding for the mathematical sciences within DOE is estimated to increase by 16.9 percent over FY 2010.

National Institutes of Health (NIH). NIH funds mathematical sciences research through the National Institute of General Medical Sciences (NIGMS; see <http://www.nigms.nih.gov/About/Overview/cbcb.htm>) and the National Institute of Biomedical Imaging and Bioengineering (NIBIB; see <http://www.nibib.nih.gov/Research/ProgramAreas/MathModeling>). Mathematical sciences areas of interest are those that support the missions of NIGMS and NIBIB. The NIGMS Center for Bioinformatics and Computational Biology supports programs in computational biology, such as the generation of mathematical models of biological networks, the development of modeling and simulation tools, the conduct of basic theoretical studies related to network organization and dynamic processes, and the development of methods for the analysis and dissemination of computational models. NIGMS is currently supporting a biomathematics initiative at around US\$12 million per year in cooperation with the National Science Foundation. NIBIB supports the mathematical sciences through its Mathematical Modeling, Simulation and Analysis Program Area. The aggregate FY 2012 budget for the mathematical sciences in NIBIB and NIGMS would increase by 3.4 percent over FY 2010.

Mathematics People

Hacon Awarded Feltrinelli Prize

CHRISTOPHER HACON of the University of Utah has been awarded the Antonio Feltrinelli Prize in Mathematics, Mechanics and Applications by Italy's Accademia Nazionale dei Lincei, or National Lincean Academy, for his work in algebraic geometry. His work involves two major topics. The first is the classification of higher-dimensional "complex projective varieties", which are geometric objects that are described by one or more polynomial equations in many variables and that typically exist in more than three dimensions. In contrast, a simple geometric object such as a sphere can be described by just one polynomial equation in three variables and therefore is an object in three-dimensional space. His second major interest is in questions arising from the "minimal model program", which is an effort to understand the properties of complex projective varieties. The origins of this field date to Italian algebraic geometers in the early twentieth century.

Hacon was born in Manchester, United Kingdom. He received his B.A. in mathematics from the University of Pisa and his master's and Ph.D. degrees in mathematics from the University of California Los Angeles. He has taught at the University of California Riverside in addition to the University of Utah. He was awarded an AMS Centennial Research Fellowship in 2006 and shared a Clay Research Award with James McKernan in 2007. Hacon and McKernan also received the 2009 AMS Frank Nelson Cole Prize in Algebra for their groundbreaking work on the minimal model program in algebraic geometry.

The Feltrinelli Prizes are considered Italy's highest scientific and cultural honors. The prize carries a cash award of 65,000 euros, or about US\$93,000.

—From a University of Utah announcement

De Bie Awarded First Clifford Prize

The International Conference on Clifford Algebras and Their Applications in Mathematical Physics (ICCA) has instituted the W. K. Clifford Prize for excellence in research in theoretical and applied Clifford algebras and their analysis and geometry. HENDRIK DE BIE of Ghent University has been selected as the recipient of the first Clifford Prize for his outstanding mathematical research achievements in the fields of harmonic and Clifford analysis with applications in theoretical physics. He received his Ph.D. from Ghent University with a thesis titled "Harmonic and Clifford analysis in superspace". According to the prize citation, he has "a beautiful and remarkable publishing record with papers published in both mathematics and



Hendrik De Bie

in theoretical physics journals. Cooperating with mathematics centers of excellence around the world, he is a real ambassador for mathematics through Clifford algebra and Clifford analysis with special emphasis on applications in theoretical physics." His chief contribution is an extensive theory of harmonic and Clifford analysis in superspaces involving special functions and group representation theory. Superspaces are, roughly speaking, spaces characterized by commuting and anticommuting variables appearing

in supersymmetry, supergravity, superstrings, random matrices, and so forth. He has also worked on Dunkl operators and the Fourier transform, important tools in the engineering sciences. The prize is intended for young researchers up to age thirty-five and carries a cash award of 1,000 euros (approximately US\$1,450).

The ICCA international conferences, organized alternatively in Europe and the Americas, are intended to bring together the leading scientists and young researchers in the field of Clifford algebras and their various applications in mathematics, physics, engineering, and other applied sciences. The English mathematician and philosopher W. K. Clifford is best remembered for what is now termed geometric algebra, a special case of the Clifford algebras named in his honor, but he also contributed significantly to other branches of mathematics, especially geometry.

The international W. K. Clifford Prize Committee included: R. Ablamowicz (United States), P. Anglès (France), F. Brackx (Belgium), K. Gürlebeck (Germany), D. Hildenbrand (Germany), J. Lasenby (United Kingdom), T. Qian (China), W. A. Rodrigues Jr. (Brazil), V. Soucek (Czech Republic), and E. Hitzer (Japan, nonvoting secretary).

—Eckhard Hitzer, University of Fukui, Japan
Photograph courtesy of Eckhard Hitzer

Prizes of the Royal Society

ANGELA MCLEAN of the University of Oxford has been awarded the 2011 Gabor Medal of the Royal Society of London for her "pivotal work on the mathematical population biology of immunity." The Gabor Medal is awarded for acknowledged distinction of interdisciplinary work between the life sciences with other disciplines and carries a cash award of £1,000 (approximately US\$1,600).

CELIA HOYLES of the University of London has been awarded the 2010 Kavli Education Medal "in recognition of her outstanding contribution to research in mathematics

education.” She presented a lecture titled “Tackling the mathematics: Potential and challenges”. The Kavli Education Medal is awarded biennially in odd years to an individual who has made a significant impact on science or mathematics education within the United Kingdom. The award is supported by the Kavli Foundation and is accompanied by a cash award of £500 (approximately US\$800).

—From a Royal Society announcement

Prizes Awarded at the ICIAM

The International Congress on Industrial and Applied Mathematics (ICIAM) was held in Vancouver, Canada, July 18–22, 2011. A number of prizes were awarded.

EMMANUEL CANDÈS of Stanford University and the California Institute of Technology was awarded the ICIAM Collatz Prize “in recognition of his outstanding contributions to numerical solution of wave propagation problems and compressive sensing, as well as anisotropic extensions of wavelets.” The prize recognizes individual scientists under forty-two years of age for outstanding work on industrial and applied mathematics and carries a cash award of US\$1,000.

ALEXANDRE J. CHORIN of the University of California Berkeley has been awarded the Lagrange Prize “in recognition of his fundamental and original contributions to applied mathematics, fluid mechanics, statistical mechanics, and turbulence modeling. His methods for the numerical solution of Navier-Stokes equations stand at the basis of the most popular codes in computational fluid mechanics.” The prize recognizes individual mathematicians who have made an exceptional contribution to applied mathematics throughout their careers. It carries a cash award of US\$3,000.

VLADIMIR ROKHLIN of Yale University has been awarded the Maxwell Prize for his work on fast multipole methods that have revolutionized such fields as numerical electromagnetism for radar and molecular dynamics for chemistry. The prize recognizes a mathematician who has demonstrated originality in applied mathematics. It carries a cash award of US\$1,000.

JAMES A. SETHIAN of the University of California Berkeley has been awarded the ICIAM Pioneer Prize “for his fundamental methods and algorithms which have had a large impact in applications such as in imaging and shape recovery in medicine, geophysics and tomography and drop dynamics in inkjets.” The Pioneer Prize was established for pioneering work introducing applied mathematical methods and scientific computing techniques to an industrial problem area or a new scientific field of applications. It carries a cash award of US\$1,000.

EDWARD LUNGU of the University of Botswana has been awarded the Su Buchin Prize for his mathematical modeling of problems related to Africa and his fundamental contribution to developing teaching, research, and organizational structures for applied mathematics in southern Africa. The prize was established to recognize an outstanding contribution by an individual in the application of mathematics to emerging economies and human

development, in particular at the economic and cultural levels in developing countries. It carries a cash award of US\$1,000.

—From an ICIAM announcement

SIAM Prizes Awarded

The Society for Industrial and Applied Mathematics (SIAM) has awarded several prizes for 2011.

SUSANNE C. BRENNER of Louisiana State University has been named the AWM-SIAM Sonia Kovalevsky Lecturer for 2011. The lecture is intended to highlight significant contributions of women to applied or computational mathematics.

INGRID DAUBECHIES of Princeton University was named the 2011 John von Neumann Lecturer. The lecture is awarded for outstanding and distinguished contributions to the field of applied mathematical sciences and for the effective communication of these ideas to the community. It carries a cash award of US\$5,000.

GUNTHER UHLMANN of the University of California Irvine was awarded the Ralph E. Kleinman Prize. The prize is awarded every two years to one individual for outstanding research or other contributions that bridge the gap between mathematics and applications. Work that uses high-level mathematics and/or invents new mathematical tools to solve applied problems from engineering, science, and technology is particularly appropriate. The prize carries a cash award of approximately US\$5,000.

DAVID E. KEYES of Columbia University and King Abdulah University of Science and Technology, Saudi Arabia, has been awarded the SIAM Prize for Distinguished Service to the Profession. The award is given to an applied mathematician who has made distinguished contributions to the furtherance of applied mathematics on the national level.

The SIAM Outstanding Paper Prizes were awarded to the following researchers: JUSTIN BRICKELL, INDERJIT DHILLON, SUVRIT SRA, all of the University of Texas, and JOEL A. TROPP, University of Michigan, for “The metric nearness problem”, in the *SIAM Journal on Matrix Analysis and Applications*, vol. 30, issue 1 (2008), pp. 375–396; CONSTANTINOS DASKALAKIS, University of California Berkeley, PAUL W. GOLDBERG, University of Liverpool, and CHRISTOS H. PAPADIMITRIOU, University of California Berkeley, for “The complexity of computing a Nash equilibrium” in the *SIAM Journal on Computing*, vol. 39, issue 1 (2009), pp. 195–259; IFTACH HAITNER, Microsoft Research, MINH-HUYEN NGUYEN, Harvard University, SHIEN JIN ONG, Harvard University, OMER REINGOLD, Weizmann Institute of Science, and SALIL VADHAN, Harvard University, for “Statistically hiding commitments and statistical zero-knowledge arguments from any one-way function” in the *SIAM Journal on Computing*, vol. 39, issue 3 (2009), pp. 1153–1218.

J. TINSLEY ODEN of the University of Texas, Austin, was awarded the SIAM/ACM Prize in Computational Science and Engineering by SIAM and the Association for Computing Machinery (ACM) in the area of computational science

in recognition of outstanding contributions to the development and use of mathematical and computational tools and methods for the solution of science and engineering problems.

BJORN ENGQUIST of the University of Texas, Austin, was awarded the Peter Henrici Prize jointly by SIAM and Eidgenössische Technische Hochschule-Zürich (ETH Zurich). The prize is awarded for original contributions to applied analysis and numerical analysis and/or for exposition appropriate for applied mathematics and scientific computing. It carries a cash award of approximately US\$5,000.

The SIAM Awards in the Mathematical Contest in Modeling were awarded to teams from Tsinghua University, People's Republic of China, and Harvey Mudd College. Each student member of the winning team receives a cash award of US\$300.

The SIAM Student Paper Prizes were awarded to the following students: NECDET SERHAT AYBAT, Columbia University, "Unified approach for minimizing composite norms"; SUNGWOO PARK, University of Maryland, College Park, "Portfolio selection using Tikhonov filtering to estimate the covariance matrix"; and XIANGXIONG ZHANG, Brown University, "On maximum-principle-satisfying high order schemes for scalar conservation laws". A cash prize of US\$1,000 is awarded for each paper.

—From a SIAM announcement

Prizes of the London Mathematical Society

The London Mathematical Society (LMS) has awarded several prizes for 2011.

E. BRIAN DAVIES of King's College London has been awarded the Pólya Prize "for his remarkable work in spectral theory, including the powerful heat kernel methods that he developed and his work on nonself-adjoint operators."

JONATHAN PILA of the University of Oxford received the Senior Whitehead Prize in recognition of his "startling recent work on the Andre-Oort and Manin-Mumford conjectures. The approach he and his collaborators have developed, which combines analytic ideas with model theory, is entirely new and shows great promise for further applications."

J. BRYCE MCLEOD of the University of Oxford has been awarded the Naylor Prize and Lectureship in Applied Mathematics "in recognition of his important and versatile achievements in analysis of nonlinear differential equations arising in applications to mechanics, physics, and biology."

Several Whitehead Prizes were awarded. JONATHAN BENNETT of the University of Birmingham was honored for his foundational work on multilinear inequalities in harmonic and geometric analysis and for a number of major results in the theory of oscillatory integrals. ALEXANDER GORODNIK of the University of Bristol was recognized for his work on homogeneous dynamics, with particular emphasis on his deep applications to diophantine problems. BARBARA NIETHAMMER of the University of Oxford

was honored for her deep and rigorous contributions to material science, especially on the Lifshitz-Slyozov-Wagner and Becker-Doering equations. ALEXANDER PUSHNITSKI of King's College London was recognized for his contributions to spectral theory of partial differential operators and, in particular, to the study of the properties of the discrete and continuous spectrum of Schrödinger operators.

—From an LMS announcement

Prizes of the Canadian Mathematical Society

The Canadian Mathematical Society (CMS) has made several awards for 2011.

ROBERT WOODROW of the University of Calgary was honored with the Graham Wright Award for Distinguished Service. According to the prize citation, he "is deeply committed to mathematics education initiatives and has assisted with mathematical competitions, the Shad Valley Enrichment Program, and training students for the Canadian and International Math Olympiads" and since 1980 has also organized and cotaught the Wednesday Mathematics Evenings at the University of Calgary, a weekly enrichment program for high school students, who challenge themselves with advanced mathematical puzzles and learn from a group of like-minded peers. He is a lifetime member of the CMS and has been actively involved with the society for more than thirty years, including serving on the Board of Directors, the Education Committee, and the Advancement of Mathematics Committee. The Graham Wright Award recognizes individuals who have made sustained and significant contributions to the Canadian mathematical community and in particular to the CMS.

MIROSLAV LOVRIC of McMaster University was honored with the Adrien Pouliot Award "for his outstanding contributions to the teaching and learning of mathematics in Canada." The prize citation reads in part: "Miroslav is an innovator, all the way from his development of a course which trained and mentored undergraduate tutors for his large applied calculus course, to his more recent concentration on literacy at the undergraduate level and the design of textbooks. His involvements in mathematics education range from the development of curricula and teaching resources to current collaborative research." The Pouliot Award is for individuals or teams of individuals who have made significant and sustained contributions to mathematics education in Canada.

YVAN SAINT-AUBIN of the Université de Montréal received the Excellence in Teaching Award. According to the citation, "he has distinguished himself by his outstanding teaching skills and attentiveness toward students as well as by playing a pivotal role in both the overall mathematical life of students and his department's efforts to revitalize the delivery of several courses and to refresh and modernize its programs." The CMS Excellence in Teaching Award focuses on the recipient's proven excellence as a teacher at the undergraduate level as exemplified by

unusual effectiveness in the classroom and/or commitment and dedication to teaching and to students.

ANDREW TOMS of Purdue University and WILHELM WINTER of the University of Nottingham are the recipients of the 2010 G. de B. Robinson Award for their paper “Z-stable ASH algebras”, published in the *Canadian Journal of Mathematics*, vol. 60, no. 3 (2008), pp. 703–720. The award recognizes the publication of excellent papers in the *Canadian Journal of Mathematics* and the *Canadian Mathematical Bulletin*.

—From a CMS announcement

2011 International Mathematical Olympiad

Young mathematicians from more than one hundred countries competed in the fifty-second International Mathematical Olympiad (IMO), held in Amsterdam, The Netherlands, July 16–24, 2011. The IMO is the preeminent mathematical competition for high school-age students from around the world. The IMO consists of solving six extremely challenging mathematical problems in a nine-hour competition administered over two days.

For the fourth straight year the team from China finished first, with 189 points out of a possible 252. Each team member received a gold medal. The U.S. team finished second, with a total of 184 points, and again each team member received a gold medal. Singapore finished third, followed by Russia and Thailand. The six members



IMO winners, left to right: Xiaoyu He, David Yang, Evan O’Dorney, Mitchell Lee, and Ben Gunby. Not pictured is Wenyu Cao.

of the U.S. team were: WENYU CAO, Phillips Academy, Andover, Massachusetts; BENJAMIN GUNBY, Georgetown Day School, Washington, D.C.; XIAOYU HE, Acton-Boxborough Regional High School, Acton, Massachusetts; MITCHELL LEE, Thomas Jefferson High School for Science and Technology, Alexandria, Virginia; EVAN O’DORNEY, Berkeley Math Circle; and DAVID YANG, Phillips Exeter Academy, Exeter, New Hampshire. David Yang tied for the fourth best score among all individuals competing in the contest. Lisa Sauermann of Germany was the highest scorer at the IMO, earning a perfect score of 42. Next year’s IMO will take place July 4–16 in Mar del Plata, Argentina.

—Elaine Kehoe

Photograph by Steve Dunbar

Mathematics Opportunities

Travel Grants for ICME

Applications for travel grants are now available to attend the Twelfth International Congress on Mathematical Education (ICME-12), which will be held in Seoul, Korea, July 8–15, 2012. (See www.icme12.org/.) Contingent on the funding of a proposal pending at the National Science Foundation, grants will be available and awarded by the beginning of 2012. These grants will support expenses related to attending ICME-12, including hotel accommodations, meal costs, and conference registration. They also can be used toward air transportation (on U.S. carriers only). Travel grant awardees under this program may not use funds from other NSF-funded programs to supplement their international travel (airfare to Korea or subsistence at ICME-12) without special permission.

The International Congresses are held every four years and offer a unique opportunity for mathematics educators from the United States to discuss issues in mathematics education with leaders in the field from around the world. Grants will enable participants to listen to world-renowned scholars in mathematics and mathematics education as

they share insights from research and best practice and to take part in small, focused study groups on a wide range of topics, including mathematics education for second-language learners, the relationship between research and practice in mathematics education, the professional development of mathematics teachers, assessment and testing in mathematics education, socioeconomic influence on students’ achievement, and analysis of uses of technology in mathematics teaching and learning.

The National Science Foundation grants are available only to U.S. citizens and permanent resident aliens and will support travel expenses to ICME-12 for pre-K–12 mathematics teachers, mathematicians, graduate students, and mathematics teacher educators from the United States.

A selection committee will review applications and award the grants for ICME-12 travel. The committee will include representatives from the National Council of Teachers of Mathematics, the Mathematical Association of America, the American Mathematical Association of Two-Year Colleges, the American Mathematical Society, and the U. S. National Commission on Mathematics Instruction.

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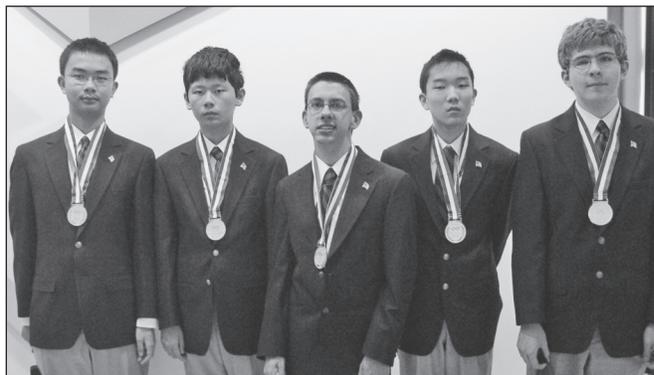
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Pre-K, elementary, middle, and high school teachers and graduate students are strongly encouraged to apply. The travel grant application and selection criteria are available on the NCTM website at www.nctm.org/icme.aspx or from Margaret Iding, 116 North Kedzie, Michigan State University, East Lansing, MI 48824; telephone (517) 355-1708, ext. 105; fax (517) 432-9868; email idingm@msu.edu. The application deadline is **September 30, 2011**. Notifications will be made by January 16, 2012. Questions can be directed to Gail Burrill, burrill@msu.edu.

—NCTM announcement

NSF Research Networks in the Mathematical Sciences

The National Science Foundation (NSF) has initiated the Research Networks in Mathematical Sciences (RNMS) Program to provide support over five to ten years for research collaborations that will cross intellectual, institutional, national, or other boundaries. The goals of the RNMS program are (1) to support coordinated research and training collaborations that link together researchers addressing significant challenges in the mathematical sciences and (2) to broaden participation in the mathematical sciences by creating new opportunities for research involvement and support. It will complement existing research award mechanisms to promote disciplinary progress in mathematics and statistics and to promote progress on multidisciplinary research agendas. It will create a new class of rich and stimulating environments for recruiting, educating, and training the next generation of mathematicians and statisticians, and it will help to form effective connections among academic researchers and researchers in government, industry, and international institutions.

Proposals may be submitted only by universities and colleges. The deadline for full proposals is **July 10, 2012**. For more information, see the website http://www.nsf.gov/pubs/2010/nsf10584/nsf10584.htm?WT.mc_id=USNSF_25&WT.mc_ev=click.

—From an NSF announcement

NSF Conferences and Workshops in Math Sciences

The National Science Foundation (NSF) supports conferences, workshops, and related events (including seasonal schools and international travel by groups). Proposals for conferences, workshops, or conference-like activities may request funding of any amount and for durations of up to three years. Proposals may be submitted only by universities and colleges and by nonprofit nonacademic institutions. For full information, including deadlines for each disciplinary program, see the website http://www.nsf.gov/pubs/2010/nsf10578/nsf10578.htm?WT.mc_id=USNSF_25&WT.mc_ev=click.

—From an NSF announcement

AMS-AAAS Mass Media Summer Fellowships

The American Mathematical Society provides support each year for a graduate student in the mathematical sciences to participate in the American Association for the Advancement of Science (AAAS) Mass Media Science and Engineering Fellows Program. This summer fellowship program pairs graduate students with major media outlets nationwide where they will research, write, and report on science news and use their skills to bring technical subjects to the general public.

The principal goal of the program is to increase the public's understanding of science and technology by strengthening the connection between scientists and journalists to improve coverage of science-related issues in the media. Past AMS-sponsored fellows have held positions at *Scientific American*, Voice of America, KUNC-FM Radio, National Geographic Television, *The Oregonian*, *Popular Science*, *The Chicago Tribune*, *Milwaukee Journal Sentinel* and WOSU-AM Radio.

Fellows receive a weekly stipend of US\$450, plus travel expenses, to work for ten weeks during the summer as reporters, researchers, and production assistants in newsrooms across the country. They observe and participate in the process by which events and ideas become news, improve their ability to communicate about complex technical subjects in a manner understandable to the public, and increase their understanding of editorial decision making and of how information is effectively disseminated. Each fellow attends an orientation and evaluation session in Washington, D.C., and begins the internship in mid-June. Fellows submit interim and final reports to AAAS. A wrap-up session is held at the end of the summer.

Mathematical sciences faculty are urged to make their graduate students aware of this program. The deadline to apply for fellowships for the summer of 2012 is **January 15, 2012**. Further information about the fellowship program and application procedures is available online at <http://www.aaas.org/programs/education/MassMedia>; or applicants may contact Rahman Culver, Manager, Mass Media Program, AAAS Mass Media Science and Engineering Fellows Program, 1200 New York Avenue, NW, Washington, DC 20005; telephone 202-326-6645; fax 202-371-9849; email raculver@aaas.org. Further information is also available at <http://www.ams.org/programs/ams-fellowships/media-fellow/massmediafellow> and through the AMS Washington office, 1527 Eighteenth Street, NW, Washington, DC 20036; telephone 202-588-1100; fax 202-588-1853; email amsdc@ams.org.

—AMS Washington office

News from IPAM

The Institute for Pure and Applied Mathematics (IPAM), located at the University of California, Los Angeles, holds long- and short-term research programs and workshops throughout the academic year for junior and senior

mathematicians and scientists who work in academia, the national laboratories, and industry. IPAM's upcoming programs are listed below. Please go to www.ipam.ucla.edu for detailed information and to find online application and registration forms.

Currently, IPAM is in the midst of its long program on genomics. Researchers from mathematics, computer science, and biological sciences, along with sequencing technology developers in both industry and academia, are in residence at IPAM this fall. A series of workshops on genomics and DNA sequencing is in progress.

In order to address urgent problems that mathematics may help solve, IPAM introduces a series of "exploratory" workshops. The first in this series is *Traffic Flow Modeling, Estimation and Control*, to be held December 7–9, 2011.

IPAM sponsors two summer programs as well. Undergraduate students may apply to *Research in Industrial Projects for Students (RIPS)* to work on industry-sponsored research problems in Los Angeles or Hong Kong. The deadline for applications is **February 12, 2012**. Graduate students and recent Ph.D.s may apply to our 2012 summer school, *Deep Learning, Feature Learning*, to be held July 9–27, 2012. Webpages and applications for both programs will be posted soon.

IPAM's Science Advisory Board meets on November 4, 2011, to consider workshop proposals for winter 2013 and long program proposals for academic year 2013–2014. Program proposals from the community are welcome; instructions are available on our website.

Upcoming Workshops. You may apply for support or register for each workshop online.

December 7–9, 2011. Mathematics of Traffic Flow Modeling, Estimation and Control.

January 9–13, 2012. Large-Scale Multimedia Search.

January 23–27, 2012. Mathematical Challenges in Graphical Models and Message-Passing Algorithms.

February 6–10, 2012. Challenges in Synthetic Aperture Radar.

February 27–March 2, 2012. Nonlocal PDEs, Variational Problems and Their Applications.

March 12–June 15, 2012. Computational Methods in High Energy Density Plasmas. You may apply online for support to be a core participant for the entire program or to attend any of the following individual workshops:

Tutorials: March 13–16, 2012.

Workshop I: Computational Challenges in Hot Dense Plasmas, March 26–30, 2012.

Workshop II: Computational Challenges in Magnetized Plasma, April 16–20, 2012.

Workshop III: Mathematical and Computer Science Approaches to High Energy Density Physics, May 7–11, 2012.

Workshop IV: Computational Challenges in Warm Dense Matter, May 21–25, 2012.

September 10–December 14, 2012. Materials Defects: Mathematics, Computation, and Engineering. You may apply online for support to be a core participant for the entire program or to attend any of the following individual workshops:

Tutorials: September 11–14, 2012.

Workshop I: Quantum and Atomistic Modeling of Materials Defects, October 1–5, 2012.

Workshop II: Atomistic and Mesoscale Modeling of Materials Defects, October 22–26, 2012.

Workshop III: Mesoscale and Continuum Scale Modeling of Materials Defects, November 13–16, 2012.

Workshop IV: Computational Methods for Multiscale Modeling of Materials Defects, December 3–7, 2012.

March 11–June 14, 2013. Interactions between Analysis and Geometry. You may apply online for support to be a core participant for the entire program or to attend any of the following individual workshops:

Tutorials: March 12–15, 2013.

Workshop I: Analysis on Metric Spaces, March 18–22, 2013.

Workshop II: Dynamics of Groups and Rational Maps, April 8–12, 2013.

Workshop III: Nonsmooth Geometry, April 29–May 3, 2013.

Workshop IV: Quasiconformal Geometry and Elliptic PDEs, May 20–24, 2013.

—From an IPAM announcement

MSRI Call for Proposals

The Mathematical Sciences Research Institute (MSRI) is now accepting proposals for scientific programs, workshops, and summer graduate schools. Materials should be submitted to the director, deputy director, any member of the Scientific Advisory Committee, or by email to proposals@msri.org. For detailed information, please see www.msri.org.

Thematic Programs. MSRI is accepting proposals for semester-long or year-long scientific programs to be held at MSRI starting in spring 2015. Organizers are encouraged to submit a letter of intent prior to preparing a preproposal. Full proposals are considered in the fall and winter of each year and should be submitted by **October 1** or **January 1**. For complete details, see <http://www.msri.org/msri-progprop>.

Proposals for Hot Topics Workshops. Each year, MSRI hosts a week-long workshop to showcase what's new, innovative, and interesting to the mathematical sciences community. Proposals for Hot Topics Workshops to be held in year N should be submitted by **October 1** or **January 1** of year $N-1$ and N . See <http://www.msri.org/msri-htw>.

Summer Graduate Schools. Each summer, MSRI organizes four 2-week long summer graduate workshops, the majority of which are held at MSRI. To be considered for the summer of year N , proposals should be submitted by October 1 or January 1 of year $N-2$ and $N-1$. See <http://www.msri.org/msri-sgw>.

—from an MSRI announcement

Reference and Book List

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

Contacting the Notices

The preferred method for contacting the *Notices* is electronic mail. The editor is the person to whom to send articles and letters for consideration. Articles include feature articles, memorial articles, communications, opinion pieces, and book reviews. The editor is also the person to whom to send news of unusual interest about other people's mathematics research.

The managing editor is the person to whom to send items for "Mathematics People", "Mathematics Opportunities", "For Your Information", "Reference and Book List", and "Mathematics Calendar". Requests for permissions, as well as all other inquiries, go to the managing editor.

The electronic-mail addresses are notices@math.wustl.edu in the case of the editor and notices@ams.org in the case of the managing editor. The fax numbers are 314-935-6839 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines

September 15, 2011: Nominations for Sloan Research Fellowships. See <http://www.sloan.org/fellowships>.

September 16, 2011: Full proposals for NSF Focused Research Groups. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5671.

September 30, 2011: Proposals for BIRS five-day workshops and summer school; preferred date for receipt of applications for BIRS Research in Teams and Focused Research Groups programs. For full information, guidelines, and online forms, see <http://www.birs.ca/>; for submission, see <https://www.birs.ca/proposals>.

September 30, 2011: Applications for travel grants for ICME. See "Mathematics Opportunities" in this issue.

September 30, 2011: Nominations for 2011 Sacks Prize. See http://www.aslonline.org/Sacks_nominations.html.

October 1, 2011: Nominations for Emanuel and Carol Parzen Prize for Statistical Innovation. Contact Thomas Wehrly, Department of Statistics, 3143 TAMU, Texas A&M University, College Station, Texas 77843-3143.

Where to Find It

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

AMS Bylaws—November 2009, p. 1320

AMS Email Addresses—February 2011, p. 326

AMS Ethical Guidelines—June/July 2006, p. 701

AMS Officers 2010 and 2011 Updates—May 2011, p. 735

AMS Officers and Committee Members—October 2011, p. 1311

Conference Board of the Mathematical Sciences—September 2010, p. 1009

IMU Executive Committee—December 2010, p. 1488

Information for Notices Authors—June/July 2011, p. 845

Mathematics Research Institutes Contact Information—August 2011, p. 973

National Science Board—January 2011, p. 77

New Journals for 2008—June/July 2009, p. 751

NRC Board on Mathematical Sciences and Their Applications—March 2011, p. 482

NRC Mathematical Sciences Education Board—April 2011, p. 619

NSF Mathematical and Physical Sciences Advisory Committee—February 2011, p. 329

Program Officers for Federal Funding Agencies—October 2011, p. 1306 (DoD, DoE); December 2010, page 1488 (NSF Mathematics Education)

Program Officers for NSF Division of Mathematical Sciences—November 2010, p. 1328

October 1 2011, and January 1, 2012: Proposals for MSRI Hot Topic Workshops for 2012. See <http://www.msri.org/msri-htw>.

October 1, 2011, and January 1, 2012: Proposals for MSRI Summer Graduate Schools for 2012. See <http://www.msri.org/msri-sgw>.

October 1, 2011; February 1, October 1, and May 1, 2012: Applications for AWM Travel Grants. See <http://www.awm-math.org/travelgrants.html#standard>; telephone: 703-934-0163; or e-mail: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 15, 2011: Proposals for NSA Mathematical Sciences Grants. See http://www.nsa.gov/research/math_research/sabbaticals/index.shtml.

October 19, 2011: Proposals for NSF Postdoctoral Research Fellowships. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5301.

October 30, 2011: Nominations for Clay Research Fellowships. See http://www.claymath.org/research_fellows or telephone Gigi Patel at 617-995-2602.

October 30, 2011: Nominations for ICTP Ramanujan Prize. See <http://prizes.ictp.it/Ramanujan/>.

November 1, 2011: Nominations for CRM-Fields-PIMS Prize. Submit nominations to crm-fields-pims-prize@fields.utoronto.ca.

November 1, 2011: Proposals for AIM Workshops. See www.aimath.org.

November 1, 2011: Applications for November review for National Academies Research Associateship Programs. See the National Academies website at http://sites.nationalacademies.org/PGA/RAP/PGA_050491 or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone 202-334-2760; fax 202-334-2759; email rap@nas.edu.

November 14, 2011: Applications for NRC-Ford Foundation Predoctoral Fellowships. See <http://sites.nationalacademies.org/PGA/FordFellowships/index.htm>. Postal address: Fellowships Office,

The National Academies, 500 Fifth Street, NW, Fifth Floor, Washington, DC 20001; telephone: 202-334-2872; email: infofell@nas.edu.

November 17, 2011: Applications for NRC-Ford Foundation Dissertation and Postdoctoral Fellowships. See <http://sites.nationalacademies.org/PGA/FordFellowships/index.htm>. Postal address: Fellowships Office, The National Academies, 500 Fifth Street, NW, Fifth Floor, Washington, DC 20001; telephone: 202-334-2872; email: infofell@nas.edu.

December 1, 2011: Applications for AMS Centennial Fellowship Program. See <http://www.ams.org/ams-fellowships/>. For paper copies of the form, write to the Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294; prof-serv@ams.org; 401-455-4105.

December 1, 2011: Applications for PIMS postdoctoral fellowships. See <http://www.pims.math.ca/scientific/postdoctoral> or contact: assistant.director@pims.math.ca.

December 2, 2011: Entries for the 2012 Ferran Sunyer i Balaguer Prize. See the website <http://ffsb.iec.cat>.

December 21, 2011: Nominations for the Schauder Medal. Contact Lech Gorniewicz, tmna@mat.uni.torun.pl.

December 31, 2011: Nominations for Otto Neugebauer Prize for the History of Mathematics. See <http://www.euro-math-soc.eu/node/995>.

February 12, 2012: Applications for IPAM summer program, Research in Industrial Projects for Students (RIPS). See "Mathematics Opportunities" in this issue.

July 10, 2012: Full proposals for NSF Research Networks in the Mathematical Sciences. See "Mathematics Opportunities" in this issue.

DoD Mathematics Staff

The following agencies of the Department of Defense and the Department of Energy fund research in the mathematical sciences. The names, addresses, and telephone numbers of the pertinent staff members are listed.

Defense Advanced Research Projects Agency

Defense Sciences Office
3701 North Fairfax Drive
Arlington, VA 22203-1714 703-526-6630
<http://www.darpa.mil/dso>

Applied and Computational Mathematics Program

Predicting Real Optimized Materials
Judah Goldwasser, Program Manager
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Fundamental Mathematics Program

Focus Areas in Theoretical Mathematics
Anthony Falcone
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Fundamental Laws of Biology
Christian Macedonia, Program Manager
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Sensor Topology for Minimal Planning
Anthony Falcone
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Air Force Office of Scientific Research

Directorate of Mathematics, Information, and Life Sciences
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Arlington, VA 22203-1768
Fax: 703-696-8450
<http://www.afosr.af.mil/>
Frederica Darema, Director

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Systems and Software

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Physics and Electronics Directorate
Patrick Carrick, Director

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Multiscale Modeling

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Army Research Office

Mathematical and Information Sciences Directorate
ATTN: RDRL-ROI
P.O. Box 12211
Research Triangle Park, NC 27709-2211 919-549-4368
<http://www.arl.army.mil/www/default.cfm?Action=29&Page=216>

Program in Mathematics

Biomathematics

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Modeling of Complex Systems

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Program in Computing Sciences

Computational Architectures and Visualization

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Information and Software Assurance

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National Security Agency

Mathematical Sciences Program
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Ft. George G. Meade, MD 20755-6557
http://www.nsa.gov/research/math_research/index.shtml
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Office of Naval Research

Mathematics, Computer, and Information Sciences Division
Office of Naval Research
One Liberty Center, Suite 1425
875 North Randolph Street
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Intelligent and Autonomous Systems

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DoE Mathematics Program

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Karen Pao
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Book List

The Book List highlights books that have mathematical themes and are aimed at a broad audience potentially

including mathematicians, students, and the general public. When a book has been reviewed in the Notices, a reference is given to the review. Generally the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers' attention to older books. Suggestions for books to include on the list may be sent to notices-booklist@ams.org.

*Added to "Book List" since the list's last appearance.

The Adventure of Reason: Interplay between Philosophy of Mathematics and Mathematical Logic, 1900-1940, by Paolo Mancosu. Oxford University Press, January 2011. ISBN-13: 978-01995-465-34.

At Home with André and Simone Weil, by Sylvie Weil. (Translation of *Chez les Weils*, translated by Benjamin Ivry.) Northwestern University Press, October 2010. ISBN-13: 978-08101-270-43. (Reviewed May 2011.)

The Autonomy of Mathematical Knowledge: Hilbert's Program Revisited, by Curtis Franks. Cambridge University Press, December 2010. ISBN-13: 978-05211-838-95.

**The Beginning of Infinity: Explanations That Transform the World*, by David Deutsch. Viking Adult, July 2011. ISBN-13: 978-06700-227-55.

The Best Writing on Mathematics: 2010, edited by Mircea Pitici. Princeton University Press, December 2010. ISBN-13: 978-06911-484-10.

The Big Questions: Mathematics, by Tony Crilly. Quercus, April 2011. ISBN-13: 978-18491-624-01.

The Black Swan: The Impact of the Highly Improbable, by Nassim Nicholas Taleb. Random House Trade Paperbacks, second edition, May 2010. ISBN-13: 978-08129-738-15. (First edition reviewed March 2011.)

**The Blind Spot: Science and the Crisis of Uncertainty*, by William Byers. Princeton University Press, April 2011. ISBN-13: 978-06911-468-43.

The Calculus Diaries: How Math Can Help You Lose Weight, Win in Vegas, and Survive a Zombie Apocalypse, by Jennifer Ouellette.

Penguin, reprint edition, August 2010. ISBN-13: 978-01431-173-77.

The Calculus of Selfishness, by Karl Sigmund. Princeton University Press, January 2010. ISBN-13: 978-06911-427-53.

Chasing Shadows: Mathematics, Astronomy, and the Early History of Eclipse Reckoning, by Clemency Montelle. Johns Hopkins University Press, April 2011. ISBN-13: 978-08018-969-10.

The Clockwork Universe: Isaac Newton, the Royal Society, and the Birth of the Modern World, by Edward Dolnick. Harper, February 2011. ISBN-13: 978-00617-195-16. (Reviewed April 2011.)

Complexity: A Guided Tour, by Melanie Mitchell. Oxford University Press, April 2009. ISBN-13: 978-01951-244-15. (Reviewed April 2011.)

Crafting by Concepts: Fiber Arts and Mathematics, by Sarah-Marie Belcastro and Carolyn Yackel. A K Peters/CRC Press, March 2011. ISBN-13: 978-15688-143-53.

**Cycles of Time: An Extraordinary New View of the Universe*, by Roger Penrose. Knopf, May 2011. ISBN-13: 978-03072-659-06.

Duel at Dawn: Heroes, Martyrs, and the Rise of Modern Mathematics, by Amir Alexander. Harvard University Press, April 2010. ISBN-13: 978-06740-466-10. (Reviewed November 2010.)

An Early History of Recursive Functions and Computability from Gödel to Turing, by Rod Adams. Docent Press, May 2011. ISBN-13: 978-09837-004-01.

The Evolution of Logic, by W. D. Hart. Cambridge University Press, August 2010. ISBN-13: 978-0-521-74772-1

The Grand Design, by Stephen Hawking and Leonard Mlodinow. Bantam, September 2010. ISBN-13: 978-05538-053-76.

Hidden Harmonies (The Lives and Times of the Pythagorean Theorem), by Robert and Ellen Kaplan. Bloomsbury Press, January 2011. ISBN-13: 978-15969-152-20.

The History and Development of Nomography, by H. A. Evesham. Docent Press, December 2010. ISBN-13: 978-14564-796-26.

Hot X: Algebra Exposed, by Danica McKellar. Hudson Street Press,

August 2010. ISBN-13: 978-15946-307-05.

I Want to Be a Mathematician: A Conversation with Paul Halmos. A film by George Csicsery. Mathematical Association of America, March 2009. ISBN-13: 978-08838-590-94. (Reviewed June/July 2011.)

Le Operazioni del Calcolo Logico, by Ernst Schröder. Original German version of Operationskreis des Logikkalküls and Italian translation with commentary and annotations by Davide Bondoni. LED Online, 2010. ISBN-13: 978-88-7916-474-0.

Loving + Hating Mathematics: Challenging the Myths of Mathematical Life, by Reuben Hersh and Vera John-Steiner. Princeton University Press, January 2011. ISBN-13: 978-06911-424-70.

A Mathematician's Lament: How School Cheats Us Out of Our Most Fascinating and Imaginative Art Form, by Paul Lockhart. Bellevue Literary Press, April 2009. ISBN-13: 978-1-934137-17-8.

Mathematics and Reality, by Mary Leng. Oxford University Press, June 2010. ISBN-13: 978-01992-807-97.

Mathematics Education for a New Era: Video Games as a Medium for Learning, by Keith Devlin. A K Peters/CRC Press, February 2011. ISBN-13: 978-1-56881-431-5.

A Motif of Mathematics: History and Application of the Mediant and the Farey Sequence, by Scott B. Guthery. Docent Press, September 2010. ISBN-13: 978-4538-105-76.

Mysteries of the Equilateral Triangle, by Brian J. McCartin. Hikari, August 2010. ISBN-13: 978-954-91999-5-6. Electronic copies available for free at <http://www.m-hikari.com/mccartin-2.pdf>.

**Newton and the Counterfeiter: The Unknown Detective Career of the World's Greatest Scientist*, by Thomas Levenson. Houghton Mifflin Harcourt, June 2009. ISBN-13: 978-01510-127-87.

NIST Handbook of Mathematical Functions, Cambridge University Press, Edited by Frank W. J. Olver, Daniel W. Lozier, Ronald F. Boisvert, and Charles W. Clark. Cambridge University Press, May 2010. ISBN-13: 978-05211-922-55 (hardback plus CD-ROM); ISBN-13: 978-05211-406-38 (paperback plus CD-ROM). (Reviewed September 2011.)

Nonsense on Stilts: How to Tell Science from Bunk, by Massimo Pigliucci. University of Chicago Press, May 2010. ISBN-13: 978-02266-678-67. (Reviewed April 2011.)

Number Freak: From 1 to 200—The Hidden Language of Numbers Revealed, by Derrick Niederman. Perigee Trade, August 2009. ISBN-10: 03995-345-98.

Numbers: A Very Short Introduction, by Peter M. Higgins. Oxford University Press, February 2011. ISBN-13: 978-0-19-958405-5.

Numbers Rule: The Vexing Mathematics of Democracy, from Plato to the Present, by George G. Szpiro. Princeton University Press, April 2010. ISBN-13: 978-06911-399-44. (Reviewed January 2011.)

**One, Two, Three: Absolutely Elementary Mathematics* [Hardcover] David Berlinski. Pantheon, May 2011. ISBN-13: 978-03754-233-38.

Origami Inspirations, by Meenakshi Mukerji. A K Peters, September 2010. ISBN-13: 978-1568815848.

The Perfect Swarm: The Science of Complexity in Everyday Life, by Len Fisher. Basic Books, March 2011 (paperback). ISBN-13: 978-04650-202-49.

The Pleasures of Statistics: The Autobiography of Frederick Mosteller. Edited by Stephen E. Fienberg, David C. Hoaglin, and Judith M. Tanur. Springer, January 2010. ISBN-13: 978-03877-795-53.

Problem-Solving and Selected Topics in Number Theory in the Spirit of the Mathematical Olympiads, by Michael Th. Rassias. Springer, 2011. ISBN-13: 978-1-4419-0494-2.

Proofiness: The Dark Arts of Mathematical Deception, by Charles Seife. Viking, September 2010. ISBN-13: 978-06700-221-68.

The Quants: How a New Breed of Math Whizzes Conquered Wall Street and Nearly Destroyed It, by Scott Patterson. Crown Business, January 2011. ISBN-13: 978-03074-533-89. (Reviewed May 2011.)

**Riot at the Calc Exam and Other Mathematically Bent Stories*, by Colin Adams. AMS, July 2009. ISBN-13: 978-08218-481-73.

Roads to Infinity: The Mathematics of Truth and Proof, by John C. Stillwell. A K Peters/CRC Press, July 2010. ISBN-13: 978-15688-146-67.

The Shape of Inner Space: String Theory and the Geometry of the Universe's Hidden Dimensions, by Shing-Tung Yau (with Steve Nadis). Basic Books, September 2010. ISBN-13: 978-04650-202-32. (Reviewed February 2011.)

The Strangest Man, by Graham Farmelo. Basic Books, August 2009. ISBN-13: 978-04650-182-77. (Reviewed in this issue.)

Street-Fighting Mathematics: The Art of Educated Guessing and Opportunistic Problem Solving, by Sanjoy Mahajan. MIT Press, March 2010. ISBN-13: 978-0-262-51429-3. (Reviewed August 2011.)

Survival Guide for Outsiders: How to Protect Yourself from Politicians, Experts, and Other Insiders, by Sherman Stein. BookSurge Publishing, February 2010. ISBN-13: 978-14392-532-74.

The Theory That Would Not Die: How Bayes' Rule Cracked the Enigma Code, Hunted Down Russian Submarines, and Emerged Triumphant from Two Centuries of Controversy, by Sharon Bertsch McGrayne. Yale University Press, April 2011. ISBN-13: 978-03001-696-90.

Train Your Brain: A Year's Worth of Puzzles, by George Grätzer. A K Peters/CRC Press, April 2011. ISBN-13: 978-15688-171-01.

**Viewpoints: Mathematical Perspective and Fractal Geometry in Art*, by Marc Frantz and Annalisa Crannell. Princeton University Press, August 2011. ISBN-13: 978-06911-259-23.

Visual Thinking in Mathematics, by Marcus Giaquinto. Oxford University Press, July 2011. ISBN-13: 978-01995-755-34.

What's Luck Got to Do with It? The History, Mathematics and Psychology of the Gambler's Illusion, by Joseph Mazur. Princeton University Press, July 2010. ISBN-13: 978-069-113890-9.

Why Beliefs Matter: Reflections on the Nature of Science, by E. Brian Davies. Oxford University Press, June 2010. ISBN-13: 978-01995-862-02.

Statistics on Women Mathematicians Compiled by the AMS

At its August 1985 meeting the Council of the AMS approved a motion to regularly assemble and report in the *Notices* information on the relative numbers of men versus women in at least the following categories: membership in the AMS, invited hour addresses at AMS meetings, speakers at Special Sessions at AMS meetings, percentage of women speakers in AMS Special Sessions by gender of organizers, and members of editorial boards of AMS journals.

It was subsequently decided that this information would be gathered by determining the sex of the individuals in the above categories based on name identification if no other means was available and that additional information on the number of Ph.D.s granted to women would also be collected using the AMS-ASA-IMS-MAA-SIAM Annual Survey. Since name identification was used, the information for some categories necessitated the use of three classifications:

Male: names that were obviously male

Female: names that were obviously female

Unknown: names that could not be identified as clearly male or female (e.g., only initials given, non-gender-specific names, etc.)

The following is the twenty-fifth reporting of this information. Updated reports will appear annually in the *Notices*.

Invited Hour Address Speakers at AMS Meetings (2001-2010)

Male:	351	84%
Female:	66	16%
Unknown:	0	0%
Total:	417	

Speakers at Special Sessions at AMS Meetings (2004-2010)

Male:	10,617	79%
Female:	2,640	20%
Unknown:	202	2%
Total:	13,459	

Percentage of Women Speakers in AMS Special Sessions by Gender of Organizers (2010)

Special Sessions with at Least One Woman Organizer

Male:	826	73%
Female:	286	25%
Unknown:	17	2%
Total:	1,129	

Special Sessions with No Women Organizers

Male:	1,384	79%
Female:	339	19%
Unknown:	33	2%
Total:	1,756	

2010 Members of the AMS Residing in the U.S.

Male:	14,038	67%
Female:	3,649	17%
Unknown:	3,421	16%
Total:	21,108	

Trustees and Council Members

	2007	2008	2009	2010
Male:	27 66%	26 66%	29 67%	28 67%
Female:	14 34%	14 37%	14 33%	14 33%
Total:	41	41	43	42

Members of AMS Editorial Committees

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Male:	190 85%	195 85%	189 84%	180 84%	184 83%	193 84%	194 84%	168 83%	178 84%	176 82%
Female:	34 15%	35 15%	35 16%	34 16%	38 17%	36 16%	36 16%	35 17%	34 16%	39 18%
Total:	224	230	224	214	222	229	230	203	212	215

Ph.D.s Granted to U.S. Citizens

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Male:	343 69%	291 70%	341 68%	347 68%	355 72%	399 72%	396 69%	431 69%	515 69%	564 71%
Female:	151 31%	127 30%	158 32%	166 32%	141 28%	153 28%	180 31%	191 31%	227 31%	225 28%
Total:	494	418	499	513	496	552	576	622	742	790

Officers and Committee Members

Numbers to the left of headings are used as points of reference in an index to AMS committees which follows this listing. Primary and secondary headings are:

1. Officers
 - 1.1. Liaison Committee
2. Council
 - 2.1. Executive Committee of the Council
3. Board of Trustees
4. Committees
 - 4.1. Committees of the Council
 - 4.2. Editorial Committees
 - 4.3. Committees of the Board of Trustees
 - 4.4. Committees of the Executive Committee and Board of Trustees
 - 4.5. Internal Organization of the AMS
 - 4.6. Program and Meetings
 - 4.7. Status of the Profession
 - 4.8. Prizes and Awards
 - 4.9. Institutes and Symposia
 - 4.10. Joint Committees
5. Representatives
6. Index

Terms of members expire on January 31 following the year given unless otherwise specified.

1. Officers

President	Eric M. Friedlander	2012
Immediate Past President	George E. Andrews	2011
Vice Presidents	Sylvain Cappell	2012
	Barbara Lee Keyfitz	2013
	Frank Morgan	2011
Secretary	Robert J. Daverman	2012
Associate Secretaries	Georgia Benkart	2011
	Michel L. Lapidus	2011
	Matthew Miller	2012
	Steven Weintraub	2012
Treasurer	Jane M. Hawkins	2012
Associate Treasurer	John M. Franks	2011

1.1. Liaison Committee

All members of this committee serve *ex officio*.

Chair	Robert J. Daverman
	Eric M. Friedlander
	Jane M. Hawkins
	Karen Vogtmann

2. Council

2.0.1. Officers of the AMS

President	Eric M. Friedlander	2012
Immediate Past President	George E. Andrews	2011
Vice Presidents	Sylvain Cappell	2012
	Barbara Lee Keyfitz	2013
	Frank Morgan	2011
Secretary	Robert J. Daverman	2012
Associate Secretaries*	Georgia Benkart	2011
	Michel L. Lapidus	2011
	Matthew Miller	2012
	Steven Weintraub	2012
Treasurer	Jane M. Hawkins	2012
Associate Treasurer	John M. Franks	2011

2.0.2. Representatives of Committees

Bulletin	Susan J. Friedlander	2011
Colloquium	Paul J. Sally, Jr.	2011
Executive Committee	Craig Huneke	2011
Executive Committee	Joseph H. Silverman	2012
Journal of the AMS	Karl Rubin	2013
Mathematical Reviews	Ronald M. Solomon	2012
Mathematical Surveys and Monographs	Ralph L. Cohen	2012
Mathematics of Computation	Chi-Wang Shu	2011
Proceedings	Ken Ono	2013
Transactions and Memoirs	Robert Guralnick	2012

*Only one Associate Secretary at a time is a voting member of the Council, namely the cognizant Associate Secretary for the scientific sessions.

2.0.3. Members at Large

Alejandro Adem	2012	Jennifer Schultens	2012
Matthew Ando	2013	Panagiotis E. Souganidis	2011
Estelle Basor	2013	T. Christine Stevens	2013
Aaron Betram	2011	Janet Talvacchia	2012
Richard Hain	2012	Christoph Thiele	2012
Patricia Hersh	2013	Michelle L. Wachs	2011
Tara S. Holm	2013	David Wright	2011
William A. Massey	2011		

2.1. Executive Committee of the Council

George E. Andrews	<i>ex officio</i>
Ralph L. Cohen	2014
Robert J. Daverman	<i>ex officio</i>
Eric M. Friedlander	<i>ex officio</i>
Craig L. Huneke	2011
Bryna Kra	2013
Joseph H. Silverman	2012

3. Board of Trustees

	John M. Franks	<i>ex officio</i>
	Eric M. Friedlander	<i>ex officio</i>
	Mark L. Green	2014
	Jane M. Hawkins	<i>ex officio</i>
	William H. Jaco	2015
Secretary	Ronald J. Stern	2013
Chair	Karen Vogtmann	2012
	Carol S. Wood	2011

4. Committees

4.1. Committees of the Council

Standing Committees

4.1.1. Editorial Boards

	Robert J. Daverman	<i>ex officio</i>
	Sergei Gelfand	<i>ex officio</i>
Chair	Michael T. Lacey	2011
	Anatoly S. Libgober	2012
	Michael F. Singer	2011
	John R. Stembridge	2013
	Sergei K. Suslov	2013
	Simon Tavenor	2012

4.1.2. Nominating Committee

Terms begin on January 1 and expire on December 31 of the year listed.

	William Beckner	2012
	Richard A. Brualdi	2013
	Richard T. Durrett	2012
	Irene Fonseca	2011
	Sheldon H. Katz	2011
	Ellen E. Kirkman	2011
	Donal O'Shea	2013
Chair	Carla D. Savage	2012
	Gunther Uhlmann	2013

4.2. Editorial Committees

4.2.1. Abstracts Editorial Committee

All members of this committee serve *ex officio*.

	Georgia Benkart
Chair	Robert J. Daverman
	Michel L. Lapidus
	Matthew Miller
	Steven Weintraub

4.2.2. Bulletin (New Series)

Consultant	Gerald L. Alexanderson	2013
Book Reviews Editor	Robert L. Devaney	2011
Chief Editor	Susan J. Friedlander	2011
Consultant	Jane Kister	2013

Associate Editors for Bulletin Articles

David J. Benson	2011	Gregory Lawler	2011
Daniel S. Freed	2011	Barry Mazur	2011
Edward Frenkel	2011	Paul H. Rabinowitz	2011
Mark Goresky	2011	Yuri Tschinkel	2011
Andrew J. Granville	2011	Michael Wolf	2011
Bryna Kra	2011		

Associate Editors for Book Reviews

Jonathan L. Alperin	2011	Ken Ono	2011
Steven G. Krantz	2011	Philip E. Protter	2011
Peter Kuchment	2011	Lisa Traynor	2011

4.2.3. Collected Works

Chair	Dusa McDuff	2012
	Elias M. Stein	2012
	William A. Veech	2011

4.2.4. Colloquium

	Yuri Manin	2013
Chair	Paul J. Sally, Jr.	2011
	Peter Sarnak	2012

4.2.5. Contemporary Mathematics

	George E. Andrews	2011
Chair	Dennis DeTurck	2011
	Abel Klein	2011
	Martin Strauss	2011

4.2.6. Graduate Studies in Mathematics

Chair	David A. Cox	2012
	Rafe Mazzeo	2011
	Martin G. Scharlemann	2011
	Gigliola Staffilani	2013

4.2.7. Journal of the AMS

	Weinan E	2013
	Sergey Fomin	2012
	Gregory Lawler	2012
	Tom Mrowka	2013
Chair	Karl Rubin	2013
	Terence Tao	2011

Associate Editors

Noga Alon	2011	Elon Lindenstrauss	2011
Alexei Borodin	2011	Jacob Lurie	2012
Robert L. Bryant	2011	Haynes R. Miller	2012
Emanuel Candes	2011	Assaf Naor	2011
Sun-Yung Alice Chang	2013	Sorin T. Popa	2011
Brian Conrad	2013	Thomas Scanlon	2012
Pavel I. Etingof	2011	Freydoon Shahidi	2012
Mark Goresky	2011	Karen Vogtmann	2013
Christopher Hacon	2012	Avi Wigderson	2012
Peter Kronheimer	2012	Lia-Sang Young	2011

4.2.8. Mathematical Reviews

AMS staff contact: Graeme Fairweather

	Cameron Gordon	2011
	Barbara Keyfitz	2013
	Peter Maass	2012
	Shigefumi Mori	2013
Chair	Ronald M. Solomon	2012
	Trevor D. Wooley	2012

4.2.9. Mathematical Surveys and Monographs

Chair	Ralph L. Cohen	2012
	Michael Singer	2013
	Benjamin Sudakov	2011
	Michael Weinstein	2013

4.2.10. Mathematics of Computation

	Susanne C. Brenner	2012
	Ronald F. Cools	2011
	Igor Shparlinski	2011
Chair	Chi-Wang Shu	2011

Associate Editors

Rémi Abgrall	2013	Gilles Pagès	2013
Daniela Calvetti	2011	Cheryl Praeger	2012
Zhiming Chen	2013	Renate Scheidler	2013
Jean-Marc Couveignes	2011	Christoph Schwab	2011
Ricardo G. Duran	2013	Jie Shen	2011
Ivan P. Gavriluk	2011	Zuowei Shen	2014
Viviette Girault	2012	Chris J. Smyth	2013
Ernst Hairer	2011	Michael Stillman	2012
Fred J. Hickernell	2011	Daniel B. Szyld	2013
Gregor Kemper	2012	Tao Tang	2012
Michael J. Mossinghoff	2013	Hans W. Volkmer	2011
Francis J. Narcowich	2011	Ya-Xiang Yuan	2013
Stanley Osher	2011	Zhimin Zhang	2012

4.2.11. Notices Editorial Board

Terms begin on January 1 and expire on December 31 of the year listed.

Editor	Steven G. Krantz	2012
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Associate Editors

Krishnaswami Alladi	2012	Robion C. Kirby	2012
David H. Bailey	2012	Rafe Mazzeo	2012
Jonathan M. Borwein	2012	Harold R. Parks	2012
Susanne Brenner	2012	Peter C. Sarnak	2012
William Casselman	2012	Mark E. Saul	2012
Robert J. Daverman	<i>ex officio</i>	Edward L. Spitznagel	2012
Lisette de Pillis	2012	John R. Swallow	2012
Susan J. Friedlander	2012		

4.2.12. Proceedings

	Mario Bonk	2011
	Lev Borisov	2013
	Kathrin Bringmann	2013
	James E. Colliander	2014
Coordinating	Walter Craig	2012
	Harm Derksen	2013
	Alexander N. Dranishnikov	2011
	Franc Forstneric	2012
	James Haglund	2013
	Michael Hitrik	2014
Coordinating	Birge Huisgen-Zimmermann	2013
	Marius Junge	2014
	Julia Knight	2012
	Bryna Kra	2011
	Michael T. Lacey	2012
	Mark M. Meerschaert	2014
	Kailash C. Misra	2014
	Lei Ni	2013
Chair	Ken Ono	2013
	Matthew Papanikolas	2013
	Irena Peeva	2013
	Richard H. Rochberg	2013
Coordinating	Daniel Ruberman	2013
Coordinating	Thomas B. Schlumprecht	2013
	Mei-Chi Shaw	2012
	Brooke E. Shipley	2012
	Sergei K. Suslov	2014
Coordinating	Chuu-Lian Terng	2013
	Pham Huu Tiep	2014
	Tatiana Toro	2014
	Walter Van Assche	2012
	Mathai Varghese	2011
	Edward C. Waymire	2011
	Michael Wolf	2013
	Yingfei Yi	2012

4.2.13. Proceedings of Symposia in Applied Mathematics

	Mary C. Pugh	2013
	Leonid Ryzhik	2011
Chair	Eitan Tadmor	2011

4.2.14. Transactions and Memoirs

	Dan Abramovich	2014
	Alejandro Adem	2012
	Luchezar L. Avramov	2012
	Richard Bass	2011
	Nathaniel Brown	2014
	Mark Feighn	2011
Chair	Robert Guralnick	2012
	Yunping Jiang	2011
	Alexander Kleshchev	2012
	Steffan Lempp	2011
	William P. Minicozzi II	2014
	Peter Polacik	2014
	Gustavo Alberto Ponce	2013
	Malabika Pramanik	2014
	Jonathan Rogawski	2011
	Wilhelm Schlag	2014
	Shankar Sen	2012
	John R. Stembridge	2013
	Mina Teicher	2012
	Erik P. Van Den Ban	2013
	Christopher Woodward	2012

Officers and Committee Members

4.2.15. Translation from Chinese

	Sun-Yung Alice Chang	
	S.-Y. Cheng	
Chair	Tsit-Yuen Lam	
	Tai-Ping Liu	
	Chung-Chun Yang	

4.2.16. Translation from Japanese

Chair	Shoshichi Kobayashi	
	Masamichi Takesaki	

Standing Committees

4.2.17. Conformal Geometry and Dynamics

	Francois Berteloot	2011
	Mario Bonk	2013
	Ursula Hamenstadt	2014
	Pekka Koskela	2012
Chair	Gaven Martin	2011
	Susan Mary Rees	2011
	Caroline Series	2012

4.2.18. History of Mathematics

	Joseph W. Dauben	2011
	Peter L. Duren	2011
	Robin Hartshorne	2012
Chair	Karen H. Parshall	2011

4.2.19. Pure and Applied Undergraduate Texts

Chair	Paul J. Sally, Jr.	2012
	Joseph H. Silverman	2012
	Francis Edward Su	2012
	Susan Tolman	2012

4.2.20. Representation Theory

	Jens Carsten Jantzen	2012
	Nicolai Reshetikhin	2012
Chair	Henrik Schlichtkrull	2012
	Freydoon Shahidi	2012
	Peter E. Trapa	2012
	David A. Vogan	2013

4.2.21. Student Mathematics Library

	Gerald B. Folland	2012
	Robin Forman	2011
Chair	Brad G. Osgood	2011
	John Stillwell	2013

4.2.22. University Lecture Series

	Jordan S. Ellenberg	2014
Chair	William P. Minicozzi II	2013
	Benjamin Sudakov	2011
	Tatiana Toro	2013

4.3. Committees of the Board of Trustees

4.3.1. Agenda and Budget

All members of this committee serve *ex officio*.
AMS staff contact: Ellen H. Heiser

	Robert J. Daverman	
	John M. Franks	
Chair	Eric M. Friedlander	
	Jane M. Hawkins	
	Karen Vogtmann	

4.3.2. Audit

All members of this committee serve *ex officio*.
AMS staff contact: Emily D. Riley.

	John M. Franks	
	Jane M. Hawkins	
Chair	Ronald J. Stern	
	Karen Vogtmann	

4.3.3. Investment

AMS staff contact: Emily D. Riley.

	John M. Franks	<i>ex officio</i>
	Jane M. Hawkins	<i>ex officio</i>
Chair	Ronald J. Stern	<i>ex officio</i>
	Rob Taylor	2012

4.3.4. Salary

All members of this committee serve *ex officio*.
AMS staff contact: Donald E. McClure.

	John M. Franks	
Chair	Jane M. Hawkins	
	Karen Vogtmann	

4.4. Committees of the Executive Committee and Board of Trustees

4.4.1. Long Range Planning

All members of this committee serve *ex officio*.
AMS staff contact: Ellen H. Heiser.

	Robert J. Daverman	
	Eric M. Friedlander	
Chair	Jane M. Hawkins	
	Bryna Kra	
	Donald E. McClure	
	Joseph H. Silverman	
	Karen Vogtmann	

4.4.2. Nominating

All members of this committee serve *ex officio*.

	Carla Savage	
	Joseph H. Silverman	
Chair	Ronald J. Stern	

4.4.3. AMS Secretary, Search Committee for

	Robert J. Daverman	2011
Consultant	Robert M. Fossum	2011
	John M. Franks	2011
	Mark L. Green	2011
	Jane M. Hawkins	2011
	Craig L. Huneke	2011
Chair	Susan R. Loepf	2011

4.4.4. Editor for Bulletin, Search Committee for

	George E. Andrews	2011
	Robert J. Daverman	2011
	Donald E. McClure	2011
	Ken Ono	2011
	Michelle Wachs	2011

4.5. Internal Organization of the American Mathematical Society

Standing Committees

4.5.1. Archives

	Bruce C. Berndt	2011
	Jonathan I. Hall	2013
	Thomas W. Hawkins	2012

4.5.2. Books and Journal Donations Steering Committee

	Toka Diagana	2012
	Jet Foncannon	2013
Chair	Huaxin Lin	2011

4.5.3. Committee on Committees

Chair	Alejandro Adem	2012
	Asuman G. Aksoy	2012
	Daniel Bates	2012
	Carlos Castillo-Chavez	2012
	Robert J. Daverman	<i>ex officio</i>
	Eric M. Friedlander	<i>ex officio</i>
	Rebecca F. Goldin	2012
	Susan R. Loepf	2012
	Russell D. Lyons	2012
	William A. Massey	2012
	Daniel Ken Nakano	2012
	Natasa Pavlovic	2012
	Natasa Sesum	2012

4.5.4. Employment Services, Advisory Board on

	Laura G. DeMarco	2011
	Patrick Barry Eberlein	2012
	Karl Peterson	2013

4.5.5. Library Committee

Co-chair	Jonathan M. Borwein	2011
	Cunera Buys	2013
	Kristine K. Fowler	2013
	Joseph Rosenblatt	2012
	Andrew V. Sills	2013
Co-chair	Linda Y. Yamamoto	2011
	Smilka Zdravkovska	2012
	_____	2013

4.5.6. Publications

AMS staff contact: Erin Buck.

	Matthew Ando	2013
	Aaron J. Bertram	2011
	Richard Brualdi	2012
	Robert J. Daverman	<i>ex officio</i>
	Eric M. Friedlander	<i>ex officio</i>
	Sergei Gelfand	<i>ex officio</i>
	Mark Goresky	2011
	Richard M. Hain	2012
	Krystyna M. Kuperberg	2013
Chair	Gregory F. Lawler	2011
	Anatoly Libgober	2011
	Donald E. McClure	<i>ex officio</i>
	Andrew M. Odlyzko	2011
	Carol S. Wood	2011

Special Committee

4.5.7. Graduate Working Group

	Daniel James Bates	2012
	Kareem Carr	2012
	Diana Davis	2012
	Eric M. Friedlander	2012
	Douglas Lind	2012
	Ellen Maycock	2012
	Frank Morgan	2012
	Ken Ono	2012
Chair	Joseph H. Silverman	2012

4.6. Program and Meetings

Standing Committees

4.6.1. Mathematics Research Communities Advisory Board

	Steven Benjamin Damelin	2013
	Robert J. Daverman	2012
Chair	David Eisenbud	2013
	William M. Goldman	2012
	Ken Ono	2012
	Kim Ruane	2013
	Henry K. Schenck	2013
	Alejandro Uribe	2012
	Kevin Wortman	2013
	Steven M. Zelditch	2013

4.6.2. Meetings and Conferences

AMS staff contact: Ellen Maycock

	Daljit S. Ahluwalia	2011
	Estelle Basor	2013
	Robert J. Daverman	<i>ex officio</i>
	Laura De Carli	2013
	Benson S. Farb	2013
Chair	David W. Farmer	2012
	Eric M. Friedlander	<i>ex officio</i>
	Alex Iosevich	2011
	William H. Jaco	2011
	William A. Massey	2011
	Donald E. McClure	<i>ex officio</i>
	Paul Muhly	2013
	Janet Talvacchia	2012

4.6.3. Program Committee for National Meetings

	J. P. Buhler	2012
	Suncica Canic	2011
	Robert J. Daverman	<i>ex officio</i>
	Michel L. Lapidus	<i>ex officio</i>
	Wilfried Schmid	2013
	Kannan Soundararajan	2012
Chair	Gigliola Staffilani	2011
	Amie Wilkinson	2013

4.6.4. Short Course Subcommittee

	Yuliy M. Baryshnikov	2011
	Robert W. Ghrist	2012
Chair	Charles M. Grinstead	2012
	Jonathan C. Mattingly	2011
	Jon McCammond	2013
	Sivaram Narayan	2013
	John Sylvester	2012

4.6.5. Central Section Program Committee

Chair	Scott Ahlgren	2011
	Georgia Benkart	<i>ex officio</i>
	Dick Canary	2012
	Brendan E. Hassett	2011
	Jared Wunsch	2012

4.6.6. Eastern Section Program Committee

Chair	John E. Meier	2011
	Igor Rodnianski	2012
	Laurent Saloff-Coste	2012
	Robert C. Vaughan	2011
	Steven Weintraub	<i>ex officio</i>

4.6.7. Southeastern Section Program Committee

Chair	Matthew Boylan	2011
	Scott McCullough	2012
	Matthew Miller	<i>ex officio</i>
	Daniel Ken Nakano	2012
	Chris Rodger	2011

4.6.8. Western Section Program Committee

	Asüman G. Aksoy	2012
	Ko Honda	2012
	Michel L. Lapidus	<i>ex officio</i>
	Daniel Tataru	2011
Chair	Chuu-Lian Terng	2011

4.6.9. Arnold Ross Lecture Series Committee

	Jonathan M. Kane	2012
	John M. (Jack) Lee	2013
	David Pollack	2012
	Daniel B. Shapiro	2011

4.6.10. Colloquium Lecture

	Ingrid Daubechies	2013
Chair	Gilbert Strang	2011
	Efim I. Zelmanov	2012

4.6.11. Gibbs Lecturer for 2011 and 2012, Committee to Select

	Robet Calderbank	2011
Chair	James G. Glimm	2011
	James A. Sethian	2011

4.6.12. AMS-Simons Travel Grants

	Amir Denbo	2011
	Donald J. Estep	2012
	Leonid Friedlander	2011
	Malay Ghosh	2012
Chair	Paul G. Goerss	2012
	James Haglund	2012
	Johnny L. Henderson	2011
	Srikanth B. Iyengar	2011
	Ohannes Karakashian	2012
	Richard Kenyon	2013
	Patricia K. Lamm	2011
	Peter W-K Li	2013
	Anna L. Mazzucato	2013
	Jon McCammond	2013
	Christoph Thiele	2011
	Michael Zieve	2013

4.6.13. Joint Mathematics Meetings Travel Grants

	Noel Brady	2012
Chair	Wai Kui Chan	2011
	Irina Mitrea	2013

4.6.14. Sectional Meetings Travel Grants Committee

	Mark Allen Hovey	2011
Chair	Michael C. Reed	2013
	Sarah Witherspoon	2013

4.7. Status of the Profession

Standing Committees

4.7.1. Academic Freedom, Tenure, and Employment Security

	Lisa Carbone	2011
	John B. Garnett	2012
	Ross Geoghegan	2013
	Carolyn S. Gordon	2013
Chair	Joseph M. Landsberg	2011
	Lance L. Littlejohn	2013
	Margaret M. Robinson	2012

4.7.2. Education

AMS staff contact: Samuel M. Rankin III.

	Ralph L. Cohen	2011
	Robert J. Daverman	<i>ex officio</i>
	Beverly E. J. Diamond	2011
	Eric M. Friedlander	<i>ex officio</i>
	Mark L. Green	2011
	Kenneth I. Gross	2012
	Tara S. Holm	2013
	Irwin Kra	2013
	David C. Manderscheid	2011
	Donald E. McClure	<i>ex officio</i>
	Harriett S. Pollatsek	2012
	Catherine Roberts	2012
	Christopher Theile	2012
Chair	David Wright	2011
	Hung-Hsi Wu	2013

4.7.3. Fan Fund

	Zhihong Jeff Xia	2013
Chair	Jinchao Xu	2011
	Tonghai Yang	2012

4.7.4. Human Rights of Mathematicians

	Mark Alber	2012
	Augustin Banyaga	2012
Chair	Raul E. Curto	2011
	Toka Diagana	2013
	Wilfrid Gangbo	2011
	Mel Nathanson	2013
	Yakov B. Pesin	2013
	Tanush Shaska	2012
	Yakov Sinai	2011

4.7.5. Profession

AMS staff contact: Ellen J. Maycock.

	Robert J. Daverman	<i>ex officio</i>
	Rachelle C. DeCoste	2013
	Ron Y. Donagi	2012
	Eric M. Friedlander	<i>ex officio</i>
	Patricia Hersh	2013
	Lorelei Koss	2012
	Donald E. McClure	<i>ex officio</i>
	Christopher K. McCord	2011
	Rick Miranda	2011
	Jennifer Schultens	2012
	Ronald J. Stern	2011
	Abigail A. Thompson	2013
	Jeffrey Vaaler	2012
	Michelle Wachs	2011
Chair	Julius Zelmanowitz	2011

4.7.6. Professional Ethics

	Miklos Bona	2012
	Petra Bonfert-Taylor	2012
	Daniel Pollack	2013
	John Roe	2012
	Margaret Fife Symington	2013
Chair	Dana P. Williams	2011

4.7.7. Science Policy

AMS staff contact: Samuel M. Rankin III.

	Alejandro Adem	2012
	George E. Andrews	<i>ex officio</i>
	Alexander Berkovich	2013
	Robert J. Daverman	<i>ex officio</i>
	Maarten V. deHoop	2013
	Eric M. Friedlander	<i>ex officio</i>
Chair	Kenneth M. Golden	2012
	David C. Manderscheid	2012
	Donald E. McClure	<i>ex officio</i>
	Claudia M. Neuhauser	2013
	George C. Papanicolaou	2011
	Panagiotis Souganidis	2011
	T. Christine Stevens	2013
	Karen Votgman	2011
	David Wright	2011

4.7.8. Young Scholars Awards

Terms expire on June 30.

	Brian R. Hunt	2013
	Irwin Kra	2012
Chair	Rafe Mazzeo	2012
	Zvezdelina E. Stankova	2013

4.8. Prizes and Awards

Standing Committees

4.8.1. AMS Public Policy Award Selection Committee

	George E. Andrews	2011
	Eric M. Friedlander	2012
	David C. Manderscheid	2011

4.8.2. Award for Distinguished Public Service, Committee to Select the Winner of the

	Richard A. Askey	2013
	C. Herbert Clemens	2013
	Roger E. Howe	2015
Chair	Richard A. Tapia	2011
	Sylvia M. Wiegand	2015

4.8.3. The Stefan Bergman Trust Fund

	Harold P. Boas	2013
	Carlos Kenig	2012
Chair	Linda Preiss Rothschild	2011

4.8.4. Centennial Fellowships

Terms expire on June 30.

	Jordan Ellenberg	2012
	Bjorn E. Engquist	2013
	Ronald A. Fintushel	2013
Chair	Ezra Getzler	2012
	Misha Kilmer	2012
	Monica Vazirani	2013
	Judy Walker	2012

4.8.5. Cole Prize, Committee to Select the Winner of the

Chair	Robert Louis Griess, Jr.	2011
	Janos Kollar	2011
	Parimala Raman	2011

4.8.6. Conant Prize, Committee to Select the Winner of the

	Jerry Bona	2012
	J. Brian Conrey	2013
Chair	Ronald M. Solomon	2011

4.8.7. Joseph L. Doob Prize

	Harold Boas	2015
	Andrew J. Granville	2012
	Robin C. Hartshorne	2012
	Neal I. Koblitz	2015
	John H. McCleary	2015

4.8.8. Exemplary Program or Achievement by a Mathematics Department, Committee to Select the Winner of the Prize for

	Carlos Castillo-Chavez	2012
	Annalisa Crannell	2012
Chair	Phil Kutzko	2012
	Suzanne M. Lenhart	2013
	Francis Edward Su	2013

4.8.9. Menger Prize, Committee to Select the Winner of the

Terms expire on May 31.

	Moon Duchin	2012
Chair	Gregory E. Fasshauer	2012
	Jonathan King	2013

4.8.10. E. H. Moore Research Article Prize, Committee to Select the Winner of the

	Sergiu Klainerman	2014
	Kenneth A. Ribet	2014
	_____	2014
	_____	2014
	_____	2014

4.8.11. National Awards and Public Representation

	George E. Andrews	<i>ex officio</i>
	James G. Arthur	2012
	Robert L. Bryant	2012
	Robert J. Daverman	<i>ex officio</i>
Chair	Eric M. Friedlander	<i>ex officio</i>
	Richard M. Schoen	2011

4.8.12. David P. Robbins Prize

	Louis J. Billera	2011
	Carol E. Fan	2011
	David J. Saltman	2011
	John R. Stembridge	2011
	Peter Winkler	2011

4.8.13. Satter Prize, Committee to Select the Winner of the

	Victor Guillemin	2013
	Jane M. Hawkins	2011
	Sijue Wu	2011

4.8.14. Steele Prizes

Chair	Peter S. Constantin	2011
	Yakov Eliashberg	2012
	John Erik Fornæss	2012
	Irene Martinez Gamba	2013
	Barbara Keyfitz	2012
	Joel A. Smoller	2011
	Terence Chi-Shen Tao	2011
	Akshay Venkatesh	2012
	Lai-Sang Young	2013

4.8.15. Whiteman Prize for 2012, Committee to Select the Winner of the

Chair	Robin Hartshorne	2011
	Marjorie Senechal	2011
	William C. Waterhouse	2011

Special Committee

4.8.16. Math in Moscow Program—Travel Support

Terms expire on June 30.

Chair	Vladimir V. Chernov	2012
	Alexander Varchenko	2013
	_____	2014

4.9. Institutes and Symposia

Standing Committees

4.9.1. Liaison Committee with AAAS

	Edward F. Aboufadel	<i>ex officio</i>
	Jerry L. Bona	2011
	Robert Calderbank	<i>ex officio</i>
	John Ewing	<i>ex officio</i>
	Lawrence Firman Gray	<i>ex officio</i>
	Jill P. Mesirov	<i>ex officio</i>
Chair	Kenneth C. Millett	<i>ex officio</i>
	Julie C. Mitchell	2011
	Jack Morava	2011
	Lior Pachter	2012
	Shmuel Weinberger	2011

4.9.2. Von Neumann Symposium Selection Committee

	Ronald A. DeVore	2011
	James Sethian	2011
Chair	Joel H. Spencer	2011

4.10. Joint Committees

4.10.1. AMS-ASA-AWM-IMS-MAA-NCTM-SIAM Committee on Women in the Mathematical Sciences

	Indrani Basak (ASA)	2012
	Marty Carr (NCTM)	2013
	K. Renee Fister (SIAM)	2012
	Patricia Hale (MAA)	2013
	Susan M. Hermiller (AMS)	2012
	Terrell Hodge (AWM)	2011
	Amy Langville (AMS)	2011
	Nicole Lazar (ASA)	2011
	Tanya Leise (MAA)	2011
Chair	Maura Mast (AWM)	2011
	Gerald Porter (MAA)	2011
	Amber Puha (IMS)	2013
	Paula Roberson (ASA)	2013
	Svetlana Roudenko (AMS)	2013
	Mary Silber (SIAM)	2011
	Jane-Ling Wang (IMS)	2013

4.10.2. AMS-ASA-MAA-SIAM Data Committee

AMS staff contact: James W. Maxwell.

	Pam Arroway (ASA)	2012
Chair	Richard J. Cleary (MAA)	2011
	Steven R. Dunbar (AMS)	2012
	Susan Geller (MAA)	2011
	Boris Hasselblatt (AMS)	2012
	Abbe H. Herzig (AMS)	2011
	Ellen Kirkman (MAA)	2013
	Peter March (AMS)	2013
	James W. Maxwell (AMS)	<i>ex officio</i>
	David Morrison (AMS)	2013
	Bart S. Ng (SIAM)	2012

4.10.3. AMS-ASA-MAA-SIAM Joint Policy Board for Mathematics

ASA and SIAM members' terms expire December 31 of the year given.

	James Crowley (SIAM)	2012
	Robert J. Daverman (AMS)	2012
	Barbara T. Faires (MAA)	2014
	Eric M. Friedlander (AMS)	2012
	Nancy Geller (ASA)	2011
	Reinhard Laubenbacher (SIAM)	2012
	Donald E. McClure (AMS)	2013
	Sastry G. Pantula (ASA)	2011
	Tina H. Straley (MAA)	2011
	L. Nick Trefethen (SIAM)	2012
	Ronald Wasserstein (ASA)	2012
	Paul Zorn (MAA)	2013

4.10.4. AMS-ASL-IMS-SIAM Committee on Translations from Russian and Other Slavic Languages

Chair	James D. Stasheff (AMS)
-------	-------------------------

AMS Subcommittee Members

Consultant	V. I. Arnol'd
	Luchezar Avramov
	Igor Dolgachev
Consultant	S. G. Gindikin
Consultant	Askol'd Georgievič Khovanskiĭ
	Robert D. MacPherson
	Grigorii A. Margulis
Consultant	N. K. Nikol'skiĭ
Chair	James D. Stasheff

ASL Subcommittee Members

Chair	Veronica Becher	2011
	Max Dickmann	2011
	Andrei Morozov	2011
	Hiroakira Ono	2011
	Kai Wehmeier	2011
	Feng Ye	2011

IMS Subcommittee Members

Chair	M. I. Freidlin
	B. Pittel
	A. Rukhin
	W. J. Studden

4.10.5. AMS-MAA Committee on Cooperation

All members of this committee serve *ex officio*.

- George E. Andrews (AMS)
- David Bressoud (MAA)
- Robert J. Daverman (AMS)
- Barbara T. Faires (MAA)
- Eric M. Friedlander (AMS)
- Donald E. McClure (AMS)
- Tina H. Straley (MAA)
- Paul Zorn (MAA)

4.10.6. AMS-MAA Committee on Mathematicians with Disabilities

- | | | |
|-------|--------------------------|------|
| | Lawrence Baggett (AMS) | 2011 |
| | Bradford Chin (MAA) | 2012 |
| | Michael Filaseta (AMS) | 2013 |
| | David M. James (MAA) | 2011 |
| | Mitchell B. Luskin (AMS) | 2013 |
| Chair | Judith Miller (MAA) | 2011 |

4.10.7. AMS-MAA Committee on Teaching Assistants and Part-time Instructors (TA/PTI)

- | | | |
|-------|--------------------------|------|
| | Morton Brown (MAA) | 2013 |
| Chair | David C. Carothers (MAA) | 2013 |
| | Mary Glaser (AMS) | 2013 |
| | Delaram Kahrobaei (AMS) | 2012 |
| | Angela K. Kubena (AMS) | 2013 |
| | Janet McShane (MAA) | 2011 |
| | James Sellers (AMS) | 2012 |
| | George T. Yates (MAA) | 2013 |

4.10.8. AMS-MAA Joint Archives Committee

- | | | |
|-------|---------------------------|------|
| | Bruce C. Berndt (AMS) | 2011 |
| | William W. Dunham (MAA) | 2011 |
| | Jonathan I. Hall (AMS) | 2013 |
| | Thomas W. Hawkins (AMS) | 2012 |
| Chair | James J. Tattersall (MAA) | 2013 |
| | David Zitarelli (MAA) | 2012 |

4.10.9. AMS-MAA Joint Meetings Committee

All members of this committee serve *ex officio*.

- | | |
|------------|--------------------|
| | Robert J. Daverman |
| | Donald E. McClure |
| Consultant | Penny Pina |
| | Tina H. Straley |
| Chair | Gerard Venema |

4.10.10. AMS-MAA Exhibits Advisory Subcommittee

- | | |
|-------|--------------------|
| | Robert J. Daverman |
| | Christine Davis |
| | Rebecca Elmo |
| | Robert Fathauer |
| | Norma Flores |
| | Elizabeth Huber |
| | Linda Lorusso |
| Chair | Penny Pina |
| | Gale Portwine |
| | Kady Safar |
| | Mary L. Simons |
| | Inez van Korlaar |
| | Gerard Venema |
| | Audra Weaver |

4.10.11. AMS-MAA Joint Program Committee for the Boston Meeting January 4-7, 2012

- J. P. Buhler (AMS)
- Robert L. Devaney (MAA)
- Skip Garibaldi (AMS)
- Rebecca F. Goldin (MAA)

4.10.12. AMS-MAA Mathfest Program Committee

- Bruce C. Berndt (AMS)
- Joseph A. Gallian (MAA)
- Robert W. Ghrist (AMS)
- Zvezdelina E. Stankova (MAA)
- Jean Taylor (AMS)

4.10.13. AMS-MAA-SIAM Joint Committee on Employment Opportunities

AMS staff contact: Ellen Maycock.

- | | | |
|-------|-------------------------|-------------------|
| | Leslie Button (SIAM) | 2013 |
| | Sharon Garthwaite (AMS) | 2013 |
| | Sue Geller (MAA) | 2011 |
| | Ellen Maycock (AMS) | <i>ex officio</i> |
| | Michael Pearson (MAA) | <i>ex officio</i> |
| Chair | Margaret Robinson (MAA) | 2012 |
| | Leon H. Seitzman (SIAM) | 2011 |
| | Sarah Ann Stewart (AMS) | 2012 |
| | Linda Thiel (SIAM) | <i>ex officio</i> |
| | Gerard Venema (MAA) | 2013 |
| | Dana P. Williams (AMS) | 2011 |

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

- | | | |
|-------|---------------------------|------|
| | Colin C. Adams (AMS) | 2013 |
| | Jill Dietz (MAA) | 2013 |
| | Kathleen Fowler (SIAM) | 2013 |
| Chair | Anna L. Mazzucato (SIAM) | 2011 |
| | Kannan Soundararjan (MAA) | 2012 |
| | Sergei Tabachnikov (AMS) | 2012 |

4.10.15. AMS-SIAM Committee to Select the Winner of the Birkhoff Prize

Terms expire on October 30.

- | | | |
|-------|---------------------|------|
| | Andrew J. Majda | 2011 |
| Chair | James A. Sethian | 2011 |
| | Michael S. Waterman | 2011 |

Special Committees

4.10.16. AMS-Romanian Mathematical Society Joint Program Committee, June 27-30, 2013

- Ioana Dumitriu
- Daniel I. Tataru
- Yuri Tschinkel
- Steven H. Weintraub

4.10.17. AMS-South African Mathematical Society (SAMA) Joint Program Committee, November 29-December 3, 2011

- | | |
|-------|-----------------|
| Chair | Percy Deift |
| | Doron Lubinsky |
| | Matthew Miller |
| | Neville Robbins |

5. Representatives

5.0.1. American Association for the Advancement of Science

Terms expire on February 21.

- | | | |
|-----------|----------------------|------|
| Section A | Robert Calderbank | 2013 |
| Section Q | Lawrence Firman Gray | 2013 |

5.0.2. Canadian Mathematical Society

- | | | |
|--|----------------|------|
| | Alejandro Adem | 2012 |
|--|----------------|------|

Officers and Committee Members

5.0.3. Conference Board of the Mathematical Sciences	Eric M. Friedlander	2012	AMS-South African Mathematical Society (SAMA) Joint Program Committee, November 29–December 3, 2011	4.10.17
5.0.4. Delbert Ray Fulkerson Prize Selection Committee	Richard P. Stanley	2011	Abstracts Editorial Committee	4.2.1
5.0.5. MAA Committee on the American Mathematics Competition Term expires on June 30.	Kiran S. Kedlaya	2012	Academic Freedom, Tenure, and Employment Security	4.7.1
5.0.6. AMS-MAA-SIAM Committee on the Porter Public Lecture	David Eisenbud	2011	Agenda and Budget	4.3.1
5.0.7. MAA Committee on Undergraduate Program in Mathematics (CUPM)	Randy McCarthy	2011	American Association for the Advancement of Science	5.0.1
	Alan Tucker	2011	American Mathematics Competition, Committee on	5.0.5
5.0.8. Mathematical Congress of the Americas Steering Committee	Susan Friedlander	2013	Archives	4.5.1
5.0.9. Professionals in Science and Technology, Commission on	Sam Rankin	2012	Arnold Ross Lecture Series Committee	4.6.9
5.0.10. U.S. National Committee on Theoretical and Applied Mechanics Term expires on October 31.	Russel Cafilisch	2012	Audit	4.3.2
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			CBMS	5.0.3
			COE	4.7.2
			CPUB	4.5.6
			CSP	4.7.7
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Mathematics Calendar

Please submit conference information for the Mathematics Calendar through the Mathematics Calendar submission form at <http://www.ams.org/cgi-bin/mathcal-submit.pl>. The most comprehensive and up-to-date Mathematics Calendar information is available on the AMS website at <http://www.ams.org/mathcal/>.

September 2011

* 13–15 **The Mathematics of the Climate System**, University of Reading, United Kingdom.

Description: This conference will be about the construction and use of mathematical models of the climate system. Such models aid our understanding of how certain climate processes interact. They also enable us to assess, interpret and diagnose more comprehensive climate models. Finally, they provide readily understandable paradigms for dynamical climate-system behaviour. The conference will focus on three related topics: 1) The extraction of mathematical models from climate data and climate-model output (homogenisation, stochastic model reduction, bistability and metastable states, low frequency variability, data-driven coarse-graining, set-oriented methods, trend identification, time-series analysis); 2) Reduced models and their dynamics (linear response theory, bifurcations, extreme events, uncertainty); and 3) Testing hypotheses about the climate system using statistical frameworks (emulators, Bayesian methods, non parametric methods, equitability).

Information: http://www.ima.org.uk/conferences/conferences_calendar/mathematics_of_the_climate_system.cfm.

* 22 **Recent Trends in Nonlinear Partial Differential Equations**, Graduate Center at CUNY, Manhattan, New York, New York.

Description: This one-day event starts a series of symposia in applied analysis organized during the academic year 2011–1012 at the

Graduate Center at CUNY. This first event will explore recent trends, applications, and future directions in the active area of nonlinear partial differential equations.

Information: <http://www.math.csi.cuny.edu/ciamcs>.

October 2011

* 8–9 **The 4th Dr. George Bachman Memorial Conference: Analysis, Measure Theory, Topology and Related Fields**, Department of Mathematics and Computer Science, St. John's College of Liberal Arts and Sciences, St. John's University, 101 Murray Street, New York, New York 10007.

Description: This year the 4th Dr. George Bachman Memorial Conference is additionally dedicated to the 70th birthday of two of Dr. Bachman's students: Dr. Lawrence Narici, Professor Emeritus, St. John's University, and Dr. Edward Beckenstein, Professor, St. John's University. NOTE: Even if you cannot attend the event in person, we recommend you submit an abstract of your paper for a concurrently run Web Conference, and later a full paper for the Proceedings, dedicated to the memory of Dr. George Bachman and the 70th birthday of Dr. Lawrence Narici and Dr. Edward Beckenstein.

Sponsor: St. John's University, New York.

Organizers: Charles Traina, Ph.D., Chair, Professor; email: trainac@stjohns.edu; Daniel Gallo, Ph.D., Deputy Chair, Professor; email: gallod@stjohns.edu; Alexander Katz, Ph.D., Associate Professor; email: katza@stjohns.edu.

Deadline for abstracts: October 1, 2011.

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 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. 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 **eight 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/July, 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 the AMS website on the World Wide Web. To access the AMS website, use the URL: <http://www.ams.org/>.

Information: <http://atlas-conferences.com/cgi-bin/abstract/cbdcn-01>.

- * 17–20 **Advanced Course and Workshop on Computational Algebraic Topology Applied to Medical Imagery**, Chipiona, Cádiz, Spain.

Description: This event will focus on the area of Computational Algebraic Topology applied to Medical Digital Imagery. Experts in the fields of Computational Algebraic Topology, Software Development, and Medical Imagery, will try to give us some insights of the potential of the methods of this mathematical discipline in Medical Imaging and will open some research lines concerning algebraic topological problems in Medical Image Context.

Information: <http://congreso.us.es/catmi2011/>.

November 2011

- * 3–6 **Mirror Symmetry in the Midwest**, Kansas State University, Manhattan, Kansas.

Description: A conference on the geometric and algebraic aspects of mirror symmetry.

Information: <http://www.math.ksu.edu/~galston/conference/>.

- * 10–12 **The Fourth International Theoretical and Practical Conference: Object Systems–2011 (English session)**, Rostov-on-Don, Russia.

Description: The conference is devoted to the principles of design, implementation and support of object systems and includes discussion on a wide range of topics. Well-known scientists and major specialists in the field of corporate information systems, representatives of universities and commercial organizations in Russia and abroad (Greece, Poland, Spain) take part in the conference. The conference is correspondence. At the end of the conference a collection of scientific works of authors is published with assigning it ISBN-code, which will be sent to the major research libraries of Russia. The electronic version of the collection is housed in the leading information directories and it is available on the conference website. This website provides an electronic personal certificate confirming participation in the conference. Participation is free.

Information: <http://www.objectsystems.ru/>.

- * 15–19 **Geometry and Arithmetic around Teichmüller Theory**, Galatasaray University, Istanbul, Turkey.

Description: This is a conference on Teichmüller theory. Sessions are devoted to talks by researchers (including Ph.D. students). The aim of the school is to introduce the geometry of the Teichmüller spaces to students and familiarize students with the new results concerning various Teichmüller spaces and their relation to arithmetic.

Information: <http://math.gsu.edu.tr/2011gatt.html>.

December 2011

- * 4–6 **National Conference on Ramanujan’s Work in the Field of Hypergeometric Series and its Applications**, Department of Mathematics, T.D.P.G. College, Jaunpur, India.

Description: Call for papers: The organizers of the Conference invite papers for presentation. The abstract not exceeding 200 words intended for presentation should be sent no later than October 31, 2011, preferably by email to Dr. S. N. Singh, 263, Line Bazar, Jaunpur . 222002 (U.P.) India. Contact No.: 05452 . 261922 Mob. No.: 09451159058, 09451161967; email: snsp39@yahoo.com. Citation: During the Conference distinguished service awards for the year 2011 will be given to Prof. R. Y. Denis and Prof. M. A. Pathan for their outstanding contributions to the cause of mathematics education and research. Proceedings of the Conference: The proceedings of the Conference will be published. The full length paper in duplicate along with a file formatted in AMS latex/ MS word/ Pdf may be submitted during the Conference by December 06, 2011. Travel

and Local Hospitality Financial support for travel (AC II class fare) will be provided to invited speakers.

- * 5–9 **Quantitative Geometry in Computer Science**, Mathematical Sciences Research Institute, Berkeley, California.

Description: Geometric problems which are inherently quantitative occur in various aspects of theoretical computer science, including a) Algorithmic tasks for geometric questions such as clustering and proximity data structures. b) Geometric methods in the design of approximation algorithms for combinatorial optimization problems, including the analysis of semidefinite programs and embedding methods. c) Geometric questions arising from computational complexity, particularly in hardness of approximation. These include isoperimetric and Fourier analytic problems. This workshop aims to present recent progress in these directions.

Information: <http://www.msri.org/web/msri/scientific/workshops/programmatic-workshops/show/-/event/Wm576>.

- * 7–9 **Mathematics of Traffic Flow Modeling, Estimation and Control**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

Description: Traffic congestion has a significant impact on economic activity throughout much of the world. An essential step towards active congestion control is the creation of accurate, reliable traffic monitoring and control systems. These systems usually run algorithms which rely on mathematical models of traffic used to power estimation and control schemes. The workshop will gather experts from various domains which range from transportation engineering to mathematics, to discuss modeling, estimation and control. Application and registration forms are available online. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM’s mission and we welcome their applications.

Information: <http://www.ipam.ucla.edu/programs/tra2011/>.

- * 12–15 **13th IMA International Conference on Cryptography and Coding**, University of Oxford, United Kingdom.

Description: The mathematical theory and practice of cryptography and coding underpins the provision of effective security and reliability for data communication, processing and storage. Theoretical and practical advances in the fields of cryptography and coding are therefore a key factor in facilitating the growth of data communications and data networks of various types. Thus, this thirteenth International Conference in an established and successful IMA series on the theme of “Cryptography and Coding” is both timely and relevant. **Invited Speakers:** Professor Ivan Damgård (Aarhus University, Denmark) Professor Paddy Farrell (Lancaster University and University of Kent, UK) Professor Jonathan Jedwab (Simon Fraser University, Canada) Professor David Naccache (ENS, France).

Information: http://www.ima.org.uk/conferences/conferences_calendar/cryptography_and_coding.cfm.

January 2012

- * 9–13 **Large Scale Multimedia Search**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

Description: The proliferation of digital multimedia data has fundamentally changed the way images, video, audio and three-dimensional data are stored and used. The huge and ever growing volume of data in online repositories such as YouTube and Flickr requires novel approaches to content based multimedia search and retrieval. The goal of this workshop is to bring together an interdisciplinary community from mathematics, computer vision, computer audition, engineering and machine learning to present and discuss the different facets of this problem. We will discuss both domain specific issues and broader topics in machine learning and large-scale computational schemes, such as metric learning, “learning to rank”

and nearest neighbors search in high dimensions. Application and registration forms are available online. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

Information: <http://www.ipam.ucla.edu/programs/ms2012/>.

* 9–May 18 **Random Spatial Processes Program**, Mathematical Sciences Research Institute, Berkeley, California.

Description: In recent years probability theory has made immense progress in understanding the basic two-dimensional models of statistical mechanics and random surfaces. Prior to the 1990s the major interests and achievements of probability theory were with respect to one-dimensional objects: Brownian motion and stochastic processes, random trees, and the like. Inspired by work of physicists in the 1970s and 1980s on conformal invariance and field theories in two dimensions, a number of leading probabilists and combinatorialists began thinking about spatial process in two dimensions: percolation, polymers, dimer models, Ising models. Major breakthroughs by Kenyon, Schramm, Lawler, Werner, Smirnov, Sheffield, and others led to a rigorous underpinning of conformal invariance in two-dimensional systems and paved the way for a new era of two-dimensional probability theory.

Information: <http://www.msri.org/web/msri/scientific/programs/show/-/event/Pm140>.

* 12–13 **Connections for Women: Discrete Lattice Models in Mathematics, Physics, and Computing**, Mathematical Sciences Research Institute, Berkeley, California.

Description: The workshop gathers discrete mathematics, probability theory, theoretical computer science and statistical physics researchers to explore topics at their interface. It focuses on combinatorial structures, probabilistic algorithms and physical systems models. This includes the study of phase transitions, probabilistic combinatorics, Markov chain Monte Carlo methods, random structures and randomized algorithms. Since discrete lattice models stand at the interface of these fields, the workshop starts with background talks in each of the three areas: Statistical and mathematical physics; Combinatorics of lattice models; Sampling and computational issues. These talks describe the general framework and recent developments in the field and is followed with shorter talks highlighting recent research in the area. The workshop celebrates academic and gender diversity, bringing together women and men at junior and senior levels of their careers from mathematics, physics, and computer science.

Information: <http://www.msri.org/web/msri/scientific/workshops/programmatic-workshops/show/-/event/Wm577>.

* 23–27 **Mathematical Challenges in Graphical Models and Message-Passing Algorithms**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

Description: Graphical models are used and studied within a variety of disciplines of computer science, mathematics and statistics. The purpose of this meeting is to highlight various mathematical questions and issues associated with graphical models and message-passing algorithms, and to bring together a group of researchers for discussion of the latest progress and challenges ahead. Application and registration forms are available online. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

Information: <http://www.ipam.ucla.edu/programs/gm2012/>.

* 30–31 **Annual International Conference on Computational Mathematics, Computational Geometry & Statistics (CMCGS 2012)**, Hotel Fort Canning, Singapore.

Description: The goal of the conference is to bring together active researchers from the various disciplines to showcase their state-of-

the-art research results and hopefully to forge new cross-disciplinary interactions among the participants. The conference provides a unique opportunity for in-depth technical discussions and exchange of ideas in mathematical and computational sciences, as well as explores the potential of their applications in natural and social sciences, engineering and technology and industry and finance.

Information: <http://www.mathsstat.org/>.

February 2012

* 6–10 **Challenges in Synthetic Aperture Radar**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

Description: This interdisciplinary workshop will address challenging problems in radar imaging. The focus will be on the following issues: 1. Exploiting data from multiple viewpoints to obtain three-dimensional information; 2. Forming images of challenging targets, such as moving targets, non-rigid targets, or targets that scatter weakly; 3. Exploiting prior information and properties such as sparsity to improve image formation; 4. Forming images through complex media, and; 5. Including more sophisticated target modeling, such as multiple scattering, polarimetric scattering, and stochastic target models, in the image formation process. Application and registration forms are available online. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

Information: <http://www.ipam.ucla.edu/programs/sar2012/>.

* 16–18 **2nd International Conference on Advances in Control and Optimization of Dynamical Systems**, Indian Institute of Science, Bangalore, India.

Description: The aim of 2nd ACODS-2012 is to bring together engineers, scientists, and academics working in advanced areas of control and optimization of dynamical systems. The theme of the conference is broad enough to encompass both theory and applications. Application areas include, but are not restricted to robotics, aerospace vehicles, manufacturing, process control, computer aided control, biomedical engineering, automation, and mechanical and electrical systems. Papers are invited in these and other areas where control and optimization of dynamical systems plays an important role. The conference will have several special sessions as well.

Information: <http://www.acods.org>.

* 27–March 2 **Nonlocal PDEs, Variational Problems and their Applications**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

Description: The last decade has seen vigorous research activity to understand systems involving long-range effects, and to directly incorporate such effects in the modeling and analysis. This research has led to fundamental questions about several classes of nonlocal partial differential equations (PDEs), such as their long-time existence and regularity. This workshop will bring together both pure and applied mathematicians with a focus on (i) partial differential equations with nonlocal diffusive and/or transport terms, and their probabilistic interpretations (ii) nonlocal problems in pattern formation and phase transitions and biology, and (iii) nonlocal techniques in image processing. Application and registration forms are available online. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

Information: <http://www.ipam.ucla.edu/programs/pde2012/>.

April 2012

* 23–25 **5TH IMA International Conference on Analytical Approaches to Conflict**, Royal Military Academy, Sandhurst, United Kingdom.

Description: This is an international event and will attract contributors from many countries. The conference is intended as a meeting

place for those who operate directly in arenas of conflict (e.g. the military, staff of NGOs, mediators), those who provide support or advice (e.g. analysts, contractors, counsellors) and others who offer theoretical concepts and practical frameworks for handling conflict (e.g. academic researchers). While the organisers, by locating this conference at RMAS, are deliberately setting out to indicate a strong military dimension, this will not be an exclusive focus: indeed it is only by working with other communities of practice that the military missions are likely to succeed.

Information: http://www.ima.org.uk/conferences/conferences_calendar/analytical_approaches_to_conflict.cfm.

May 2012

* 7–11 **AIM Workshop: Motivic Donaldson-Thomas theory and singularity theory**, Renyi Institute, Budapest, Hungary.

Description: This workshop, sponsored by AIM, the Renyi Institute, and the NSF, will bring together experts from Donaldson-Thomas theory and singularity theory to explore the exciting connections which have recently emerged between these two fields.

Information: <http://aimath.org/ARCC/workshops/motivicdt.html>.

July 2012

* 22–27 **Vibration and structural acoustics measurement and analysis**, Universidade do Porto, Porto, Portugal.

Abstracts: Extended abstracts are due by November 30, 2011. A sample abstract is available at: http://paginas.fe.up.pt/clme/icem15/abstract_sample.doc.

Information: <http://paginas.fe.up.pt/clme/icem15>.

* 23–27 **Algebraic Topology: applications and new directions Stanford Symposium 2012**, Stanford University, Palo Alto, California.

Description: A conference to be held in honour of Gunnar Carlsson, Ralph Cohen and Ib Madsen to celebrate their 60th and 70th birthdays.

Information: <http://people.maths.ox.ac.uk/tillmann/StanfordSymposium.html>.

August 2012

* 6–8 **The Sixth Global Conference on Power Control and Optimization PCO 2012**, Monte Carlo Resort and Casino, Las Vegas, Nevada.

Description: It is our great pleasure to announce the sixth Global Conference on Power Control and Optimization PCO 2012, which will be held in the Mount Carlo Hotel, Las Vegas, United States of America, from 6 - 8 August 2012. The scope of the conference is contemporary and original research and educational development in the area of mechanical, electrical, communication, sustainable energy, controllers, robotics, wireless sensors, biomedicine, computing, nano-science, management, environment, business, continuous and hybrid optimization. Prospective authors from universities or other educational institutes and industry are invited to submit abstract and/or full paper by email before the deadline. All papers submitted before the deadline will be peer reviewed by independent specialists.

Information: <http://www.pcoglobal.com>.

* 20–December 21 **Cluster Algebras Program**, Mathematical Sciences Research Institute, Berkeley, California.

Description: Cluster algebras were conceived in the Spring of 2000 as a tool for studying dual canonical bases and total positivity in semisimple Lie groups. They are constructively defined commutative algebras with a distinguished set of generators (cluster variables) grouped into overlapping subsets (clusters) of fixed cardinality. Both the generators and the relations among them are not given from the outset, but are produced by an iterative process of successive mutations. The program will focus on links between cluster algebras and other areas, such as: polyhedral combinatorics; triangulations of surfaces; Y, Q, and T-systems; additive categorification via quiver

representations; quivers with potentials and Donaldson-Thomas invariants; Lie theory and monoidal categorification; Poisson geometry and Teichmüller theory.

Information: <http://www.msri.org/web/msri/scientific/programs/show/-/event/Pm144>.

September 2012

* 10–December 14 **Materials Defects: Mathematics, Computation and Engineering**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

Description: Material defects present a huge challenge for mathematical modeling and simulation, as anything that breaks up the regular, homogenous structure of a calculation requires special consideration. In recent years, there has been particular focus on the multiscale nature of materials research—how computational methods and mathematical models for describing materials vary from the atomistic to the continuum scale. This program aims to promote collaboration among scientists to assess the current status of defect modeling, promote the development of new computational techniques, and stimulate new applications. An application is available online. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

Information: <http://www.ipam.ucla.edu/programs/md2012/>.

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

October 2012

* 3–6 **International Conference on Applied and Computational Mathematics (ICACM)**, Middle East Technical University (METU), Ankara, Turkey.

Description: We are going to celebrate the 10th anniversary of the Foundation of the Institute of Applied Mathematics (IAM).

January 2013

* 14–May 24 **Noncommutative Algebraic Geometry and Representation Theory**, Mathematical Sciences Research Institute, Berkeley, California.

Description: Over the last few decades noncommutative algebraic geometry (in its many forms) has become increasingly important, both within noncommutative algebra/representation theory, as well as having significant applications to algebraic geometry and other neighbouring areas. The goal of this program is to explore and expand upon these subjects and their interactions. Topics of particular interest include noncommutative projective algebraic geometry, noncommutative resolutions of (commutative or noncommutative) singularities, Calabi-Yau algebras, deformation theory and Poisson structures, as well as the interplay of these subjects with the algebras appearing in representation theory—like enveloping algebras, symplectic reflection algebras and the many guises of Hecke algebras.

Information: <http://www.msri.org/web/msri/scientific/programs/show/-/event/Pm145>.

March 2013

* 11–14 **Interactions Between Analysis and Geometry**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.

Description: Within mathematics, as within science in general, there is a need for greater communication between workers from different research specialties. The purpose of this program is to promote the interaction between two core areas of mathematics—analysis and geometry. Geometers can give analysts new perspectives and focus for their research; geometers can benefit from an exchange of ideas with

analysts by becoming more familiar with the powerful tools of their field. An application is available online. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

Information: <http://www.ipam.ucla.edu/programs/iag2013/>.

May 2013

- * 19–23 **SIAM Conference on Applications of Dynamical Systems (DS13)**, Snowbird Ski and Summer Resort, Snowbird, Utah.

Description: The application of dynamical systems theory to areas outside of mathematics continues to be a vibrant, exciting and fruitful endeavor. These application areas are diverse and multidisciplinary, ranging over all areas of applied science and engineering, including biology, chemistry, physics, finance, and industrial applied mathematics. This conference strives to achieve a blend of application-oriented material and the mathematics that informs and supports it. The goals of the meeting are a cross-fertilization of ideas from different application areas, and increased communication between the mathematicians who develop dynamical systems techniques and applied scientists who use them.

Information: <http://www.siam.org/meetings/ds13/>.

July 2013

- * 8–10 **SIAM Conference on Control and Its Applications (CT13)**, Town and Country Resort and Convention Center, San Diego, California.

Description: The field of control theory is central to a wide range of aerospace, industrial, automotive and advanced technological systems and increasingly recognized as fundamental for emerging fields ranging from nanotechnology to cell regulation. Moreover, in addition to its traditional ubiquity in process regulation for the physical sciences and engineering, control concepts now pervade the biological, computer, and social sciences. This conference will showcase a wide range of topics in control and systems theory. The topics and applications include real-time optimization and data assimilation, cellular and biological regulation, control of hybrid systems, numerical methods for control and optimization, control techniques for financial mathematics, cooperative control for unmanned autonomous vehicles, differential games, biomedical control, risk sensitive control and filtering, control of smart systems, flow control and quantum control.

Information: <http://www.siam.org/meetings/ct13/>.

August 2013

- * 19–December 20 **Mathematical General Relativity**, Mathematical Sciences Research Institute, Berkeley, California.

Description: The study of Einstein's general relativistic gravitational field equation, which has for many years played a crucial role in the modeling of physical cosmology and astrophysical phenomena, is increasingly a source for interesting and challenging problems in geometric analysis and PDE. This semester-long program aims to bring together researchers working in mathematical relativity, differential geometry, and PDE who wish to explore this rapidly growing area of mathematics.

Information: <http://www.msri.org/web/msri/scientific/programs/show/-/event/Pm8946>.

- * 19–December 20 **Optimal Transport: Geometry and Dynamics**, Mathematical Sciences Research Institute, Berkeley, California.

Description: In the past two decades, the theory of optimal transportation has emerged as a fertile field of inquiry, and a diverse tool for exploring applications within and beyond mathematics. This transformation occurred partly because long-standing issues could finally be resolved, but also because unexpected connections emerged which linked these questions to classical problems in geometry, partial differential equations, nonlinear dynamics, natural

sciences, design problems and economics. The aim of this program will be to gather experts in optimal transport and areas of potential application to catalyze new investigations, disseminate progress, and invigorate ongoing exploration.

Information: <http://www.msri.org/web/msri/scientific/programs/show/-/event/Pm8952>.

- * 20–May 24 **Commutative Algebra Program**, Mathematical Sciences Research Institute, Berkeley, California.

Description: Commutative algebra was born in the 19th century from algebraic geometry, invariant theory, and number theory. Today it is a mature field with activity on many fronts. The year-long program will highlight exciting recent developments in core areas such as free resolutions, homological and representation theoretic aspects, Rees algebras and integral closure, tight closure and singularities, and birational geometry. In addition, it will feature the important links to other areas such as algebraic topology, combinatorics, mathematical physics, noncommutative geometry, representation theory, singularity theory, and statistics. The program will reflect the wealth of interconnections suggested by these fields, and will introduce young researchers to these diverse areas.

Information: <http://www.msri.org/web/msri/scientific/programs/show/-/event/Pm142>.

January 2014

- * 20–May 23 **Model Theory and Number Theory**, Mathematical Sciences Research Institute, Berkeley, California.

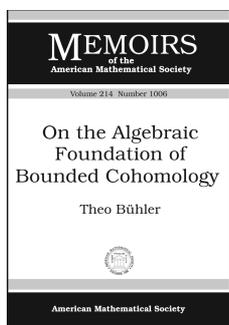
Description: The program aims to further the flourishing interaction between model theory and other parts of mathematics, especially number theory and arithmetic geometry. At present the model theoretical tools in use arise primarily from geometric stability theory and o-minimality. Current areas of lively interaction include motivic integration, valued fields, diophantine geometry, and algebraic dynamics.

Information: <http://www.msri.org/web/msri/scientific/programs/show/-/event/Pm146>.

New Publications Offered by the AMS

To subscribe to email notification of new AMS publications, please go to <http://www.ams.org/bookstore-email>.

Algebra and Algebraic Geometry



On the Algebraic Foundation of Bounded Cohomology

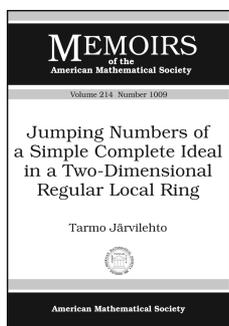
Theo Bühler, *ETH Zurich, Switzerland*

Contents: Introduction and main results; *Part 1. Triangulated categories:* Triangulated categories; The derived category of an exact category; Abstract

truncation: t -structures and hearts; *Part 2. Homological algebra for bounded cohomology:* Categories of Banach spaces; Derived categories of Banach G -modules; *Part 3. Appendices:* Appendix A. Mapping cones, homotopy push-outs, Mapping cylinders; Appendix B. Pull-back of exact structures; Appendix C. Model categories; Appendix D. Standard Borel G -spaces are regular; Appendix E. The existence of Bruhat functions; Bibliography.

Memoirs of the American Mathematical Society, Volume 214, Number 1006

October 2011, 97 pages, Softcover, ISBN: 978-0-8218-5311-5, 2010 *Mathematics Subject Classification:* 18E30; 57Txx, 20J05, 46M18, 18G60, 18E10, **Individual member US\$42**, List US\$70, Institutional member US\$56, Order code MEMO/214/1006



Jumping Numbers of a Simple Complete Ideal in a Two-Dimensional Regular Local Ring

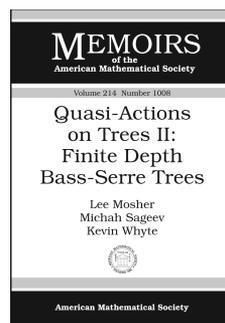
Tarmo Järvilehto

Contents: Introduction; Preliminaries on complete ideals; Arithmetic of the point basis; The dual graph; Multiplier ideals and jumping numbers; Main theorem; Proof of main theorem; Jumping numbers

of a simple ideal; Jumping numbers of an analytically irreducible plane curve; Bibliography.

Memoirs of the American Mathematical Society, Volume 214, Number 1009

October 2011, 78 pages, Softcover, ISBN: 978-0-8218-4811-1, 2010 *Mathematics Subject Classification:* 13H05; 14B05, **Individual member US\$39.60**, List US\$66, Institutional member US\$52.80, Order code MEMO/214/1009



Quasi-Actions on Trees II: Finite Depth Bass-Serre Trees

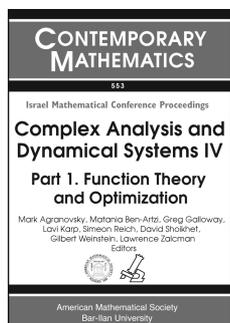
Lee Mosher, *Rutgers University, Newark, NJ*, Michah Sageev, *Technion, Israel University of Technology, Haifa, Israel*, and Kevin Whyte, *University of Illinois at Chicago, IL*

Contents: Introduction; Preliminaries; Depth zero vertex rigidity; Finite depth graphs of groups; Tree rigidity; Main theorems; Applications and examples; Bibliography; Index.

Memoirs of the American Mathematical Society, Volume 214, Number 1008

October 2011, 105 pages, Softcover, ISBN: 978-0-8218-4712-1, 2010 *Mathematics Subject Classification:* 20F65, **Individual member US\$42**, List US\$70, Institutional member US\$56, Order code MEMO/214/1008

Analysis



Complex Analysis and Dynamical Systems IV

Part 1. Function Theory and Optimization

Mark Agranovsky, *Bar-Ilan University, Ramat-Gan, Israel*, **Matania Ben-Artzi**, *Hebrew University, Jerusalem, Israel*, **Greg Galloway**, *University of Miami, Coral Gables, FL*, **Lavi Karp**, *ORT Braude College, Karmiel, Israel*, **Simeon Reich**, *Technion, Haifa, Israel*, **David Shoikhet**, *ORT Braude College, Karmiel, Israel*, **Gilbert Weinstein**, *University of Alabama at Birmingham, AL*, and **Lawrence Zalcman**, *Bar-Ilan University, Ramat-Gan, Israel*, Editors

The papers in this volume cover a wide variety of topics in the geometric theory of functions of one and several complex variables, including univalent functions, conformal and quasiconformal mappings, and dynamics in infinite-dimensional spaces. In addition, there are several articles dealing with various aspects of Lie groups, control theory, and optimization. Taken together, the articles provide the reader with a panorama of activity in complex analysis and quasiconformal mappings, drawn by a number of leading figures in the field.

The companion volume (Contemporary Mathematics, Volume 554) is devoted to general relativity, geometry, and PDE.

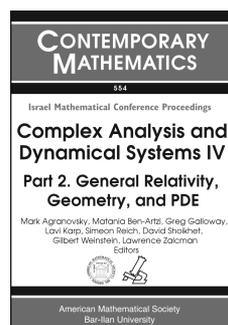
This book is co-published with Bar-Ilan University (Ramat-Gan, Israel).

Contents: **L. Aizenberg** and **N. Tarkhanov**, The Schwarz kernel in Clifford analysis; **C. Bisi** and **F. Polizzi**, Proper polynomial self-maps of the affine space: State of the art and new results; **A. A. Danielyan**, The peak-interpolation theorem of Bishop; **R. J. Dwiłewicz**, Global holomorphic approximations of Cauchy-Riemann functions; **P. Ebenfelt**, **D. Khavinson**, and **H. S. Shapiro**, Two-dimensional shapes and lemniscates; **Y. A. Gaidov** and **V. P. Golubyatnikov**, On the existence and stability of cycles in gene networks with variable feedbacks; **G. Gentili** and **F. Vlacci**, On fixed points of regular Möbius transformations over quaternions; **A. Golberg**, Homeomorphisms with integrally restricted moduli; **A. Hinkkanen**, A conjecture on martingales and rotations; **I. Ioslovich**, **P.-O. Gutman**, and **R. Linker**, Optimal control of a dynamical biological system: Maintenance of balanced growth and development; **Y. Kondratiev**, **Y. Kozitsky**, and **D. Shoikhet**, Dynamical systems on sets of holomorphic functions; **S. L. Krushkal** and **R. Kühnau**, Quasiconformal reflection coefficient of level lines; **G. A. Kurina** and **E. V. Smirnova**, Asymptotic solution of optimal control problems with a small parameter and intermediate points in performance index; **A. M. Kytmanov** and **S. G. Myslivets**, On conditions of δ -closed extensions of differential forms; **D. S. Lubinsky**, An operator associated with de Branges

spaces and universality limits; **J. R. Muir, Jr.** and **T. J. Suffridge**, De la Vallée Poussin means of holomorphic mappings of the ball; **S. A. Plaksa**, **S. V. Gryshchuk**, and **V. S. Shpakivskyi**, Commutative algebras of monogenic functions associated with classic equations of mathematical physics; **S. Reich** and **A. J. Zaslavski**, Convergence of inexact orbits of continuous mappings in complete metric spaces; **S. V. Selivanova** and **S. K. Vodopyanov**, Algebraic and analytic properties of quasimetric spaces with dilations; **Z. Zajac**, Harmonic mappings and quasihomographies in the theory of Teichmüller space; **A. J. Zaslavski**, Two turnpike results for a continuous-time optimal control system.

Contemporary Mathematics, Volume 553

October 2011, 317 pages, Softcover, ISBN: 978-0-8218-5196-8, LC 2011025997, 2010 *Mathematics Subject Classification*: 30-XX, 32-XX, 49-XX, **AMS members US\$84**, List US\$105, Order code CONM/553



Complex Analysis and Dynamical Systems IV

Part 2. General Relativity, Geometry, and PDE

Mark Agranovsky, *Bar-Ilan University, Ramat-Gan, Israel*, **Matania Ben-Artzi**, *Hebrew University, Jerusalem, Israel*, **Greg Galloway**, *University of Miami, Coral Gables, FL*, **Lavi Karp**, *ORT Braude College, Karmiel, Israel*, **Simeon Reich**, *Technion, Haifa, Israel*, **David Shoikhet**, *ORT Braude College, Karmiel, Israel*, **Gilbert Weinstein**, *University of Alabama at Birmingham, AL*, and **Lawrence Zalcman**, *Bar-Ilan University, Ramat-Gan, Israel*, Editors

The papers in this volume cover a wide variety of topics in differential geometry, general relativity, and partial differential equations. In addition, there are several articles dealing with various aspects of Lie groups and mathematics physics. Taken together, the articles provide the reader with a panorama of activity in general relativity and partial differential equations, drawn by a number of leading figures in the field.

The companion volume (Contemporary Mathematics, Volume 553) is devoted to function theory and optimization.

This item will also be of interest to those working in differential equations and mathematical physics.

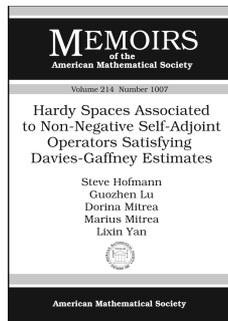
This book is co-published with Bar-Ilan University (Ramat-Gan, Israel).

Contents: **D. Akhiezer**, Stein manifolds and multiplicity-free representations of compact Lie groups; **L. Andersson**, **M. Eichmair**, and **J. Metzger**, Jang's equation and its applications to marginally trapped surfaces; **R. Beig**, The stationary n -body problem in general relativity; **G.-Q. G. Chen** and **M. Feldman**, Shock reflection-diffraction and nonlinear partial differential equations of mixed type; **Y. Choquet-Bruhat**, **P. T. Chruściel**,

and **J. M. Martín-García**, An existence theorem for the Cauchy problem on a characteristic cone for the Einstein equations; **P. T. Chruściel, J. Corvino, and J. Isenberg**, Construction of N -body time-symmetric initial data sets in general relativity; **J. Isenberg, J. M. Lee, and I. Allen**, Asymptotic gluing of asymptotically hyperbolic vacuum initial data sets; **L. Kapitanski**, Analytic form of the Pontrjagin-Hopf invariants; **I. Ly and N. Tarkhanov**, The Dirichlet to Neumann operator for nonlinear elliptic equations; **M. Monastyrsky**, Kramers-Wannier duality for non-abelian lattice spin systems and Hecke surfaces; **V. S. Rabinovich and S. Roch**, Exponential estimates of solutions of pseudodifferential equations with operator-valued symbols: Applications to Schrödinger operators with operator-valued potentials; **M. Reiris**, Scalar curvature, isoperimetric collapse and general relativity in the constant mean curvature gauge; **M. Reissig**, Rates of decay for structural damped models with coefficients strictly increasing in time; **E. Saucan**, Curvature based triangulation of metric measure spaces; **B. Smith**, Black hole initial data with a horizon of prescribed intrinsic and extrinsic geometry; **J. Smulevici**, On the global geometry of spacetimes with toroidal or hyperbolic symmetry; **C. Williams**, A black hole with no marginally trapped tube asymptotic to its event horizon; **M. Zaidenberg**, Discrete convolution operators in positive characteristic: A variation on the Floquet-Bloch theory.

Contemporary Mathematics, Volume 554

September 2011, 284 pages, Softcover, ISBN: 978-0-8218-5197-5, LC 2011025997, 2010 *Mathematics Subject Classification*: 35-XX, 53-XX, 83-XX, Order code CONM/554



Hardy Spaces Associated to Non-Negative Self-Adjoint Operators Satisfying Davies-Gaffney Estimates

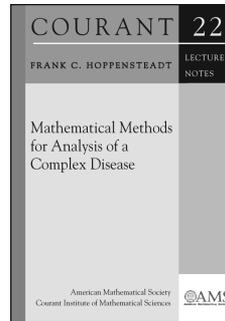
Steve Hofmann, *University of Missouri-Columbia, MO*, **Guozhen Lu**, *Wayne State University, Detroit, MI*, **Dorina Mitrea** and **Marius Mitrea**, *University of Missouri-Columbia, MO*, and **Lixin Yan**, *Zhongshan University, Guangzhou, People's Republic of China*

Contents: Introduction; Notation and preliminaries; Davies-Gaffney estimates; The decomposition into atoms; Relations between atoms and molecules; $BMO_{L,M}(X)$: Duality with Hardy spaces; Hardy spaces and Gaussian estimates; Hardy spaces associated to Schrödinger operators; Further properties of Hardy spaces associated to operators; Bibliography.

Memoirs of the American Mathematical Society, Volume 214, Number 1007

October 2011, 78 pages, Softcover, ISBN: 978-0-8218-5238-5, 2010 *Mathematics Subject Classification*: 42B20, 42B25; 46B70, 47G30, **Individual member US\$39.60**, List US\$66, Institutional member US\$52.80, Order code MEMO/214/1007

Applications



Mathematical Methods for Analysis of a Complex Disease

Frank C. Hoppensteadt, *Courant Institute of Mathematical Sciences, New York University, NY*

Complex diseases involve most aspects of population biology, including genetics, demographics, epidemiology, and ecology.

Mathematical methods, including differential, difference, and integral equations, numerical analysis, and random processes, have been used effectively in all of these areas. The aim of this book is to provide sufficient background in such mathematical and computational methods to enable the reader to better understand complex systems in biology, medicine, and the life sciences. It introduces concepts in mathematics to study population phenomena with the goal of describing complicated aspects of a disease, such as malaria, involving several species.

The book is based on a graduate course in computational biology and applied mathematics taught at the Courant Institute of Mathematical Sciences in fall 2010. The mathematical level is kept to essentially advanced undergraduate mathematics, and the results in the book are intended to provide readers with tools for performing more in-depth analysis of population phenomena.

This item will also be of interest to those working in differential equations and analysis.

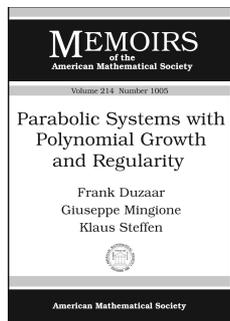
Titles in this series are co-published with the Courant Institute of Mathematical Sciences at New York University.

Contents: Population dynamics; Random processes; Microbial ecology; Propagation of epidemic diseases; Population genetics; Stratifications of disease systems; MATLAB® programs; Bibliography; Index.

Courant Lecture Notes, Volume 22

October 2011, 149 pages, Softcover, ISBN: 978-0-8218-7286-4, LC 2011026635, 2010 *Mathematics Subject Classification*: 35Q92, 37N25, 46N60, 62P10, 92B05, 92C42, 97M60, 92C60, 92D30, 00A72, 34K60, 65Cxx, 34A34, 34C28, 35Q70, 45G15, 47N70, **AMS members US\$24.80**, List US\$31, Order code CLN/22

Differential Equations



Parabolic Systems with Polynomial Growth and Regularity

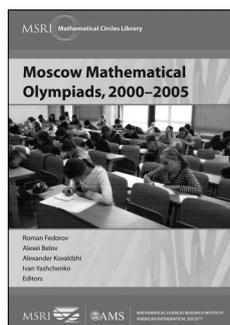
Frank Duzaar, *Universität Erlangen-Nürnberg, Germany*,
Giuseppe Mingione, *Università di Parma, Italy*, and **Klaus Steffen**,
Heinrich-Heine-Universität, Düsseldorf, Germany

Contents: Results; Basic material, assumptions; The A -caloric approximation lemma; Partial regularity; Some basic regularity results and a priori estimates; Dimension estimates; Hölder continuity of u ; Non-linear Calderón-Zygmund theory; Bibliography.

Memoirs of the American Mathematical Society, Volume 214, Number 1005

October 2011, 118 pages, Softcover, ISBN: 978-0-8218-4967-5, 2010 *Mathematics Subject Classification*: 35-XX, **Individual member US\$42.60**, List US\$71, Institutional member US\$56.80, Order code MEMO/214/1005

General Interest



Moscow Mathematical Olympiads, 2000–2005

Roman Fedorov, *Max Planck Institute for Mathematics, Bonn, Germany*, **Alexei Belov**, *Moscow Institute of Open Education, Russia*, and **Shanghai University, People's Republic of China**,
Alexander Kovaldzhi, *"Second School" Lyceum, Moscow, Russia*, and **Ivan Yashchenko**, *Moscow Center for Continuous Mathematical Education, Russia*,
 Editors

The Moscow Mathematical Olympiad has been challenging high-school students with stimulating, original problems of different degrees of difficulty for over 75 years. The problems are nonstandard; solving them takes wit, thinking outside the box, and, sometimes, hours of contemplation. Some are within the reach of most mathematically competent high-school students, while others are difficult even for a mathematics professor. Many mathematically inclined students have found that tackling these problems, or even

just reading their solutions, is a great way to develop mathematical insight.

In 2006 the Moscow Center for Continuous Mathematical Education began publishing a collection of problems from the Moscow Mathematical Olympiads, providing for each an answer (and sometimes a hint) as well as one or more detailed solutions. This volume represents the years 2000–2005.

The problems and the accompanying material are well suited for math circles. They are also appropriate for problem-solving classes and practice for regional and national mathematics competitions.

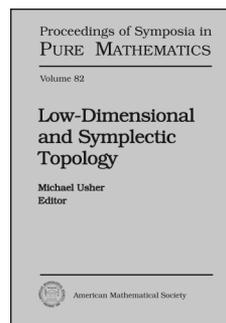
Titles in this series are co-published with the Mathematical Sciences Research Institute (MSRI).

Contents: Problems; Hints; Answers; Solutions; Reference facts; Bibliography; Problem authorship.

MSRI Mathematical Circles Library, Volume 7

October 2011, 176 pages, Softcover, ISBN: 978-0-8218-6906-2, LC 2011026991, 2010 *Mathematics Subject Classification*: 00A07, 97-01, 97D50, 00A08, **AMS members US\$31.20**, List US\$39, Order code MCL/7

Geometry and Topology



Low-Dimensional and Symplectic Topology

Michael Usher, *University of Georgia, Athens, GA*, Editor

Every eight years since 1961, the University of Georgia has hosted a major international topology conference aimed at disseminating important recent results and bringing together researchers at different stages of their careers.

This volume contains the proceedings of the 2009 conference, which includes survey and research articles concerning such areas as knot theory, contact and symplectic topology, 3-manifold theory, geometric group theory, and equivariant topology. Among other highlights of the volume, a survey article by Stefan Friedl and Stefano Vidussi provides an accessible treatment of their important proof of Taubes' conjecture on symplectic structures on the product of a 3-manifold and a circle, and an intriguing short article by Dennis Sullivan opens the door to the use of modern algebraic-topological techniques in the study of finite-dimensional models of famously difficult problems in fluid dynamics.

Continuing what has become a tradition, this volume contains a report on a problem session held at the conference, discussing a variety of open problems in geometric topology.

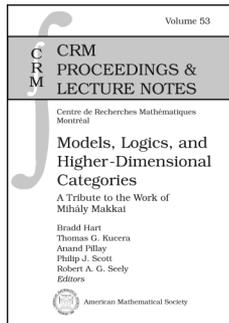
Contents: **D. Sullivan**, Algebra, topology and algebraic topology of 3D ideal fluids; **R. Charney** and **K. Vogtmann**, Subgroups and quotients of automorphism groups of RAAGs; **M. Borodzik**, Abelian ρ -invariants of iterated torus knots; **L. Watson**, A surgical perspective on quasi-alternating links; **Y. Ni**, Thurston norm and cosmetic surgeries; **E. Etgü** and **B. Ozbagci**, On the relative Giroux correspondence; **J. A. Baldwin** and **J. B. Etnyre**, A note on the support norm of a contact structure; **S. Hainz** and **U. Hamenstädt**, Topological properties of Reeb orbits on boundaries of star-shaped

domains in \mathbb{R}^4 ; **S. Friedl** and **S. Vidussi**, Twisted Alexander polynomials and fibered 3-manifolds; **D. McDuff**, Displacing Lagrangian toric fibers via probes; **H. Yang**, Equivariant Bredon cohomology and Čech hypercohomology; **S. Schleimer**, Sphere recognition lies in NP; Open problems in geometric topology.

Proceedings of Symposia in Pure Mathematics, Volume 82

November 2011, approximately 231 pages, Hardcover, ISBN: 978-0-8218-5235-4, 2010 *Mathematics Subject Classification*: 57-06, 20F36, 53D12, 53D35, 55P48, 57M25, 57M27, 57R17, 57R91, **AMS members US\$48.80**, List US\$61, Order code PSPUM/82

Logic and Foundations



Models, Logics, and Higher-Dimensional Categories

A Tribute to the Work of Mihály Makkai

Bradd Hart, *McMaster University, Hamilton, ON, Canada*, **Thomas G. Kucera**, *University of Manitoba, Winnipeg, MB, Canada*, **Anand Pillay**, *University of Leeds, United Kingdom*, and *University of Illinois, Urbana, IL*, **Philip J. Scott**, *University of Ottawa, ON, Canada*, and **Robert A. G. Seely**, *McGill University, Montreal, QC, Canada*, Editors

This book deals with the main themes in Mihály Makkai’s research career: traditional model theory, categorical model theory and logics, and higher-dimensional category theory. Included are both research papers and survey papers, giving useful material for experts and students in these fields. Particularly valuable are papers that show how the techniques and understanding in one field can be productively applied to another; examples are the paper by Harnik, which explains how Shelah’s T^{eq} construction (in model theory) is the same as the categorical notion of pretopos completion; the paper by Kamensky, which gives category-theoretic treatments of sophisticated notions from stability theory; and the paper by Prest relating categorical logic and the model theory of modules. These and other papers in this volume should make this a valuable resource for any mathematician interested in classical or categorical model theory or higher dimensional category theory.

This item will also be of interest to those working in algebra and algebraic geometry.

Titles in this series are co-published with the Centre de Recherches Mathématiques.

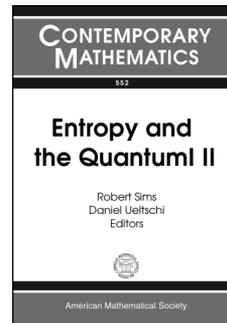
Contents: **N. L. Ackerman**, The number of countable models in categories of sheaves; **M. Bunge** and **C. Hermida**, Pseudomonodacy and 2-stack completions; **C. Enns** and **T. G. Kucera**, Purity and pure-injectivity for topological modules; **V. Harnik**, Model theory vs. categorical logic: Two approaches to pretopos completion (a.k.a. T^{eq}); **P. J. W. Hofstra**, The dialectica

monad and its cousins; **M. Kamensky**, A categorical approach to internality; **J. F. Knight**, Computable structures of Scott rank ω_1^{CK} ; **J. Lambek**, The Lorentz category in special relativity; **R. Moosa**, A model-theoretic counterpart to Moishczon morphisms; **A. Pillay** and **P. Tanović**, Generic stability, regularity, and quasiminimality; **J. Power**, Indexed Lawvere theories for local state; **M. Prest**, Model theory in additive categories; **G. E. Reyes**, A derivation of Einstein’s vacuum field equations; **M. Sadzadeh**, An adventure into Hungarian word order with cyclic pregroups; **S. Shelah**, No limit model in inaccessible; **M. A. Warren**, The strict ω -groupoid interpretation of type theory; **M. Zawadowski**, Lax monoidal fibrations.

CRM Proceedings & Lecture Notes, Volume 53

September 2011, 426 pages, Softcover, ISBN: 978-0-8218-7281-9, LC 2011024611, 2010 *Mathematics Subject Classification*: 03-06, 03C45, 03C52, 03C90, 03G30, 18C10, 18D05, 18D30, **AMS members US\$104**, List US\$130, Order code CRMP/53

Mathematical Physics



Entropy and the Quantum II

Robert Sims, *University of Arizona, Tucson, AZ*, and **Daniel Ueltschi**, *University of Warwick, Coventry, United Kingdom*, Editors

The goal of the Entropy and the Quantum schools has been to introduce young researchers to some of the exciting current topics in mathematical physics. These topics often involve analytic techniques that can easily be understood with a dose of physical intuition.

In March of 2010, four beautiful lectures were delivered on the campus of the University of Arizona. They included Isoperimetric Inequalities for Eigenvalues of the Laplacian by Rafael Benguria, Universality of Wigner Random Matrices by Laszlo Erdős, Kinetic Theory and the Kac Master Equation by Michael Loss, and Localization in Disordered Media by Günter Stolz. Additionally, there were talks by other senior scientists and a number of interesting presentations by junior participants. The range of the subjects and the enthusiasm of the young speakers are testimony to the great vitality of this field, and the lecture notes in this volume reflect well the diversity of this school.

This item will also be of interest to those working in analysis.

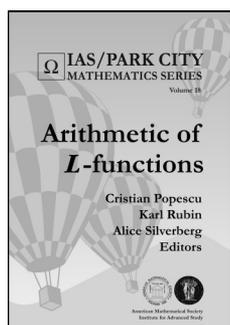
Contents: **E. Carlen**, **M. C. Carvalho**, and **M. Loss**, Kinetic theory and the Kac Master equation; **R. D. Benguria**, Isoperimetric inequalities for eigenvalues of the Laplacian; **N. Gamara**, **A. Hasnaoui**, and **L. Hermi**, Max-to-mean ratio estimates for the fundamental eigenfunction of the Dirichlet Laplacian; **G. Stolz**, An introduction to the mathematics of Anderson localization; **H. Krüger**, Schrödinger operators with potential $V(n) = n^{-\gamma} \cos(2\pi n^\rho)$; **A. Joye**, Random unitary models and their localization properties; **S. Starr**, Universality of correlations for random analytic functions; **A. Maltsev** and **B. Schlein**, A Wegner estimate for Wigner matrices; **B. Nachtergaele**, **A. Vershynina**, and **V. A. Zagrebnov**, Lieb-Robinson bounds and existence of the

thermodynamic limit for a class of irreversible quantum dynamics; **C. Goldschmidt**, **D. Ueltschi**, and **P. Windridge**, Quantum Heisenberg models and their probabilistic representations.

Contemporary Mathematics, Volume 552

October 2011, 224 pages, Softcover, ISBN: 978-0-8218-6898-0, LC 2011023679, 2010 *Mathematics Subject Classification*: 35Q20, 60B12, 60K35, 81Q10, 82B10, 82B44, 82C10, 82C40, 15B52, 35P15, **AMS members US\$63.20**, List US\$79, Order code CONM/552

Number Theory



Arithmetic of *L*-functions

Cristian Popescu, *University of California, San Diego, La Jolla, CA*, and **Karl Rubin** and **Alice Silverberg**, *University of California, Irvine, CA*, Editors

The overall theme of the 2009 IAS/PCMI Graduate Summer School was connections

between special values of *L*-functions and arithmetic, especially the Birch and Swinnerton-Dyer Conjecture and Stark's Conjecture. These conjectures are introduced and discussed in depth, and progress made over the last 30 years is described. This volume contains the written versions of the graduate courses delivered at the summer school. It would be a suitable text for advanced graduate topics courses on the Birch and Swinnerton-Dyer Conjecture and/or Stark's Conjecture. The book will also serve as a reference volume for experts in the field.

Titles in this series are co-published with the Institute for Advanced Study/Park City Mathematics Institute. Members of the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM) receive a 20% discount from list price.

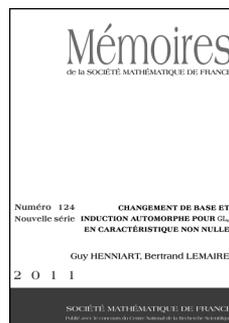
Contents: **C. Popescu**, **K. Rubin**, and **A. Silverberg**, Introduction; *Part I: Stark's conjecture:* **J. Tate**, Stark's basic conjecture; **H. Stark**, The origin of the "Stark conjectures"; **C. Popescu**, Integral and *p*-adic refinements of the abelian Stark conjecture; **M. Kolster**, Special values of *L*-functions at negative integers; **D. Burns**, An introduction to the equivariant Tamagawa number conjecture: The relation to Stark's conjecture; *Part II: Birch and Swinnerton-Dyer conjecture:* **A. Silverberg**, Introduction to elliptic curves; **B. H. Gross**, Lectures on the conjecture of Birch and Swinnerton-Dyer; **D. Ulmer**, Elliptic curves over function fields; **B. Birch**, Heegner's proof; **V. Vatsal**, Complex multiplication: A concise introduction; **G. Kings**, The equivariant Tamagawa number conjecture and the Birch-Swinnerton-Dyer conjecture; *Part III: Analytic and cohomological methods:* **D. E. Rohrlich**, Root numbers; **K. Rubin**, Euler systems and Kolyvagin systems.

IAS/Park City Mathematics Series, Volume 18

October 2011, 501 pages, Hardcover, ISBN: 978-0-8218-5320-7, LC 2011020548, 2010 *Mathematics Subject Classification*: 11G40, 11R42, 14G10, **AMS members US\$67.20**, List US\$84, Order code PCMS/18

New AMS-Distributed Publications

Algebra and Algebraic Geometry



Changement de Base et Induction Automorphe Pour GL_n en Caractéristique non Nulle

Guy Henniart, *Université Paris-Sud, Orsay, France*, and **Bertrand Lemaire**, *Université Aix-Marseille II, France*

Let E/F be a finite cyclic extension of local or global fields, of degree d . The theory of base change from $GL_n(F)$ to $GL_n(E)$ and the theory of automorphic induction from $GL_m(E)$ to $GL_{md}(F)$ are two instances of Langlands' functoriality principle: when F is local, they correspond respectively to restriction to E of representations of the Weil-Deligne group of F , and induction to F of representations of the Weil-Deligne group of E . If F is a finite extension of a p -adic field \mathbb{Q}_p , these theories were established long ago (Arthur-Clozel, Henniart-Herb).

In this memoir the authors extend them to the case where F is a non-Archimedean locally compact field of positive characteristic. They also prove, for a global functions field F , that these two local theories are compatible with the global maps of base change and automorphic induction deduced, via the Langlands correspondence proved by Lafforgue, from restriction and induction of global Galois representations.

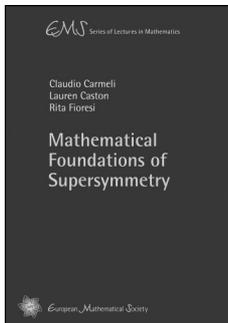
A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Le lemme fondamental pour le changement de base pour GL_n sur un corps local de caractéristique non nulle; Sur le changement de base local pour GL_n ; Formules de caractères pour l'induction automorphe, II; Sur le changement de base et l'induction automorphe pour les corps de fonctions; Bibliographie.

Mémoires de la Société Mathématique de France, Number 124

July 2011, 194 pages, Softcover, ISBN: 978-2-85629-311-9, 2010 *Mathematics Subject Classification*: 22E50, **Individual member US\$40.50**, List US\$45, Order code SMFMEM/124

Analysis



Mathematical Foundations of Supersymmetry

Claudio Carmeli, *Università di Genova, Italy*, **Lauren Caston**, *RAND Corporation, Santa Monica, CA*, and **Rita Fiorese**, *Università di Bologna, Italy*

Supersymmetry is a highly active area of considerable interest among physicists and mathematicians. It is not only fascinating in its own right, but there is also indication that it plays a fundamental role in the physics of elementary particles and gravitation.

The purpose of the book is to lay down the foundations of the subject, providing the reader with a comprehensive introduction to the language and techniques, as well as detailed proofs and many clarifying examples.

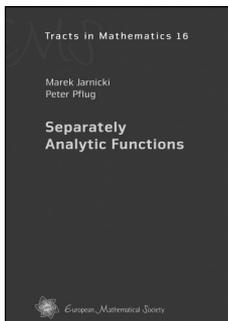
This book is aimed ideally at second-year graduate students. After the first three introductory chapters, the text is divided into two parts: the theory of smooth supermanifolds and Lie supergroups, including the Frobenius theorem, and the theory of algebraic superschemes and supergroups. There are three appendices. The first introduces Lie superalgebras and representations of classical Lie superalgebras, the second collects some relevant facts on categories, sheafification of functors and commutative algebra, and the third explains the notion of Fréchet space in the super context.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: $\mathbb{Z}/2\mathbb{Z}$ -graded linear algebra; Sheaves, functors and the geometric point of view; Supergeometry; Differentiable supermanifolds; The local structure of morphisms; The Frobenius theorem; Super Lie groups; Actions of super Lie groups; Homogeneous spaces; Supervarieties and superschemes; Algebraic supergroups; Appendices (with the assistance of Ivan Dimitrov); Bibliography; Index.

EMS Series of Lectures in Mathematics, Volume 15

August 2011, 300 pages, Softcover, ISBN: 978-3-03719-097-5, 2010 *Mathematics Subject Classification*: 58-02, 58A50, 58C50, 14M30, 17A70, 32C11, 81Q60, **AMS members US\$46.40**, List US\$58, Order code EMSSERLEC/15



Separately Analytic Functions

Marek Jarnicki, *Jagiellonian University, Kraków, Poland*, and **Peter Pflug**, *University of Oldenburg, Germany*

The story of separately holomorphic functions began about 100 years ago. During the second half of the 19th century,

it became known that a separately continuous function is not necessarily continuous as a function of all variables. At the beginning of the 20th century, the study of separately holomorphic functions started due to the fundamental work of Osgood and Hartogs.

This book provides the first self-contained and complete presentation of the study of separately holomorphic functions, from its beginnings to current research. Most of the results presented have never been published before in book form.

The text is divided into two parts. The first part deals with separately holomorphic functions, “without singularities”. The second part addresses the situation of existing singularities. A discussion of the classical results related to separately holomorphic functions leads to the most fundamental result, the classical cross theorem as well as various extensions and generalizations, to more complicated “crosses”. Additionally, several applications for other classes of “separately regular” functions are given.

A solid background in basic complex analysis is a prerequisite. To make the book self contained, all the results are collected in special introductory chapters and referred to at the beginning of each section.

This book is addressed to students and researchers in several complex variables as well as mathematicians and theoretical physicists interested in this area of mathematics.

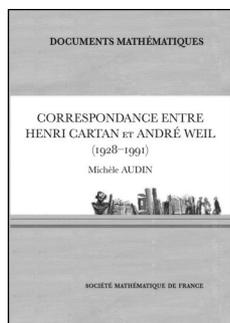
A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: *Cross theorems without singularities*: Classical results I; Prerequisites; Relative extremal functions; Classical results II; Classical cross theorem; Discs method; Non-classical cross theorems; Boundary cross theorems; *Cross theorems with singularities*: Extension with singularities; Cross theorem with singularities; Separately meromorphic functions; Bibliography; Symbols; List of symbols; Subject index.

EMS Tracts in Mathematics, Volume 16

August 2011, 306 pages, Hardcover, ISBN: 978-3-03719-098-2, 2010 *Mathematics Subject Classification*: 32-02, 32D15, 32A10, 32A17, 32D05, 32D10, 32D26, 32U15, **AMS members US\$62.40**, List US\$78, Order code EMSTM/16

General Interest



Correspondance Entre Henri Cartan et André Weil (1928-1991)

Michèle Audin, *Université de Strasbourg, France*, Editor

The Cartan-Weil correspondence is a lively introduction to part of 20th century mathematics. This book presents the correspondence, followed by 240 pages of notes and references, on the mathematical and political landscape. Readers will learn about, among other things, the birth and life of Bourbaki, the genesis, in jail, of André Weil's proof of the Riemann hypothesis on finite fields and the ferment of ideas on topology and on complex analysis which followed the invention of sheaf theory during the 1940s. They will also observe the effects of the turmoils of the century (including the rise of fascism, World War II) on mathematicians and mathematics.

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

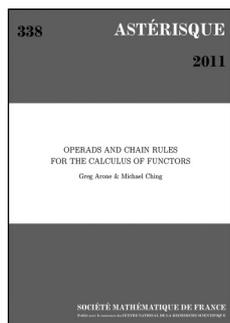
A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Premières lettres 1928-1933; La guerre 1939-1945; Strasbourg-São Paulo 1945-1947; Paris-Chicago 1947-1958; Après 1958; Notes sur la correspondance; Bibliographie; Index des personnes présentes sur les figures; Quelques-uns des sujets abordés dans ce livre; Index.

Documents Mathématiques, Number 6

July 2011, 720 pages, Hardcover, ISBN: 978-2-85629-314-0, 2010 *Mathematics Subject Classification*: 01-XX, 01Axx, 01A60, 11-XX, 28-03, 32-XX, 55-XX; 01A74, 11Gxx, 11Rxx, 32-03, **Individual member US\$81**, List US\$90, Order code SMFDM/6

Geometry and Topology



Operads and Chain Rules for the Calculus of Functors

Greg Arone, *University of Virginia, Charlottesville, VA*, and Michael Ching, *University of Georgia, Athens, GA*

The authors study the structure possessed by the Goodwillie derivatives of a pointed

homotopy functor of based topological spaces. These derivatives naturally form a bimodule over the operad consisting of the derivatives of the identity functor. The authors then use these bimodule structures to give a chain rule for higher derivatives in the calculus of functors, extending the work of Klein and Rognes. This

chain rule expresses the derivatives of FG as a derived composition product of the derivatives of F and G over the derivatives of the identity.

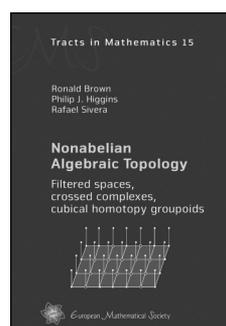
There are two main ingredients in the authors' proofs. First, they construct new models for the Goodwillie derivatives of functors of spectra. These models allow for natural composition maps that yield operad and module structures. Then, they use a cosimplicial cobar construction to transfer this structure to functors of topological spaces. A form of Koszul duality for operads of spectra plays a key role in this.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Basics; Operads and modules; Functors of spectra; Functors of spaces; Appendix A. Categories of operads, modules and bimodules; Bibliography.

Astérisque, Number 338

June 2011, 158 pages, Softcover, ISBN: 978-2-85629-308-9, 2010 *Mathematics Subject Classification*: 55P65, 55P48, **Individual member US\$54**, List US\$60, Order code AST/338



Nonabelian Algebraic Topology

Filtered Spaces, Crossed Complexes, Cubical Homotopy Groupoids

Ronald Brown, *Bangor University, Gwynedd, United Kingdom*, Philip J. Higgins, *Durham University, United Kingdom*, and Rafael Sivera, *Universitat de València, Spain*

The main theme of this book is that the use of filtered spaces rather than just topological spaces allows the development of basic algebraic topology in terms of higher homotopy groupoids; these algebraic structures better reflect the geometry of subdivision and composition than those commonly in use. Exploration of these uses of higher dimensional versions of groupoids has been largely the work of the first two authors since the mid 1960s.

The structure of the book is intended to make it useful to a wide class of students and researchers for learning and evaluating these methods, primarily in algebraic topology but also in higher category theory and its applications in analogous areas of mathematics, physics, and computer science.

Part I explains the intuitions and theory in dimensions 1 and 2, with many figures and diagrams, and a detailed account of the theory of crossed modules. Part II develops the applications of crossed complexes. The engine driving these applications is the work of Part III on cubical ω -groupoids, their relations to crossed complexes, and their homotopically defined examples for filtered spaces. Part III also includes a chapter suggesting further directions and problems, and three appendices give accounts of some relevant aspects of category theory. Endnotes for each chapter give further history and references.

This item will also be of interest to those working in algebra and algebraic geometry.

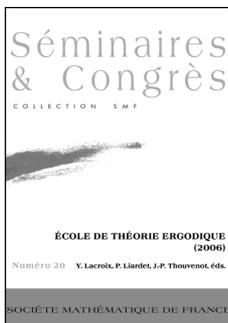
A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: *Part I. 1- and 2-dimensional results:* Introduction to Part I; History; Homotopy theory and crossed modules; Basic algebra of crossed modules; Coproducts of crossed P -modules; Induced crossed modules; Double groupoids and the 2-dimensional Seifert-van Kampen Theorem; *Part II. Crossed complexes:* Introduction to Part II; The basics of crossed complexes; The higher homotopy Seifert-van Kampen Theorem (HHSvKT) and its applications; Tensor products and homotopies of crossed complexes; Resolutions; The cubical classifying space of a crossed complex; Nonabelian cohomology: spaces, groupoids; *Part III. Cubical ω -groupoids:* Introduction to Part III; The algebra of crossed complexes and cubical ω -groupoids; The cubical homotopy ω -groupoid of a filtered space; Tensor products and homotopies; Future directions?; Appendices; Bibliography; Glossary of symbols; Index.

EMS Tracts in Mathematics, Volume 15

August 2011, 703 pages, Hardcover, ISBN: 978-3-03719-083-8, 2010 *Mathematics Subject Classification:* 55-02, 18B40, 18G50, 55P15, AMS members US\$94.40, List US\$118, Order code EMSTM/15

Number Theory



École de Théorie Ergodique (2006)

Y. Lacroix, *Université du Sud-Toulon-Var SITV, La Valette du Var, France*, P. Liardet, *Université de Provence, Marseille, France*, and J.-P. Thouvenot, *Université Pierre et Marie Curie, Paris, France*, Editors

This volume, which contains a selection of papers that were presented at the School in Ergodic Theory, CIRM (Marseille, France) during April 2006, explores several themes.

Dynamical properties of interval maps are studied in case of unimodal transformations and piecewise monotonic maps, but also for generalized β -shift and some Gibbs properties related to the Erdős measure, linked to the Golden Number, are investigated. In geometry, combinatorial and ergodic properties of geodesic flows are studied through a coding of such a flow on an hyperbolic surface, and an original approach of the unique ergodicity property of the directional flow on a surface translation (KMS theorem) is provided.

Rank one, mixing, self-joining transformation, and some rigidity properties, are the subject of three papers. For symbolic dynamics, low complexity is represented by the introduction of generalized Toeplitz sequences, and high disorder is involved in searching properties of measures both invariant under the shift and some cellular automata.

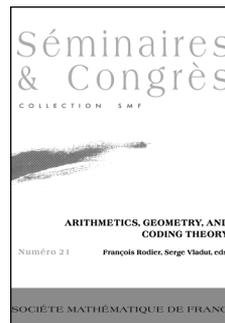
A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico.

Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: R. Abe, The cross section map for geodesic flows related to the Hecke and Picard groups; H. Bruin, Combinatorics of Fibonacci-like unimodal maps; J. Buzzzi, Entropy theory on the interval; K. Dajani and C. Kalle, A note on the Greedy β -transformation with arbitrary digits; E. H. El Abdalaoui, M. El Machkouri, and A. Nogueira, A criterion of weak mixing property; S. Gouëzel and E. Lanneau, Un théorème de Kerckhoff, Masur et Smillie: unique ergodicité sur les surfaces plates; F. Krieger, Toeplitz subshifts and odometers for residually finite groups; E. Olivier and A. Thomas, Infinite convolution of Bernoulli measures, PV numbers and related problems in the dynamics of fractal geometry; V. V. Ryzhikov, Self-joinings of rank-one actions and applications; M. Sablik, Recherche de mesures invariantes pour l'action conjointe d'un automate cellulaire et du décalage; A. I. Danilenko, Uncountable collection of mixing rank-one actions for locally normal groups.

Séminaires et Congrès, Number 20

June 2011, 251 pages, Softcover, ISBN: 978-2-85629-312-6, 2010 *Mathematics Subject Classification:* 11A67, 11K55, 15A48, 28A12, 28D05, 28D20, 30F30, 32G15, 37Axx, 37A05, 37A25, 37Bxx, 37B05, 37B10, 37B15, 37D40, 37D45, 37E05, 53D25, 57R30, **Individual member US\$54**, List US\$60, Order code SECO/20



Arithmetics, Geometry, and Coding Theory

François Rodier and Serge Vladut, *Institut de Mathématiques de Luminy, Marseille, France*, Editors

The Conference on Arithmetics, Geometry, and Coding Theory was held at the

International Center of Mathematical Meetings of Luminy (CIRM) in Marseilles from September 26–30, 2005. The conference focused on the interaction between number theory and algebraic geometry and the interaction between coding theory and cryptography. It addressed such subjects as curves covered by the Hermitian curve, towers of function fields, bilinear complexity of the multiplication in the finite fields, codes on various varieties, estimate of the Picard number of surfaces via p -adic cohomology, minimal distance of codes on a surface, and the Euler-Kronecker constant on global fields.

Public key cryptography provided an opportunity for talks on curves and their jacobians: jacobians of C_{ab} curves, a CRT algorithm to construct genus 2 curves over finite fields, hyperelliptic jacobians and the Steinberg representations. Other talks were devoted to the relations between the enumerator polynomial of codes and modular forms and to a similar construction with construction A of lattices from binary codes to build convolutional codes starting from block codes.

This item will also be of interest to those working in algebra and algebraic geometry.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: **K. Betsumiya** and **Y. Choie**, Invariant ring of Clifford-Weil group and Jacobi forms over totally real field; **R. Blache**, **J. E. Sarlabous**, and **M. Petkova**, A geometric interpretation of reduction in the Jacobians of C_{ab} curves; **A. Garcia** and **F. Torres**, On unramified coverings of maximal curves; **G. M. Hana**, Schubert unions and codes on 1-step flag varieties; **M. Giulietti**, **J. W. P. Hirschfeld**, **G. Korchmáros**, and **F. Torres**, A family of curves covered by the Hermitian curve; **Y. Ihara**, The Euler-Kronecker invariants in various families of global fields; **J. P. Hansen**, **T. Johnsen**, and **K. Ranestad**, Grassman codes and Schubert unions; **T. G. Abbott**, **K. S. Kedlaya**, and **D. Roe**, Bounding Picard numbers of surfaces using p -adic cohomology; **K. Eisenträger** and **K. Lauter**, A CRT algorithm for constructing genus 2 curves over finite fields; **T. Nakashima**, Relative Reed-Muller codes on projective bundles; **S. Ballet**, **D. Le Brigand**, and **R. Rolland**, On an application of the definition field descent of a tower of function fields; **P. Solé**, Construction A for convolutional codes; **J. F. Volochi** and **M. Zarzar**, Algebraic geometric codes on surfaces; **Y. G. Zarhin**, Hyperelliptic jacobians and Steinberg representations.

Séminaires et Congrès, Number 21

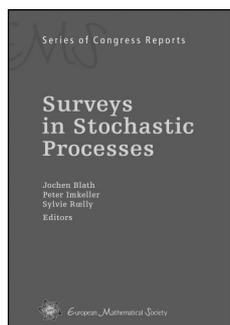
June 2011, 225 pages, Softcover, ISBN: 978-2-85629-279-2, 2010 *Mathematics Subject Classification*: 11E10, 11F41, 11Gxx, 11R37, 11R42, 11T71, 14C22, 14F30, 14G05, 14G15, 14G50, 14H25, 14H40, 14H45, 14M15, 14Q05, 15A63, 15A66, 94B10, 05E15, 11H99, 11R47, 11R58, 14F40, 14Gxx, 14J20, 14K05, 94B05, 94B27, 94B65, **Individual member US\$54**, List US\$60, Order code SECO/21

COGARCH: A review, with news on option pricing and statistical inference; **S. Martinez** and **J. San Martin**, Some properties of quasi-stationary distributions for finite Markov chains; **P. Mörters**, The parabolic Anderson model with heavy-tailed potential; **E. Pardoux** and **A. Wakolbinger**, From exploration paths to mass excursions—variations on a theme of Ray and Knight; **G. Reinert**, Gaussian approximation of functionals: Malliavin calculus and Stein's method; **L. Saloff-Coste** and **J. Zúñiga**, Merging and stability for time inhomogeneous finite Markov chains; **A. Schied** and **A. Slynko**, Some mathematical aspects of market impact modeling; **G. Slade**, The self-avoiding walk: A brief survey; **M. Takeda**, L^p -independence of growth bounds of Feynman-Kac semigroups; **F.-Y. Wang**, Some recent progress on functional inequalities and applications; List of contributors.

EMS Series of Congress Reports, Volume 4

August 2011, 260 pages, Hardcover, ISBN: 978-3-03719-072-2, 2010 *Mathematics Subject Classification*: 60-06, 60Gxx, 60Jxx, **AMS members US\$78.40**, List US\$98, Order code EMSSCR/4

Probability and Statistics



Surveys in Stochastic Processes

Jochen Blath, *Technical University of Berlin, Germany*,
Peter Imkeller, *Humboldt University of Berlin, Germany*,
 and **Sylvie Roelly**, *University of Potsdam, Germany*, Editors

The 33rd Bernoulli Society Conference on Stochastic Processes and Their Applications was held in Berlin from July 27 to July 31, 2009. It brought together more than 600 researchers from 49 countries to discuss recent progress in the mathematical research related to stochastic processes, with applications ranging from biology to statistical mechanics, finance and climatology.

This book collects survey articles highlighting new trends and focal points in the area written by plenary speakers of the conference, all of them outstanding international experts. A particular aim of this collection is to inspire young scientists to pursue research goals in the wide range of fields represented in this volume.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: **S. Hamadène**, Optimal switching, systems of reflected BSDEs and systems of variational inequalities with inter-connected obstacles; **C. Klüppelberg**, **R. Maller**, and **A. Szimayer**, The

Classified Advertisements

Positions available, items for sale, services available, and more

CALIFORNIA

UNIVERSITY OF CALIFORNIA, BERKELEY Department of Mathematics

We invite applications for the following positions: 1. One or more tenure-track positions 2. Charles B. Morrey, Jr. Assistant Professorship 3. Visiting Assistant Professorships (partially funded by the NSF). These positions begin July 1, 2012. For more information on these positions and how to apply for them, please go to: http://math.berkeley.edu/employment_academic.html.

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UCLA Department of Mathematics

The Department of Mathematics invites applications for a tenure-track/tenure faculty position. Salary is commensurate with the level of experience.

We also plan to make temporary and visiting appointments in the categories 1-4 below. Depending on the level, candidates must give evidence of potential or demonstrated distinction in scholarship and teaching.

Temporary Positions: (1) E.R. Hedrick Assistant Professorships. Salary is \$61,200 and appointments are for three years. The teaching load is four one-quarter courses per year.

(2) Computational and Applied Mathematics (CAM) Assistant Professorships. Salary is \$61,200, and appointments are for three years. The teaching load is normally

reduced by research funding to two quarter courses per year.

(3) Program in Computing (PIC) Assistant Adjunct Professorships. Salary is \$65,500. Applicants for these positions must show very strong promise in teaching and research in an area related to computing. The teaching load is four one-quarter programming courses each year and one additional course every two years. Initial appointments are for one year and possibly longer, up to a maximum service of four years.

(4) Assistant Adjunct Professorships and Research Postdocs. Normally appointments are for one year, with the possibility of renewal. Strong research and teaching background required. The salary range is \$53,200-\$59,500. The teaching load for adjuncts is six one-quarter courses per year.

Applications and supporting documentation must be submitted electronically via <http://www.mathjobs.org>. All letters of evaluation are subject to UCLA campus policies on confidentiality. Refer potential reviewers to the UCLA Statement of Confidentiality at <http://www.math.ucla.edu/people/confidentiality.pdf>.

For fullest consideration, all application materials should be submitted on or before December 9, 2011. A Ph.D. is required for all positions.

The university is an Equal Opportunity/Affirmative Action Employer. UCLA and the Department of Mathematics have a strong commitment to the achievement of excellence in teaching and research and diversity among its faculty and staff. The University of California asks that

applicants complete the Equal Opportunity Employer survey for Letters and Science at the following URL: <http://cis.ucla.edu/facultysurvey>. Under Federal law, the University of California may employ only individuals who are legally authorized to work in the United States as established by providing documents specified in the Immigration Reform and Control Act of 1986.

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CONNECTICUT

FAIRFIELD UNIVERSITY Assistant Professor in Mathematics Tenure-Track position

The Department of Mathematics and Computer Science at Fairfield University invites applications for one tenure-track position in mathematics, at the rank of assistant professor, to begin in September 2012. We seek a highly qualified candidate with a commitment to and demonstrated excellence in teaching, and strong evidence of research potential. A doctorate in mathematics or a related field is required. The teaching load is 3 courses/9 credit hours per semester and consists primarily of courses at the undergraduate level. The successful candidate will be expected to teach a wide variety of courses from elementary calculus and statistics to graduate level courses; in particular, Fairfield University's core curriculum includes two semesters of mathematics for all undergraduates.

Special consideration will be given to candidates in applied areas of mathematics,

Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

The 2011 rate is \$3.25 per word. No discounts for multiple ads or the same ad in consecutive issues. For an additional \$10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Headlines will be centered in boldface at no extra charge. Ads will appear in the language in which they are submitted.

There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified ads.

Upcoming deadlines for classified advertising are as follows: November 2011 issue–August 30, 2011; December 2011 issue–September 28, 2011; January

2012 issue–October 31, 2011; February 2012 issue–November 28, 2011; March 2012 issue–December 28, 2011; April 2012 issue–January 30, 2012.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 667 (vol. 56).

Situations wanted advertisements from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the U.S. and Canada or 401-455-4084 worldwide for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940; or via fax: 401-331-3842; or send email to classads@ams.org. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Advertisers will be billed upon publication.

or to those who are interested in playing an active role in our statistics curriculum.

Fairfield University is a Catholic Jesuit institution and is consistently ranked as a top comprehensive university in New England. It is located in the scenic shoreline community of Fairfield, CT, one hour from New York City along Long Island Sound. Our six colleges and professional schools enroll approximately 3,500 undergraduate and 1,200 graduate students with a strong emphasis on liberal arts education. The Department of Mathematics and Computer Science has an active faculty of 15 full-time tenured or tenure-track members. We offer a BS and an MS in mathematics, as well as a BS in computer science. The MS program is an evening program and attracts students from various walks of life—secondary school teachers, eventual Ph.D. candidates, and people working in industry or business, among others.

Fairfield offers competitive salaries and compensation benefits. Fairfield is an Affirmative Action/Equal Opportunity Employer.

How to Apply: Applicants are required to apply electronically through <http://MathJobs.org>. For full consideration, please submit an application with all supporting materials by the deadline stated below. Applications must include the following: a curriculum vitae, teaching and research statements, and three letters of recommendation commenting on the applicant's experience and promise as a teacher and scholar. Reference letter writers should be asked to submit their letters online through <http://MathJobs.org>. If they are unable to do so, they may send their letters to the following address: Matt Coleman, Chair of the Department of Mathematics and Computer Science, Fairfield University, 1073 N. Benson Rd., Fairfield CT 06824-5195. Full consideration will be given to complete applications received by December 9, 2011. We will be interviewing at the Joint Mathematics Meetings in Boston, January 4-7, 2012. Please let us know if you will be attending.

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HAWAII

UNIVERSITY OF HAWAII Department of Meteorology

The University of Hawaii at Manoa, Department of Meteorology, invites applications for two full-time tenure-track positions supported by general funds at the assistant professor level (appointment at the associate professor level may be considered in cases where the applicant has a proven record of outstanding research and teaching), to begin approximately January 1, 2012, subject to position clearance. The department seeks candidates with demonstrated research expertise preferably in the areas of physical, satel-

lite, boundary layer or tropical meteorology. Candidates with outstanding track records in other areas are also encouraged to apply. In addition, candidates will be expected to teach undergraduate and graduate courses preferably in one or more of the areas of radiative transfer, cloud physics, satellite meteorology, meteorological instrumentation, air-sea interaction, synoptic, tropical, and boundary layer meteorology. A Ph.D. earned no later than January 1, 2012, in the area of meteorology or a closely related field is required, as are excellent communication skills; a demonstrated capability for creative, high-quality research; and evidence of effectively teaching and mentoring undergraduate and graduate students. For the associate professor level, a minimum of four years teaching and research experience is also required. Applicants should submit curriculum vitae; detailed statement of research and teaching interests; and the names, addresses, phone numbers, and email addresses of at least three references to: Prof. Bin Wang, Chair, Department of Meteorology, University of Hawaii, 2525 Correa Rd., Hawaii Institute of Geophysics Building Room 350, Honolulu, HI 96822. Inquiries: phone (808) 956-8775; fax (808) 956-2877; email: metdept@hawaii.edu. Review of applications will begin August 15, 2011, and will continue until the positions are filled. The University of Hawaii is an Equal Employment Opportunity/Affirmative Action Institution.

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ILLINOIS

UNIVERSITY OF CHICAGO Department of Mathematics

The University of Chicago Department of Mathematics invites applications for the following positions:

1. L.E. Dickson Instructor: This is open to mathematicians who have recently completed or will soon complete a doctorate in mathematics or a closely related field, and whose work shows remarkable promise in mathematical research and teaching. The appointment typically is for two years, with the possibility of renewal for a third year. The teaching obligation is up to four one-quarter courses per year.

2. Simons Fellow (at the rank of Dickson Instructor): This is open to candidates who receive the Ph.D. within the period September 1, 2011, through August 31, 2012. The duration of the fellowship is three years, and the teaching obligation is four one-quarter courses during the three-year fellowship. This appointment would be at the University's rank of Dickson Instructor but would also carry the title of Simons Fellow within the Department of Mathematics.

3. Assistant Professor: This is open to mathematicians who are further along in their careers, typically two or three years

past the doctorate. These positions are intended for mathematicians whose work has been of outstandingly high caliber. Appointees are expected to have the potential to become leading figures in their fields. The appointment is generally for three years, with a teaching obligation of three one-quarter courses per year.

Applicants will be considered for any of the positions above which seem appropriate. Complete applications consist of (a) a cover letter, (b) a curriculum vitae, (c) three or more letters of reference, at least one of which addresses teaching ability, and (d) a description of previous research and plans for future mathematical research. Applicants are strongly encouraged to include information related to their teaching experience, such as a teaching statement or evaluations from courses previously taught, as well as an AMS cover sheet. If you have applied for an NSF Mathematical Sciences Postdoctoral Fellowship, please include that information in your application, and let us know how you plan to use it if awarded. If you are eligible for the Simons Fellowship and wish to be considered for it, please indicate this in your cover letter. Applications must be submitted online through <http://www.mathjobs.org>. Questions may be directed to apptsec@math.uchicago.edu. We will begin screening applications on December 1, 2011. Screening will continue until all available positions are filled. The University of Chicago is an Affirmative Action / Equal Opportunity Employer.

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MASSACHUSETTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY Department of Mathematics

The Mathematics Department at MIT is seeking to fill positions in pure and applied mathematics, statistics, and applied probability at the level of instructor, assistant professor or higher beginning September 2012. Appointments are based primarily on exceptional research qualifications. Appointees will be expected to fulfill teaching duties and to pursue their own research program. Ph.D. required by employment start date.

For more information, and to apply, please visit <http://www.mathjobs.org>.

To receive full consideration, please submit applications by December 1, 2011. Recommendations should be submitted through <http://mathjobs.org>, but may also be sent as PDF attachments to hiring@math.mit.edu, or as paper copies mailed to: Mathematics Search Committee, Room 2-345, Department of

Mathematics, MIT, 77 Massachusetts Ave., Cambridge, MA 02139-4307.

Please do not mail or email duplicates of items already submitted via <http://mathjobs.org>.

MIT is an Equal Opportunity, Affirmative Action Employer.

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NEW JERSEY

INSTITUTE FOR ADVANCED STUDY School of Mathematics

The School of Mathematics has a limited number of memberships with financial support for research in mathematics and computer science at the Institute during the 2012-13 academic year. During the 2012-13 academic year, the school will have a special program on Univalent Foundations of Mathematics. The program will be organized by Steve Awodey of Carnegie Mellon University, Thierry Coquand of the University of Gothenburg, and Vladimir Voevodsky of the Institute. The main goal of the program is to make available to a wider mathematical audience the recent advances which may finally make it practical for pure mathematicians to use "proof assistants" in their work. More information about the special program can be found at "special years" on the school's home page at: <http://www.math.ias.edu>. Several years ago the school established the von Neumann Fellowships, and up to 6 of these fellowships will be available for the 2012-13 year. To be eligible for a von Neumann Fellowship, applicants should be at least 5, but no more than 15, years following the receipt of their Ph.D. The Veblen Research Instructorship is a 3-year position which the School of Mathematics and the Department of Mathematics at Princeton University established in 1998. Three-year instructorships will be offered each year to candidates in pure and applied mathematics who have received their Ph.D. within the last 3 years. The first and third year of the instructorship will be spent at Princeton University and will carry regular teaching responsibilities. The second year will be spent at the Institute and dedicated to independent research of the instructor's choice. Candidates must have given evidence of ability in research comparable at least with that expected for the Ph.D. degree. Application materials may be requested from Applications, School of Mathematics, Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540; email: applications@math.ias.edu. Postdoctoral computer science and discrete mathematics applicants may be interested in applying for a joint (2-year) position with one of the following: The Department of Computer Science at Princeton University, <http://www.cs.princeton.edu>; DIMACS at Rutgers, The State University of New Jersey, <http://www.dimacs.rutgers.edu>; or the Intractability Center, <http://intractability.princeton.edu>. For a joint appointment, applicants should apply to the School of Mathematics as well as to the above noting their interest in a joint appointment. Applications may be made online at: <http://applications.ias.edu>. The deadline for all applications is December 1, 2011. The Institute for Advanced Study is committed to diversity and strongly encourages applications from women and minorities.

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NEW YORK

CORNELL UNIVERSITY Department of Mathematics

The Department of Mathematics at Cornell University invites applications for two tenure-track assistant professor positions, or higher rank, pending administrative approval, starting July 1, 2012. The searches are open to all areas of mathematics with an emphasis on the areas of probability, number theory, and PDE. The department actively encourages applications from women and minority candidates.

Applicants must apply electronically at: <http://www.mathjobs.org>.

For information about our positions and application instructions see: <http://www.math.cornell.edu/Positions/facpositions.html>. Applicants will be automatically considered for all eligible positions. Deadline: November 1, 2011. Early applications will be regarded favorably. Cornell University is an Affirmative Action/Equal Opportunity Employer and Educator.

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CORNELL UNIVERSITY H.C. Wang Assistant Professor

The Department of Mathematics at Cornell University invites applications for two H.C. Wang Assistant Professors, non-renewable, 3-year position beginning July 1, 2012. Successful candidates are expected to pursue independent research at Cornell and teach three courses per year. A Ph.D. in mathematics is required. The department actively encourages applications from women and minority candidates.

Applicants must apply electronically at <http://www.mathjobs.org>.

For information about our positions and application instructions, see: <http://www.math.cornell.edu/Positions/positions.html>.

Applicants will be automatically considered for all eligible positions. Deadline December 1, 2011. Early applications will be regarded favorably. Cornell University is an Affirmative Action/Equal Opportunity Employer and Educator.

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NORTH CAROLINA

WAKE FOREST UNIVERSITY Department of Mathematics

Applications are invited for one tenure-track position in statistics at the assistant professor level beginning July 2012. Hiring at the associate professor level may be considered. We seek highly qualified candidates who have a commitment to excellence in both teaching and research. A Ph.D. in statistics or a related area is required. The department has twenty members and offers both a B.A. and a B.S. in mathematics, with an optional concentration in statistics, a B.S. in interdisciplinary mathematics, and a B.S. in each of mathematical business and mathematical economics. The department has a graduate program offering an M.A. in mathematics. A complete application will include a letter of application, curriculum vitae, teaching statement, research statement, graduate transcripts, and three letters of recommendation. The application deadline is December 1, 2011. Applicants are encouraged to post materials electronically at <http://www.mathjobs.org>. Hard copy can be sent to Edward Allen, Wake Forest University, Department of Mathematics, P.O. Box 7388, Winston-Salem, NC 27109. AA/EO Employer.

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OREGON

UNIVERSITY OF OREGON Department of Mathematics

The University of Oregon department of mathematics seeks applicants for full-time tenure-related positions at the rank of assistant professor, in any area of pure or applied mathematics. Minimum qualifications are a Ph.D. in mathematics or closely related field. An outstanding research record, and active participation and excellence in teaching at the undergraduate and graduate levels will be the most important criteria for selection. Please see <http://hr.uoregon.edu/jobs/> for a full position announcement. Applicants should provide a standard AMS cover page, CV, research statement, three letters of recommendation, and apply online at <http://mathjobs.org>. Deadline for applications: December 15, 2011. Candidates should have the ability to work effectively with a diverse community. The University of Oregon is an EO/AA/ADA Institution committed to cultural diversity.

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PENNSYLVANIA

**PENN STATE, UNIVERSITY PARK
Faculty Positions, Department of
Mathematics**

Subject to availability of funding, the Penn State Mathematics Department will seek to fill openings for S. Chowla Research Assistant Professors and for tenure and tenure-track faculty positions.

S. Chowla Research Assistant Professor

Successful candidates will be new or recent Ph.D.s with exceptional research potential and a commitment to excellence in teaching. These non-tenure-track appointments are for three years. Starting salary is \$51,500 for the nine month academic year. The Chowla program is designed to maximize the professional development of its participants and provides a research stipend. The department may in addition make other postdoctoral appointments. Applicants for the Chowla position will automatically be considered for these appointments also. Initial offers will be made in January 2012.

Tenure or Tenure-Track Faculty Position

This position may be at the assistant, associate, or full professor level dependent on the qualifications and experience of the appointee. The area of emphasis for hiring includes partial differential equations, dynamical systems, and geometry. However, outstanding candidates from all areas of mathematics will be considered. A Ph.D. degree or its equivalent is required. Online application via <http://www.mathjobs.org> is strongly preferred. Review of applications will begin November 28, 2011, and will continue until positions are filled. Required application materials include:

- Online application
- At least three reference letters, one of which should address in detail the candidate's abilities as a teacher
- Curriculum Vitae
- Publication List
- Research Statement
- Teaching Statement

Persons who are unable to apply using the <http://mathjobs.org> website or who do not wish to do so may send application materials to:

Search Committee
Department of Mathematics
Penn State University
107 McAllister Building
University Park, PA 16802

Applications from women and members of underrepresented groups are welcomed. Penn State is committed to affirmative action, equal opportunity, and the diversity of its workforce.

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TEXAS

**TEXAS A&M UNIVERSITY
Department of Mathematics**

The Department of Mathematics anticipates several openings for postdoctoral positions at the level of visiting assistant professor, subject to budgetary approval. Our visiting assistant professor positions are three-year appointments and carry a three-course-per-year teaching load. They are intended for those who have recently received their Ph.D. and preference will be given to mathematicians whose research interests are close to those of our regular faculty members. We also anticipate several short-term (semester or year-long) visiting positions at various ranks, depending on budget. A complete dossier should be received by December 15, 2011. Early applications are encouraged since the department will start the review process in October 2011. Applicants should send the completed "AMS Application Cover Sheet", a vita, a summary statement of research and teaching experience, and arrange to have letters of recommendation sent to: Faculty Hiring, Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, Texas 77843-3368. Further information can be obtained from: <http://www.math.tamu.edu/hiring>.

Texas A&M University is an Equal Opportunity Employer. The university is dedicated to the goal of building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a multicultural environment and strongly encourages applications from women, minorities, individuals with disabilities, and veterans. The university is responsive to the needs of dual career couples.

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**THE UNIVERSITY OF TEXAS AT AUSTIN
Department of Mathematics
Austin, Texas 78712**

Expected openings for Fall 2012 include: (a) Instructorships, some that have R.H. Bing Faculty Fellowships, RTG Postdoctoral Instructorships, attached to them, and (b) possibly two or more positions at the tenure-track/tenure level.

(a) Instructorships at The University of Texas at Austin are postdoctoral appointments, renewable for two additional years. It is assumed that applicants for instructorships will have completed all Ph.D. requirements by August 17, 2011. Other factors being equal, preference will be given to those whose doctorates were conferred in 2010 or 2011. Candidates should show superior research ability and have a strong commitment to teaching. Consideration will be given only to applicants whose research interests have some overlap with those of the permanent faculty. Duties consist of teaching undergraduate or graduate courses and

conducting independent research. The projected salary is \$46,000 for the nine-month academic year.

Each R.H. Bing Fellow holds an instructorship in the Mathematics Department, with a teaching load of two courses in one semester and one course in the other. The combined Instructorship-Fellowship stipend for nine-months is \$54,000, which is supplemented by a travel allowance of \$1,000. Pending satisfactory performance of teaching duties, the Fellowship can be renewed for two additional years. Applicants must show outstanding promise in research. Bing Fellowship applicants will automatically be considered for other departmental openings at the postdoctoral level, so a separate application for such a position is unnecessary.

Each R.T.G. Instructor holds an instructorship in the Mathematics Department, with a teaching load of two courses per year. The combined Instructorship-Fellowship stipend for nine-months will be at least \$50,000, which is supplemented by a travel allowance of \$3,000 and \$10,000 summer salary for the first two years, pending availability of grant support. For satisfactory performance of teaching duties, the instructorship may be renewed for two additional years. Applicants must show outstanding promise in research.

Those wishing to apply for instructor positions are asked to send a vita and a brief research summary to the above address c/o Instructor Committee. Transmission of the preceding items via the Internet (URL: <http://www.ma.utexas.edu/jobs/application>) is encouraged.

(b) An applicant for a tenure-track or tenured position must present a record of exceptional achievement in her or his research area and must demonstrate a proficiency at teaching. In addition to the duties indicated above for instructors, such an appointment will typically entail the supervision of Ph.D. students. The salary will be commensurate with the level at which the position is filled and the qualifications of the person who fills it.

Those wishing to apply for tenure-track/tenured positions are asked to send a vita and a brief research summary to the above address, c/o Recruiting Committee. Transmission of the preceding items via the Internet (URL: <http://www.ma.utexas.edu/jobs/application/TenureTrack>) is encouraged.

All applications should be supported by four or more letters of recommendation, at least one of which speaks to the applicant's teaching credentials. The screening of applications will begin on November 1, 2011.

Background check will be conducted on the applicant selected. The University of Texas at Austin is an Affirmative Action/Equal Opportunity Employer.

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THE UNIVERSITY OF TEXAS AT AUSTIN
Department of Mathematics
Austin, Texas 78712
Research Assistant Professor in
Mathematics (non-tenure-track)

The University of Texas at Austin, Department of Mathematics invites applicants for one position in pure and applied mathematics, with the title Research Assistant Professor. The initial appointment will be for the 2012-2013 academic year, with the possible renewal to a second year pending successful completion of the first. We are looking for candidates who will further strengthen the department's research in the areas of analysis, applied mathematics, numerical analysis and PDE with applications to multiscale problems in complex phenomena. Candidates should have a Ph.D. in mathematics with previous postdoctoral experience by the time of the appointment. Applications should be submitted directly to the department and should include (1) cover sheet for academic appointment (2) curriculum vitae, (3) research and teaching statements, and (4) four letters of recommendation, one of which discusses the candidate's teaching qualifications. For more information, please visit <http://www.math.utexas.edu>. Screening of applicants will begin on February 1, 2012, and will continue until the position is filled. The University of Texas at Austin is an Affirmative Action/Equal Opportunity Employer and especially encourages applications from women and minority candidates.

Submit the following:

- Curriculum Vitae
- Research Statement
- Teaching Statement
- Four Reference Letters

Mathematics Department
 c/o Linda Porras
 University of Texas at Austin
 1 University Station/C1200
 Austin, Texas 78704.

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HONG KONG

THE UNIVERSITY OF HONG KONG
IMR Postdoctoral Fellow in the
Department of Mathematics

Applications are invited for appointment as postdoctoral fellow (2-3 posts) in the Department of Mathematics, from September 1, 2012, or as soon as possible thereafter, on a two-year term and with the possibility of renewal. An earlier start date can be discussed if a successful candidate finds it desirable.

Applicants should possess a Ph.D. degree. Preference will be given to those who have obtained their Ph.D. degrees within the last 6 years and whose areas of expertise fall within the following areas of concentration: algebra and number theory; geometry and Lie groups; optimization,

theoretical computer science and information theory; several complex variables and complex geometry; and probability theory, stochastics and mathematical finance. They are expected to show strong potential in mathematical research. The appointees will be associated with the Institute of Mathematical Research (IMR, <http://www0.hku.hk/math/>) and will be primarily engaged in mathematical research. They will also take an active role in the activities of IMR and contribute to the academic activities as assigned by the head of the Department of Mathematics.

A highly competitive salary commensurate with qualifications and experience will be offered. Annual leave and medical/dental benefits will be provided.

Applicants are requested to apply online at <https://jobs.hku.hk>. Please also upload a C.V. containing information on educational experience, including the title of the thesis and the name of the thesis supervisor for the Ph.D. degree, professional experience, a list of publications, a survey of past research experience, a description of current research interests, and a research plan for the next few years via the online application system. Review of applications will start after December 31, 2011, and will continue until the posts are filled. Candidates who are not contacted by April 30, 2012, may consider their applications unsuccessful.

The university is an Equal Opportunity Employer and is committed to a No-Smoking Policy.

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KOREA

KOREA INSTITUTE FOR ADVANCED
STUDY (KIAS)
Postdoctoral Research Fellowships

The School of Mathematics at the Korea Institute for Advanced Study (KIAS) invites applicants for the positions at the level of postdoctoral research fellows in pure and applied mathematics. KIAS, founded in 1996, is committed to the excellence of research in basic sciences (mathematics, theoretical physics, and computational sciences) through high-quality research programs and a strong faculty body consisting of distinguished scientists and visiting scholars.

Applicants are expected to have demonstrated exceptional research potential, through the doctoral dissertation and beyond. The annual salary ranges from approximately 37,000,000 Korean won-70,000,000 Korean won (equivalent to US\$ 34,000-US\$ 64,000). In addition, research funding in the amount of approximately 10,000,000 Korean won-15,000,000 Korean won (equivalent to US\$ 9,000-US\$ 14,000) is provided each year.

Appointments may start as early as March 1, 2012. The initial appointment will be for two years with a possibility of

renewal for two additional years. Those interested are encouraged to contact a faculty member in their research areas at: <http://www.kias.re.kr/en/about/members.jsp>. Also, for more information please visit http://www.kias.re.kr/en/notice/job_opportunity.jsp. Applicants should send a cover letter specifying the research area, a curriculum vita with a list of publications, and a summary of research plan, and arrange for three recommendation letters to be sent to:

School of Mathematics
 Mr. Kang Won Lee (kwlee@kias.re.kr)
 KIAS, 207-43 Cheongnyangni-dong
 Dongdaemun-gu, Seoul, 130-722,
 Korea

Email applications are strongly encouraged. We review the applications twice a year; the deadlines are June 30 and December 31.

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SINGAPORE

NATIONAL UNIVERSITY OF SINGAPORE
(NUS)
Department of Mathematics

The Department of Mathematics at the National University of Singapore (NUS) invites applications for tenured, tenure-track and visiting positions at all levels, beginning in August 2012.

NUS is a research-intensive university that provides quality undergraduate and graduate education. The Department of Mathematics has about 65 faculty members and teaching staff whose expertise cover major areas of contemporary mathematical research.

We seek promising scholars and established mathematicians with outstanding track records in any field of pure and applied mathematics. The department, housed in a newly renovated building equipped with state-of-the-art facilities, offers internationally competitive salary with start-up research grants, as well as an environment conducive to active research, with ample opportunities for career development. The teaching load for junior faculty is kept especially light.

The department is particularly interested in, but not restricted to, considering applicants specializing in any of the following areas:

Analysis, Probability, and Ergodic Theory
 Number Theory, Arithmetic Geometry
 Computational Science, including but not restricted to,
 Computational Biology, Medical Imaging, Computational
 Materials Science and Nanoscience
 Financial Mathematics
 Operations Research

Application materials should be sent to the Search Committee via email (as PDF

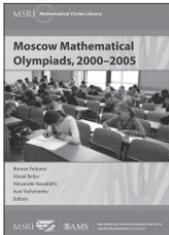
MSRI Mathematical Circles Library

Mathematical Circles are gatherings of motivated students and teachers looking for new challenges in mathematics as well as a deeper understanding of the subject. While solving problems is emphasized, the circles also pay considerable attention to mathematical ideas and techniques.

This book series is designed as a resource for leaders and participants in mathematical clubs and circles. Books may also be of interest to parents and teachers.

Titles in this series are co-published with the Mathematical Sciences Research Institute (MSRI).

Recent releases...



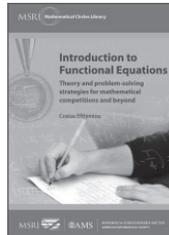
Moscow Mathematical Olympiads, 2000–2005

Roman Fedorov, Alexei Belov, Alexander Kovaldzhii, and Ivan Yashchenko, Editors

The Moscow Mathematical Olympiad has been challenging high-school students with stimulating, original problems of different degrees of difficulty for over 75 years. The problems are nonstandard; solving them takes wit, thinking outside the box, and, sometimes, hours of contemplation. Many mathematically inclined students have found that tackling these problems, or even just reading their solutions, is a great way to develop mathematical insight.

In 2006 the Moscow Center for Continuous Mathematical Education began publishing a collection of problems from the Moscow Mathematical Olympiads, providing for each an answer (and sometimes a hint) as well as one or more detailed solutions. This volume represents the years 2000–2005.

Volume 7; 2011; 176 pages; Softcover; ISBN: 978-0-8218-6906-2; List US\$39; AMS members US\$31.20; Order code MCL/7



Introduction to Functional Equations

Theory and problem-solving strategies for mathematical competitions and beyond

Costas Efthimiou

Functions and their properties have been part of the rigorous precollege curriculum for decades. And functional equations have been a favorite topic of the leading national and international mathematical competitions. Yet the subject has not received equal attention by authors at an introductory level. The majority of the books on the topic remain unreachable to the curious and intelligent precollege student. The present book is an attempt to eliminate this disparity.

Each chapter is complemented with many solved examples, the majority of which are taken from mathematical competitions and professional journals. The book ends with a chapter of unsolved problems and some other auxiliary material.

Volume 6; 2011; 363 pages; Softcover; ISBN: 978-0-8218-5314-6; List US\$52; AMS members US\$41.60; Order code MCL/6

Additional books in this series...

Math from Three to Seven

The Story of a Mathematical Circle for Preschoolers

Alexander Zvonkin

Volume 5; 2011; 300 pages; Softcover; ISBN: 978-0-8218-6873-7; List US\$49; AMS members US\$39.20; Order code MCL/5

Moscow Mathematical Olympiads, 1993–1999

Roman Fedorov, Alexei Belov, Alexander Kovaldzhii, and Ivan Yashchenko, Editors

Volume 4; 2011; 220 pages; Softcover; ISBN: 978-0-8218-5363-4; List US\$39; AMS members US\$31.20; Order code MCL/4

Geometry

A Guide for Teachers

Judith D. Sally and Paul J. Sally, Jr.

Volume 3; 2011; 202 pages; Softcover; ISBN: 978-0-8218-5362-7; List US\$39; AMS members US\$31.20; Order code MCL/3

Circle in a Box

Sam Vandervelde

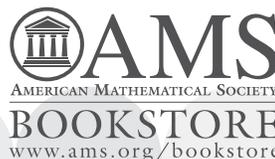
Volume 2; 2009; 217 pages; Softcover; ISBN: 978-0-8218-4752-7; List US\$39; AMS members US\$31.20; Order code MCL/2

A Decade of the Berkeley Math Circle

The American Experience, Volume I

Zvezdelina Stankova and Tom Rike, Editors

Volume 1; 2008; 326 pages; Softcover; ISBN: 978-0-8218-4683-4; List US\$49; AMS members US\$39.20; Order code MCL/1



To order, visit www.ams.org/bookstore/mclseries

Classified Advertisements

files): <http://search@math.nus.edu.sg>.

Please include the following supporting documentation in the application:

1. an American Mathematical Society Standard Cover Sheet;
2. a detailed CV including publications list;
3. a statement (max. of 3 pages) of research accomplishments and plan;
4. a statement (max. of 2 pages) of teaching philosophy and methodology. Please attach evaluation on teaching from faculty members or students of your current institution, where applicable;
5. at least three letters of recommendation including one which indicates the candidate's effectiveness and commitment in teaching. Please ask your referees to send their letters directly to: search@math.nus.edu.sg

Enquiries may also be sent to this email address. Review process will begin on 15 October, and will continue until positions are filled.

For further information about the department, please visit <http://www.math.nus.edu.sg>.

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NEW PUBLICATIONS

BOOKS AND A JOURNAL FROM SAMPLING PUBLISHING

Sampling Publishing announces the publication this year of 1. "Introduction to Wavelets" by Abdul J. Jerri, and its accompanying Student's Solutions Manual, and 2. "Advances in the Gibbs Phenomenon", Abdul J. Jerri, Editor.

It also announces "Introduction to Integral Equations with Applications", by Abdul J. Jerri and its accompanying Student's Solutions Manual.

There is also the journal "Sampling Theory in Signal and Image Processing", which is in its tenth volume.

For more information, please visit <http://www.stsip.org>. See "Published books", or contact Sampling Publishing, 73 Leroy Street, Potsdam, NY 13676; email: bethat@yahoo.com.

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Mathematical Sciences Employment Center

*Hynes Convention Center, Boston, Massachusetts
January 4–7, 2012*

The Employment Center offers a convenient, safe, and practical meeting place for employers and applicants attending the Joint Meetings. The focus of the Employment Center is on Ph.D.-level mathematical scientists and those that seek to hire them from academia, business, and government.

Employment Center Web Services

New this year, the Employment Center information will be accessed through the Mathjobs.org system. For those who do not have existing Mathjobs.org accounts, it will be possible to set up special Employment Center accounts on Mathjobs.org. The website and all information will be available beginning in early October 2011, and will remain accessible through the period of the Employment Center. While some schools may delay appointment-setting until late December, virtually all scheduling will be done before travel takes place, so applicants should expect few or no further appointments after arrival. Registering on site, for applicants, serves no real purpose.

There will be no printed books or paper forms. Also, there will be no paper message center since the new electronic system allows for interview arrangements. Computer scheduling is no longer provided at the Employment Center.

No Admittance Without a JMM Badge

All applicants and employers planning to enter the Employment Center—even just for one interview—must present a 2012 Joint Meeting Registration badge or they will be denied admittance. This is not a new policy, but it is now strictly enforced. Meeting badges are obtained by registering for the Joint Mathematics Meetings and paying a meeting registration fee. See the JMM website at: http://jointmathematicsmeetings.org/meetings/national/jmm2012/2138_intro for registration instructions and rates.

Employers: Choose a Table

There are two table types available for employers, based on the number of interviewers who will be present at any one time:

- one or two interviewers per table in the “Quiet Area” (US\$285), additional table (US\$110).

- three to six interviewers per table in the “Committee Table” area (US\$365), additional table (US\$110).

• All Employment Center information is now housed on the Mathjobs.org site. An existing account can be used for accessing Employment Center services and paying appropriate fees, or if no account exists, participants can start an account solely for Employment Center use.

Please note, individual registration for the JMM is also required for all interviews and no admittance is possible without a JMM badge.

2012 Employment Center Schedule:

November 15, 2011—Suggested deadline for electronic forms submission to allow for advanced scheduling.

December 15, 2011—Advance registration deadline for JMM. Meeting badge will be required for admittance. After this date, meeting registration fees go up and meeting registration may only happen on site in Boston.

OPEN HOURS (NO access before opening time):

Wednesday, January 4, 2012—8:00 a.m.–6:00 p.m.

Thursday, January 5, 2012—8:00 a.m.–6:00 p.m.

Friday, January 6, 2012—8:00 a.m.–6:00 p.m.

Saturday, January 7, 2012—9:00 a.m.–12:00 noon.

Location: Exhibit Hall C, Hynes Convention Center, 900 Boylston St., Boston, Massachusetts

Do not schedule an interview to begin until 15 minutes after opening.

Note: When deciding on travel dates, keep in mind that employers may wish to conduct interviews on any of the days listed above.



Employers: How to Register

- Registration runs from early October 2011 through January 4, 2012, at the following website: www.Mathjobs.org. The suggested deadline is November 15 if possible.
- Use your existing Mathjobs.org account or create a new Employer account at Mathjobs.org. Once a table is reserved, the ad can be placed at any time (or never) and will run until late January.

- Each person who will need to enter the Employment Center area must have a meeting badge (obtained by registering for the JMM and paying a meeting registration fee).

Once registered, employers will gain access to applicant data as it is submitted to the site. There will be applicant resumes on the site, but employers will want to notice especially the resumes marked "Employment Center" (EC logo). There is no automated scheduling system in Mathjobs.org, so participants will be making their own arrangements privately.

To display an ad on site, and use no Employment Center services at all, submit your one-page paper ad on site in Boston to the Employment Center staff. There is no fee for this service.

For complete information, visit <http://www.ams.org/emp-reg/>.

Applicants: Making the Decision to Attend

- The Employment Center offers no guarantees of interviews or jobs. Hiring decisions are not made during or immediately following interviews. In the current job market, the ratio of applicants to employers is about 10:1, and many applicants go completely unnoticed.

- There will ordinarily be no research-oriented post-doctoral positions listed or discussed at the Employment Center.

- Interviews will go to applicants who applied to jobs during the fall and are now being sought out by the institutions for in-person meetings during the JMM.

- There will be no opportunity to speak to employers without a pre-arranged interview, and no walk-up job information tables.

In the current job market, the majority of Employment Center employers are academic departments of mathematical sciences seeking to meet a short list of applicants who applied for their open positions during the fall. Each year,

a few government or industry employers are present. Often, they are seeking U.S. citizens only due to existing contracts.

All job postings and resumes are available on the website in advance, and now that this electronic service is in place, there is no other messaging conducted on paper.

Past attendees have pointed out that all interviews are arranged in advance, and there is no opportunity to make connections on site if it has not happened before the meeting.

In a recent survey, fifty percent of applicants responding reported being invited for at least one on-campus visit to an employer they had interviewed with at the Employment Center. Please visit the Employment Center website for further advice, information, and program updates at www.ams.org/emp-reg/.

Applicants: How to Register

- Early registration is vital since most employers will finalize schedules before arriving in Boston.

- Register for the JMM by completing a meeting registration form and paying a meeting registration fee. No admittance without a meeting badge.

- Create an Applicant account on the Employment Center by using your Mathjobs.org account. Review job ads with the "EC" logo, upload documents, and apply for jobs.

There are no Employment Center fees for applicants; however, admission to the Employment Center room requires a 2012 JMM badge, obtainable by registering (and paying a fee) for the Joint Mathematics Meetings. To register for the meeting, go to http://jointmathematicsm meetings.org/meetings/national/jmm2012/2138_intro.

It is possible to attend one or more privately arranged interviews without official Employment Center registration, however, a meeting badge is required to access the interview room.

For complete information, visit <http://www.ams.org/emp-reg/>.

Questions about the Employment Center registration and participation can be directed to Steve Ferrucci, AMS Membership and Programs Department, at 800-321-4267, ext. 4113, or by e-mail to emp-info@ams.org.

AMS Short Courses in Boston, MA

2012 AMS Short Courses

Two Short Course proposals have been selected for presentation just before the Joint Mathematics Meetings begin. These Short Courses will take place on January 2 and 3, 2012 (Monday and Tuesday), Sheraton Boston. Topics will be *Random Fields and Random Geometry and Computing with Elliptic Curves using Sage*.

The cost to participate is the same for both courses. Advance registration fees are: member of the AMS or MAA, US\$102; nonmembers are US\$145; students, unemployed, or emeritus are US\$50. These fees are in effect until December 15. If you choose to register at the meeting, the fees are US\$136 for members of the AMS or MAA, US\$175 for nonmembers, and US\$71 for students, unemployed, or emeritus. Advance registration will begin on September 1, 2011. Onsite registration will take place on Monday, January 2, 2012, 8:00 a.m.–noon, Back Bay Ballroom D, Sheraton.

Random Fields and Random Geometry

Location: Back Bay Ballroom A, 2nd Floor, Sheraton
Organizer: Robert Adler, Technion–Israel Institute of Technology
Moderator: Jonathan Taylor, Stanford University

Introduction

The main theme of the lectures will be to describe the geometric aspects of smooth Gaussian and related random processes over parameter spaces of dimension 2 and higher. The study of such processes—known as random fields—has seen significant theoretical advances over the past decade. While these developments have occurred primarily with the framework of Probability and Stochastic Geometry, the new results and techniques are feeding ideas back into the mathematical world of topology and are finding new applications in areas which have traditionally used random fields as stochastic models. Among these are:

1. Physical oceanography: Here the random field is typically water pressure or surface temperature, and interest lies in spatio-temporal pattern analysis.
2. Cosmology: This includes the analysis of COBE and WMAP microwave data as well as galactic density data. The main applications of random field theory here lie in the analysis of patterns in the data in order to differentiate between competing cosmological theories.

3. Theoretical physics: In quantum chaos random planar waves replace deterministic (but unobtainable) solutions of Schrödinger equations, with primary interest centered on the behavior of nodal lines. In spin glasses random fields are a basic tool in modeling low energy states and can be used to study replica symmetry breaking.

4. Medical imaging: This application is one of the most developed. Here random field geometry is used as a statistical tool for establishing (or refuting) hypotheses of relations between physical or intellectual activity and brain morphology.

The lectures and tutorials of this short course will be designed to give a broad introduction to the modern theory of smooth random fields as well as describing some of its more exciting and important applications.

Lectures

We have the following confirmed speakers with preliminary titles and abstracts for their talks.

Gaussian Fields and Kac-Rice formulae

Robert Adler, Technion

In the first half of his lecture Adler will give a general introduction to the modern theory of Gaussian and Gaussian related random fields, describing their construction and basic sample path properties. In the second half, he will discuss various versions of the Kac-Rice formula, which allows the computation of moments of many point set random variables generated by (not necessarily) Gaussian fields. These formulae will appear, in one form or another, in most of the other lectures.

The Gaussian kinematic formula

Jonathan Taylor, Stanford

Taylor will review some concepts from integral geometry, focusing on kinematic formulae and tube formulae on Euclidean space and the sphere. The key quantities involved are integral geometric invariants known as curvature measures. These quantities, along with some Gaussian analogues, appear in the Gaussian Kinematic Formula (GKF) which describes average integral geometric quantities of paths of smooth Gaussian random fields.

Random matrices and Gaussian analytic functions

Balint Virag, Toronto

Virag will discuss Gaussian analytic functions and their zero sets, as well as their relationship to random matrix

eigenvalues. This will include describing phenomena such as the local repulsion of zeros, laws of large numbers and central limit theorems. Probabilistic aspects of these processes will be emphasized.

Gaussian models in fMRI image analysis

Jonathan Taylor, Stanford

In this lecture Taylor will review the application of some of the results of smooth random fields to medical image analysis, particularly functional MRI (fMRI). The main mathematical tool is the expected Euler characteristic heuristic, which links a geometric quantity (the Euler characteristic) to the distribution of the maximum of a smooth random field. Time permitting, other applications, such as approximations to the size of the largest component of an excursion set, will also be considered.

Random fields in physics

Mark Dennis, Bristol

Dennis will describe uses of random field theory in areas of physics including quantum chaos, statistical optics, cosmology and quantum turbulence. In all of these cases, the topology of the nodes (preimages of zero) play an important role in understanding the physics behind the random geometry. Particular focus will be placed on open problems in statistical topology, such as the distribution of knot types in zeros of Gaussian random functions from 3-space to the complex plane.

Random metrics

Dmitry Jakobson, Montreal

Jakobson will discuss two models of random Riemannian metrics on compact manifolds: random metrics in a fixed conformal class (with applications to the study of scalar curvature) and, more generally, all metrics on a given manifold. From a technical point of view, this amounts to introducing Gaussian measures on appropriate spaces of metrics. He will describe connections to conformal field theory, quantum gravity, random wave model in quantum chaos, and the theory of Gaussian random fields on manifolds.

Schedule

It is planned that each lecture will be 75 minutes long. There will be two lectures each morning and one following lunch. On the first day the remainder of the afternoon will be devoted to tutorial sessions aimed at getting hands-on experience with the basic results of Gaussian random field theory. On the second day there will be discussion groups on each of the application areas treated in the main lectures.

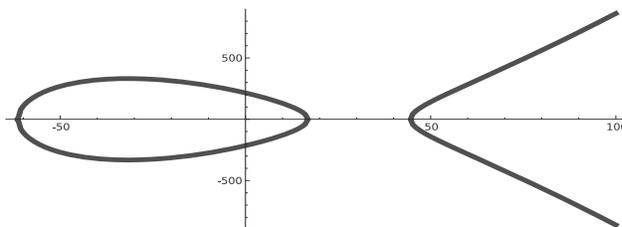
Computing with Elliptic Curves Using Sage

Location: Back Bay Ballroom B, 2nd Floor, Sheraton
Organizer: William Stein, University of Washington

Introduction

This short course will explore computing with elliptic curves using the free open source mathematical software

system Sage. Half of the lectures will be accessible to a general mathematical audience with little prior exposure to elliptic curves, and will provide a good way for mathematicians to learn about Sage in the context of strikingly beautiful mathematics.



An elliptic curve is a curve defined by a cubic equation of the form

$$y^2 = x^3 + Ax + B$$

in two variables x and y . The extent to which elliptic curves play a central role in both pure and applied modern number theory is astounding. Deep problems in number theory such as the *congruent number problem*—which integers are the area of a right triangle with rational side lengths?—translate naturally into questions about elliptic curves. Other questions, such as the famous unsolved *Birch and Swinnerton-Dyer conjecture*, propose startling relationships between algebra and analysis. Elliptic curves also play a starring role in Andrew Wiles's proof of *Fermat's Last Theorem* by arising naturally from any counterexample to the assertion. In a more applied direction, the abelian groups attached to elliptic curves over finite fields are extremely advantageous in the construction of public-key cryptosystems. In particular, elliptic curves are widely believed to provide good security with small key sizes, which is useful in applications—if we are going to print an encryption key on a postage stamp, it is helpful if the key is short!

Sage (see <http://sagemath.org>) is a free open-source mathematics software system licensed under the GNU Public License. It has extensive capabilities for computing with elliptic curves. Sage is built out of around 100 open-source packages and features a unified interface. Sage can be used to study elementary and advanced, pure and applied mathematics. This includes a huge range of mathematics, including basic algebra, calculus, elementary to advanced number theory, cryptography, numerical computation, commutative algebra, group theory, combinatorics, graph theory, exact linear algebra and much more. It combines various software packages and seamlessly integrates their functionality into a common experience. It is well suited for education and research. The user interface is a notebook in a Web browser or the command line. Using the notebook, Sage connects either locally to your own Sage installation or to a Sage server on the network. Inside the Sage notebook you can create embedded graphics, beautifully typeset mathematical expressions, add and delete input, and share your work across the network.

Topics covered in the course may include:

1. How to program Sage using Python.
2. How to use databases of elliptic curves with Sage.

3. How to construct and work with public-key cryptosystems using elliptic curves over finite fields. How to count points on elliptic curves over finite fields.
4. How to compute quantities appearing in the Birch and Swinnerton-Dyer conjecture: torsion points, Tamagawa numbers, Mordell-Weil groups, L -series, etc.
5. How to compute p -adic L -series and p -adic regulators, and use them to bound Shafarevich-Tate groups.

Lectures

1. Introduction to Python and Sage

Kiran Kedlaya, UC San Diego

Kedlaya will give an overview of how to use Sage using the Python programming language. No prior knowledge of Python or Sage will be assumed.

2. Computing with elliptic curves over finite fields using Sage

Ken Ribet, UC Berkeley

Ribet will explain how to use Sage to perform the sort of computations with elliptic curves over finite fields that are needed to follow along with a cryptography book and do exercises that involve long computations.

3. Computing with elliptic surfaces

Noam Elkies, Harvard University

Elkies's lectures will link some of the same arithmetical ideas that appear in the other lectures with other mathematical topics including algebraic geometry of surfaces, Euclidean and hyperbolic lattices, etc., that either are already or should be in Sage. This topic will also touch on elliptic curves of high rank, since every rank record is obtained by specialization from an elliptic surface (or possibly an elliptic curve over \mathbf{P}^n for some $n > 1$).

4. Computing with Shafarevich-Tate Groups using Sage

Jared Weinstein, Boston University

The Shafarevich-Tate group is the most mysterious invariant attached to an elliptic curve. Weinstein will explain how to use Sage to compute information about Shafarevich-Tate groups. His talk may touch on work of Heegner, Kolvyagin, Kato, Schneider, Mazur, and others.

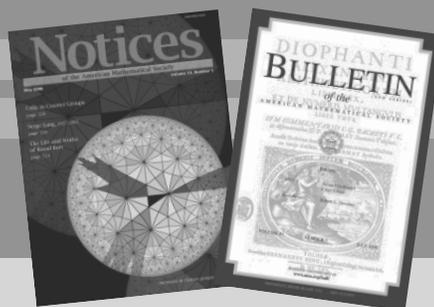
5. Using Sage to explore the Birch and Swinnerton-Dyer conjecture

William Stein, University of Washington

Stein will introduce the Birch and Swinnerton-Dyer conjecture via the congruent number problem. He will then discuss how to use Sage to compute Mordell-Weil groups, values of L -functions, regulators, heights, and Tamagawa numbers. He will also talk about computing the Birch and Swinnerton-Dyer invariants for various tables of elliptic curves.



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Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices*. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See <http://www.ams.org/meetings/>. Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL and in an electronic issue of the *Notices* as noted below for each meeting.

Winston-Salem, North Carolina

Wake Forest University

September 24–25, 2011

Saturday – Sunday

Meeting #1073

Southeastern Section

Associate secretary: Matthew Miller

Announcement issue of *Notices*: June 2011

Program first available on AMS website: August 11, 2011

Program issue of electronic *Notices*: September 2011

Issue of *Abstracts*: Volume 32, Issue 4

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired

For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Benjamin B. Brubaker, Massachusetts Institute of Technology, *Square ice, symmetric functions, and their connections to automorphic forms.*

Shelly Harvey, Rice University, *4-dimensional equivalence relations on knots.*

Allen Knutson, Cornell University, *Modern developments in Schubert calculus.*

Seth M. Sullivan, North Carolina State University, *Algebraic statistics.*

Special Sessions

Algebraic and Geometric Aspects of Matroids, **Hoda Bidkhor**, **Alex Fink**, and **Seth Sullivan**, North Carolina State University.

Applications of Difference and Differential Equations to Biology, **Anna Mummert**, Marshall University, and **Richard C. Schugart**, Western Kentucky University.

Combinatorial Algebraic Geometry, **W. Frank Moore**, Wake Forest University and Cornell University, and **Allen Knutson**, Cornell University.

Extremal Combinatorics, **Tao Jiang**, Miami University, and **Linyuan Lu**, University of South Carolina.

Geometric Knot Theory and its Applications, **Yuanan Diao**, University of North Carolina at Charlotte, **Jason Parsley**, Wake Forest University, and **Eric Rawdon**, University of St. Thomas.

Low-Dimensional Topology and Geometry, **Shelly Harvey**, Rice University, and **John Etnyre**, Georgia Institute of Technology.

Modular Forms, Elliptic Curves, and Related Topics, **Matthew Boylan**, University of South Carolina, and **Jeremy Rouse**, Wake Forest University.

New Developments in Graph Theory, **Joshua Cooper** and **Kevin Milans**, University of South Carolina, and **Carlos**

Nicolas and **Clifford Smyth**, University of North Carolina at Greensboro.

Noncommutative Algebra, **Ellen E. Kirkman** and **James J. Kuzmanovich**, Wake Forest University.

Nonlinear Boundary Value Problems, **Maya Chhetri**, University of North Carolina at Greensboro, and **Stephen B. Robinson**, Wake Forest University.

Nonlinear Dispersive Equations, **Sarah Raynor**, Wake Forest University, **Jeremy Marzuola**, University of North Carolina at Chapel Hill, and **Gideon Simpson**, University of Toronto.

Recent Advances in Infectious Disease Modeling, **Fred Chen** and **Miaohua Jiang**, Wake Forest University.

Set Theoretic Topology, **Peter Nyikos**, University of South Carolina.

Symmetric Functions, Symmetric Group Characters, and Their Generalizations, **Sarah Mason**, Wake Forest University, **Aaron Lauve**, Loyola University-Chicago, and **Ed Allen**, Wake Forest University.

Lincoln, Nebraska

University of Nebraska-Lincoln

October 14–16, 2011

Friday – Sunday

Meeting #1074

Central Section

Associate secretary: Georgia Benkart

Announcement issue of *Notices*: August 2011

Program first available on AMS website: September 1, 2011

Program issue of electronic *Notices*: October 2011

Issue of *Abstracts*: Volume 32, Issue 4

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired

For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtg/sectional.html.

Invited Addresses

Lewis P. Bowen, Texas A&M University, *Entropy theory for actions of sofic groups*.

Emmanuel Candes, Stanford University, *Recovering the unseen: Some recent advances in low-rank matrix reconstruction* (Erdős Memorial Lecture).

Alina Cojocaru, University of Illinois at Chicago and Mathematics Institute of the Romanian Academy, *Questions about the reductions modulo primes of an elliptic curve*.

Michael Zieve, University of Michigan, *The happy marriage between arithmetic geometry and dynamical systems*.

Special Sessions

Algebraic Geometry and Graded Commutative Algebra, **Susan Cooper** and **Brian Harbourne**, University of Nebraska-Lincoln.

Algorithmic and Geometric Properties of Groups and Semigroups, **Susan Hermiller** and **John Meakin**, University of Nebraska-Lincoln.

Association Schemes and Related Topics, **Sung Y. Song**, Iowa State University, and **Paul Terwilliger**, University of Wisconsin Madison.

Asymptotic Behavior and Regularity for Nonlinear Evolution Equations, **Petronela Radu** and **Lorena Bociu**, University of Nebraska-Lincoln.

Coding Theory, **Christine Kelley** and **Judy Walker**, University of Nebraska-Lincoln.

Commutative Algebra, **Christina Eubanks-Turner**, University of Louisiana at Lafayette, and **Aihua Li**, Montclair State University.

Computational and Applied Mathematics, **Ludwig Kohaupt**, Beuth University of Technology Berlin, Germany, and **Yan Wu**, Georgia Southern University.

Continuous and Numerical Analysis in the Control of PDE's, **George Avalos**, **Mohammad Rammaha**, and **Daniel Toundykov**, University of Nebraska-Lincoln.

Discrete Methods and Models in Biomathematics, **Dora Matache** and **Jim Rogers**, University of Nebraska-Omaha, and **Alan Veliz-Cuba**, University of Nebraska-Lincoln.

Dynamic Systems on Time Scales with Applications, **Lynn Erbe** and **Allan Peterson**, University of Nebraska-Lincoln.

Dynamical Systems and Operator Algebras, **Lewis Bowen**, Texas A&M University, and **David Kerr**, Texas A&M University at Galveston.

Extremal and Probabilistic Combinatorics, **Stephen Hartke** and **Jamie Radcliffe**, University of Nebraska-Lincoln.

Invariants in Knot Theory and Low-dimensional Topology, **Mark Brittenham**, University of Nebraska-Lincoln, and **Robert Todd**, University of Nebraska-Omaha.

Local Commutative Algebra, **H. Ananthnarayan**, University of Nebraska-Lincoln, **Inês B. Henriques**, University of California Riverside, and **Hamid Rahmati**, Syracuse University.

Matrices and Graphs, **In-Jae Kim**, Minnesota State University, **Adam Berliner**, St. Olaf College, **Leslie Hogben**, Iowa State University, and **Bryan Shader**, University of Wyoming.

Quantum Groups and Representation Theory, **Jonathan Kujawa**, University of Oklahoma, and **Natasha Rozhkovskaya**, Kansas State University.

Recent Directions in Number Theory, **Alina Cojocaru**, University of Illinois at Chicago, and **Michael Zieve**, University of Michigan.

Recent Progress in Operator Algebras, **Allan P. Donsig** and **David R. Pitts**, University of Nebraska-Lincoln.

Salt Lake City, Utah

University of Utah

October 22–23, 2011

Saturday – Sunday

Meeting #1075

Western Section

Associate secretary: Michel L. Lapidus

Announcement issue of *Notices*: August 2011

Program first available on AMS website: September 8, 2011

Program issue of electronic *Notices*: October 2011

Issue of *Abstracts*: Volume 32, Issue 4

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired

For abstracts: Expired

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Graeme Milton, University of Utah, *Metamaterials: High contrast composites with unusual properties.*

Lei Ni, University of California San Diego, *Gap theorems on Kähler manifolds.*

Igor Pak, University of California Los Angeles, *The future of combinatorial bijections.*

Monica Visan, University of California Los Angeles, *Dispersive partial differential equations at critical regularity.*

Special Sessions

Algebraic Geometry, **Tommaso de Fernex** and **Christopher Hacon**, University of Utah.

Applied Analysis, **Marian Bocea**, North Dakota State University, and **Mihai Mihăilescu**, University of Craiova Romania.

Category Theory in Graphs, Geometry and Inverse Problems, **Robert Owczyński**, Enfitec. Inc., and **Hanna Makaruk**, Los Alamos National Laboratory NM.

Celestial and Geometric Mechanics, **Lennard Bakker** and **Tiancheng Ouyang**, Brigham Young University.

Commutative Algebra, **Chin-Yi Jean Chan**, Central Michigan University, and **Lance E. Miller** and **Anurag K. Singh**, University of Utah.

Computational and Algorithmic Algebraic Geometry, **Zach Teitler**, Boise State University, and **Jim Wolper**, Idaho State University.

Electromagnetic Wave Propagation in Complex and Random Environments, **David Dobson**, University of Utah, and **Peijun Li**, Purdue University.

Geometric Evolution Equations and Related Topics, **Andrius Treibergs**, University of Utah Salt Lake City, **Lei Ni**, University of California San Diego, and **Brett Kotschwar**, Arizona State University.

Geometric, Combinatorial, and Computational Group Theory, **Eric Freden**, Southern Utah University, and **Eric Swenson**, Brigham Young University.

Harmonic Analysis and Dispersive Partial Differential Equations, **Xiaoyi Zhang**, University of Iowa, and **Monica Visan** and **Betsy Stovall**, University of California Los Angeles.

Hypergeometric Functions and Differential Equations, **Laura F. Matusevich**, Texas A&M University, and **Christine Berkesch**, Stockholm University.

Inverse Problems and Homogenization, **Elena Cherkaev** and **Fernando Guevara Vasquez**, University of Utah.

Noncommutative Geometry and Algebra, **Kenneth R. Goodearl**, University of California Santa Barbara, and **Milen Yakimov**, Louisiana State University.

Nonlinear Waves, **Zhi-Qiang Wang** and **Nghiem Nguyen**, Utah State University.

Recent Progress in Numerical Partial Differential Equations, **Jichun Li**, University of Nevada, Las Vegas, and **Shue-Sum Chow**, Brigham Young University.

Reductive Groups and Hecke Algebras, **Dan Ciubotaru**, University of Utah, **Cathy Krilloff**, Idaho State University, and **Peter Trapa**, University of Utah.

Understanding Bio-fluids via Modeling, Simulation and Analysis, **Christel Hohenegger**, University of Utah.

Port Elizabeth, Republic of South Africa

Nelson Mandela Metropolitan University

November 29 – December 3, 2011

Tuesday – Saturday

Meeting #1076

First Joint International Meeting between the AMS and the South African Mathematical Society.

Associate secretary: Matthew Miller

Announcement issue of *Notices*: July 2011

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: Not applicable

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/internmtgs.html.

Invited Addresses

Mark J. Ablowitz, University of Colorado, *Nonlinear systems—from oceans to number theory*.

Zoltan Furedi, University of Illinois, Urbana-Champaign, *Title to be announced*.

Mikhail Petrov, University of Swaziland, *Title to be announced*.

James Raftery, University of Kwazulu Natal, *Title to be announced*.

Daya Reddy, University of Cape Town, *Title to be announced*.

Peter Sarnak, Princeton University, *Mobius randomness and dynamics*.

Lindi Tshabalala, Thuthuzekani Primary School, *Title to be announced*.

Amanda Weltman, University of Cape Town, *Title to be announced*.

Special Sessions

Combinatorial and Computational Group Theory with Applications, **Gilbert Baumslag**, City College of New York, **Mark Berman**, University of Cape Town, and **Vladimir Shpilrain**, City College of New York.

Combinatorics and Graph Theory, **Michael Henning**, University of Johannesburg, **Robin Thomas**, Georgia Institute of Technology, and **Jacques Verstraete**, University of California, San Diego.

Computer Vision, High Performance Computing, and Imaging, **Steve Damelin**, Georgia Southern University and University of the Witwatersrand, and **Hari Kumar**, University of the Witwatersrand.

Finite Groups and Combinatorial Structures, **Jashmid Moori**, North-West University, Mafikeng, and **B. Rodrigues**, University of Kwazulu-Natal, Westville.

Geometry and Differential Equations, **Jesse Ratzkin**, University of Cape Town.

High Performance Computing and Imaging, **Steven B. Damelin**, Georgia Southern University and University of the Witwatersrand, and **Hari Kumar**, University of the Witwatersrand.

Mathematical Inequalities and Applications, **Saver S. Dragomir**, University of Witwatersrand and Victoria University, Australia.

Nonlinear Waves and Integrable Systems, **Mark Ablowitz**, University of Colorado at Boulder, and **Barbara Prinari**, University of Colorado at Colorado Springs.

Operator and Banach Algebras, and Noncommutative Analysis, **David Blecher**, University of Houston, **Garth Dales**, University of Leeds, **Louis Labuschagne**, North-West University, Potchefstroom Campus, and **Anton Stroh**, University of Pretoria.

Recent Advances in Computational Methods for Partial Differential Equations, **Kailash C. Patidar**, University of the Western Cape.

Theoretical and Numerical Aspects of Dynamical Systems, Partial Differential Equations, and Inequalities, Arising in Applications, **J. M.-S. Lubuma**, University of Pretoria, and **B. D. Reddy**, University of Cape Town.

Topology and Categories, **Hans-Peter Kuenzi**, University of Cape Town.

Boston, Massachusetts

John B. Hynes Veterans Memorial Convention Center, Boston Marriott Hotel, and Boston Sheraton Hotel

January 4–7, 2012

Wednesday – Saturday

Meeting #1077

Joint Mathematics Meetings, including the 118th Annual Meeting of the AMS, 95th Annual Meeting of the Mathematical Association of America, 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), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Michel L. Lapidus

Announcement issue of *Notices*: October 2011

Program first available on AMS website: November 1, 2011

Program issue of electronic *Notices*: January 2012

Issue of *Abstracts*: Volume 33, Issue 1

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired

For abstracts: September 22, 2011

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtg/national.html.

Joint Invited Addresses

Erik Demaine, Massachusetts Institute of Technology, *Geometric puzzles: Algorithms and complexity* (AMS-MAA-SIAM Gerald and Judith Porter Public Lecture).

Allen Knutson, Cornell University, *Title to be announced* (AMS-MAA Invited Address).

Hee Oh, Brown University, *Title to be announced* (AMS-MAA Invited Address).

Joint Prize Session

Prize Session and Reception: In order to showcase the achievements of the recipients of various prizes, the AMS and MAA are cosponsoring this event at 4:25 p.m. on Thursday. A cash bar reception will immediately follow. All participants are invited to attend. The AMS, MAA, and SIAM will award the Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student. The AMS will announce the winners of the George David Birkhoff Prize in Applied Mathematics, Frank Nelson Cole Prize for Algebra, Levi L. Conant Prize, Leroy P. Steele Prizes, and the Award for Distinguished Public Service. The MAA will award the Beckenbach Book

Prize, Chauvenet Prize, Euler Book Prize, Yueh-Gin Gung and Dr. Charles Y. Hu Award for Distinguished Service to Mathematics, Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching of Mathematics, and Certificates of Meritorious Service. The AWM will present the Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman, the Louise Hay Award for Contributions to Mathematics Education, and the Gweneth Humphreys Award for Mentorship of Undergraduate Women in Mathematics.

This session will also be the venue for the announcement of the Joint Policy Board for Mathematics Communication Award.

118th Meeting of the AMS

AMS Invited Addresses

George E. Andrews, Penn State University, *Title to be announced* (AMS Retiring Presidential Address).

Bradley Efron, Stanford University, *A 250-year argument: Belief, behavior, and the bootstrap* (AMS Josiah Willard Gibbs Lecture).

Edward Frenkel, University of California Berkeley, *Langlands program, trace formulas, and their geometrization* (AMS Colloquium Lectures).

Larry Guth, University of Toronto, *The polynomial method in combinatorial geometry*.

Assaf Naor, Courant Institute of Mathematical Sciences, *The Ribe program*.

Eric Rains, California Institute of Technology, *Beyond q : Special functions on elliptic curves*.

Wilhelm Schlag, University of Chicago, *Invariant manifolds and dispersive Hamiltonian evolution equations*.

AMS Special Sessions

Some sessions are cosponsored with other organizations. These are noted within the parenthesis at the end of each listing, where applicable.

Advanced Investigations on Applied Optimization and Multiple Fractional Programming (Code: SS 6A), **Ram U. Verma**, Texas A&M University, and **Alexander J. Zaslavski**, Technion, Israel.

Advances in Coding Theory (Code: SS 10A), **Sarah Spence Adams**, Olin College of Engineering, **Gretchen L. Matthews**, Clemson University, and **Judy L. Walker**, University of Nebraska-Lincoln.

Advances in Mathematical Biology (Code: SS 56A), **David Chan** and **Rebecca Segal**, Virginia Commonwealth University.

Algebraic and Geometric Aspects of Integrable Systems and Random Matrices (Code: SS 58A), **Anton Dzhamay**, University of Northern Colorado, and **Kenichi Maruno** and **Virgil Pierce**, University of Texas, Pan American.

Arithmetic Geometry (Code: SS 51A), **Bo-Hae Im**, Chung-Ang University, South Korea, **Jennifer Johnson-Leung**, University of Idaho, and **Jennifer Paulhus**, Grinnell College.

Calculus of Functors and Its Applications (Code: SS 11A), **Brian Munson** and **Ismar Volic**, Wellesley College.

Classical Fourier Analysis and Partial Differential Equations (Code: SS 27A), **William O. Bray**, University of Maine, and **Mark A. Pinsky**, Northwestern University.

Climate Modeling and Geophysical Fluid Dynamics (Code: SS 39A), **Qingshan Chen**, Florida State University, **Nathan Glatt-Holtz**, Indiana University, and **Mickael Chekrour**, University of California, Los Angeles.

Combinatorial Geometry of Polytopes (Code: SS 42A), **Egon Schulte**, Northeastern University, and **Asia Ivic Weiss**, York University.

Computational and Applied Topology (Mathematics Research Communities session) (Code: SS 61A), **Radmila Sazdonovic**, University of Pennsylvania, **Daniel Mueller**, Stanford University, and **Mikael Vejdemo-Johansson**, University of St. Andrews.

Control Theory and Inverse Problems for Partial Differential Equations (Code: SS 18A), **Shitao Liu**, University of Virginia, and **Ting Zhou**, University of California, Irvine.

Control of Biological and Physical Systems (Code: SS 36A), **Wandi Ding**, Middle Tennessee State University, **Volodymyr Hrynkyv**, University of Houston-Downtown, and **Suzanne Lenhart**, University of Tennessee, Knoxville, and NIMBioS.

Difference Equations and Applications (Code: SS 3A), **Michael Radin**, Rochester Institute of Technology.

Differential Algebraic Geometry and Galois Theory (in memory of Jerald Kovacic) (Code: SS 7A), **Phyllis Joan Cassidy**, Smith College and the City University of New York, **Richard Churchill**, Hunter College and Graduate Center at CUNY, **Claude Mitschi**, Université de Strasbourg, France, and **Michael Singer**, North Carolina State University.

Dynamical Systems in Algebraic and Arithmetic Geometry (Code: SS 19A), **Patrick Ingram**, University of Waterloo, Canada, **Michelle Manes**, University of Hawaii, Honolulu, and **Clayton Petsche**, Hunter College (CUNY).

Enumerative and Algebraic Combinatorics (Code: SS 40A), **Ira Gessel**, Brandeis University, and **Alexander Posnikov** and **Richard Stanley**, Massachusetts Institute of Technology.

Fractal Geometry in Pure and Applied Mathematics (in memory of Benoit Mandelbrot) (Code: SS 4A), **Michael L. Lapidus**, University of California, Riverside, **Erin Pearse**, University of Oklahoma, and **Machiel van Frankenhuijsen**, Utah Valley University.

Fractional, Hybrid, and Stochastic Dynamical Systems with Applications (Code: SS 12A), **John Graef**, University of Tennessee at Chattanooga, **Gangaram S. Ladde**, University of South Florida, Tampa, and **Aghala S. Vatsala**, University of Louisiana at Lafayette.

Frontiers in Geomathematics (Code: SS 55A), **Willi Freeden**, University of Kaiserslautern, **Volker Michel**, University of Siegen, and **M. Zuhair Nashed**, University of Central Florida.

Generalized Cohomology Theories in Engineering Practice (Code: SS 37A), **Robert Kotiuga**, Boston University.

Geometric Invariants of Groups and Related Topics (Code: SS 14A), **Nic Koban**, University of Maine, Farmington, and **Peter N. Wong**, Bates College.

Geometry of Real Projective Structures (Mathematics Research Communities session) (Code: SS 60A), **Jeffrey Danciger**, Stanford University, **Kelly Delp**, Buffalo State College, **Sean Lawton**, University of Texas, Pan American, and **Kathryn Mann**, University of Chicago.

Global Dynamics of Rational Difference Equations with Applications (Code: SS 33A), **Mustafa R. S. Kulenovic**, **Gerasimos Ladas**, and **Orlando Merino**, University of Rhode Island.

Groups, Algorithms, Complexity, and Theory of Security (Code: SS 28A), **Maggie Habeeb** and **Delaram Kahrobaei**, City University of New York.

History of Mathematics (Code: SS 65A), **Sloan Despeaux**, Western Carolina University, **Craig Fraser**, University of Toronto, and **Deborah Kent**, Hillsdale College (AMS-MAA).

Homotopy Theory (Code: SS 5A), **Mark Behrens**, Massachusetts Institute of Technology, **Mark W. Johnson**, Pennsylvania State University, Altoona, **Haynes R. Miller**, Massachusetts Institute of Technology, **James Turner**, Calvin College, and **Donald Yau**, Ohio State University.

Hyperbolicity in Manifolds and Groups (Code: SS 25A), **David Futer**, Temple University, and **Genevieve Walsh**, Tufts University.

Life and Legacy of Alan Turing (Code: SS 13A), **Damir Dzhafarov**, University of Chicago and University of Notre Dame, **Jeff Hirst**, Appalachian State University, and **Carl Mummert**, Marshall University (AMS-ASL).

Knot Theory (Code: SS 0A), **Tim Cochran** and **Shelly Harvey**, Rice University.

Linear Algebraic Groups: Their Arithmetic, Geometry, and Representations (Code: SS 49A), **R. Skip Garibaldi**, Emory University, and **George McNinch**, Tufts University.

Local Field Properties, Microstructure, and Multiscale Modeling of Heterogeneous Media (Code: SS 23A), **Silvia Jiménez** and **Bogdan Vernescu**, Worcester Polytechnic Institute.

Mathematical Principles and Theories of Integrable Systems (Code: SS 35A), **Wen-Ziu Ma**, University of South Florida, **Syed Tauseef Mohyud-Din**, HITEC University, and **Zhijun Qiao**, University of Texas, Pan American.

Mathematical Theory of Control of Quantum Systems (Code: SS 38A), **Francesca Albertini**, University of Padua, **Domenico D'Alessandro**, Iowa State University, **Raffaele Romano**, University of Trieste, and **Francesco Ticozzi**, University of Padua.

Mathematics and Education Reform (Code: SS 41A), **William Barker**, Bowdoin College, **William McCallum**, University of Arizona, and **Bonnie Saunders**, University of Illinois at Chicago (AMS-MAA-MER).

Mathematics and Statistics in Computational Biology (Code: SS 52A), **Mark A. Kon**, Boston University.

Mathematics in Industry (Code: SS 34A), **Kirk E. Jordan**, IBM T. J. Watson Research, **Donald Schwendeman**, Rensselaer Polytechnic Institute, and **Burt S. Tilley** and **Suzanne L. Weekes**, Worcester Polytechnic Institute.

Mathematics in Natural Resource Modeling (Code: SS 9A), **Catherine Roberts**, College of the Holy Cross.

Mathematics of Computation: Algebra and Number Theory (Code: SS 16A), **Jean-Marc Couveignes**, Université de Toulouse, **Michael J. Mossinghoff**, Davidson College,

and **Igor E. Shparlinski**, Macquarie University, Australia (AMS-SIAM).

Mathematics of Computation: Differential Equations, Linear Algebra, and Applications (Code: SS 26A), **Chi-Wang Shu**, Brown University (AMS-SIAM).

Mathematics of Decisions, Elections, and Games (Code: SS 57A), **Karl-Dieter Crisman**, Gordon College, **Michael Jones**, *Mathematical Reviews*, and **Michael Orrison**, Harvey Mudd College.

Matrices and Graphs (Code: SS 50A), **Leslie Hogben**, Iowa State University and American Institute of Mathematics, and **Bryan L. Shader**, University of Wyoming.

My Favorite Graph Theory Conjectures (Code: SS 29A), **Ralucca Gera**, Naval Postgraduate School, and **Craig Larson**, Virginia Commonwealth University.

New Perspectives in Multiplicative Number Theory (Mathematics Research Communities session) (Code: SS 62A), **Leo Goldmakher**, University of Toronto, **Jonathan Kish**, University of Colorado at Boulder, **Micah Millinovich**, University of Mississippi, and **Paul Pollack**, University of British Columbia/Simon Fraser University.

Noncommutative Birational Geometry and Cluster Algebras (Code: SS 44A), **Arkady Berenstein**, University of Oregon, and **Vladimir Retakh**, Rutgers University.

Nonlinear Analysis of Partial Differential Equation Models in Biology and Chemical Physics (Code: SS 48A), **Zhonghai Ding**, University of Nevada, Las Vegas, and **Zhaosheng Feng**, University of Texas-Pan American.

Nonlinear Hyperbolic Partial Differential Equations (Code: SS 32A), **Barbara Lee Keyfitz** and **Charis Tsikkou**, Ohio State University (AMS-AWM).

Operator Theory on Analytic Function Spaces (Code: SS 43A), **Robert F. Allen**, University of Wisconsin, La Crosse, and **Katherine C. Heller** and **Matthew A. Pons**, North Central College.

Optimal Control in Applied Mathematical Modeling (Code: SS 45A), **Natali Hritonenko**, Prairie View A&M University, and **Yuri Yatsenko**, Houston Baptist University.

Progress in Free Analysis (Code: SS 46A), **J. William Helton**, University of California, San Diego, and **Paul S. Muhly**, University of Iowa.

Radon Transforms and Geometric Analysis (in honor of Sigurdur Helgason's 85th birthday) (Code: SS 17A), **Jens Christensen**, University of Maryland, and **Fulton Gonzalez** and **Todd Quinto**, Tufts University. A satellite workshop will take place January 8–9 at Tufts University on Geometric Analysis on Euclidean and Homogeneous Spaces; see <http://go.tufts.edu/workshop2012> for details.

Rational Points on Varieties (Code: SS 30A), **Jennifer Balakrishnan** and **Bjorn Poonen**, Massachusetts Institute of Technology, **Bianca Viray**, Brown University, and **Kirsten Wickelgren**, Harvard University.

Reaction Diffusion Equations and Applications (Code: SS 31A), **Jerome Goddard II** and **Shivaji Ratnasingham**, Mississippi State University, and **Junping Shi**, College of William and Mary.

Recent Advances in Mathematical Biology, Ecology, and Epidemiology (Code: SS 21A), **Sophia R. Jang**, Texas Tech University, **Andrew L. Nevai**, University of Central Florida, and **Lih-Ing W. Roeger**, Texas Tech University.

Recent Trends in Graph Theory (Code: SS 24A), **Ralucca Gera**, Naval Postgraduate School.

Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs (Code: SS 66A), **Bernard Brooks** and **Jobby Jacob**, Rochester Institute of Technology, **Jacqueline Jensen**, Sam Houston State University, and **Darren A. Narayan**, Rochester Institute of Technology (AMS-MAA).

Science for Policy and Policy for Science: Career Opportunities at the Intersection of Science and Policy (Code: SS 59A), **Cynthia Robinson** and **Shar Steed**, AAAS Science & Technology Fellowships (AMS-AAAS).

Set-Valued Optimization and Variational Problems (Code: SS 47A), **Andreas H. Hamel**, Yeshiva University, **Akhtar A. Khan**, Rochester Institute of Technology, and **Miguel Sama**, E.T.S.I. Industriales.

Several Complex Variables and Multivariable Operator Theory (Code: SS 8A), **Ronald Douglas**, Texas A&M University, and **John McCarthy**, Washington University.

Some Nonlinear Partial Differential Equations — Theory and Application (Code: SS 54A), **Jerry L. Bona**, University of Illinois, Chicago, and **Laihan Luo**, New York Institute of Technology.

Stability Analysis for Infinite Dimensional Hamiltonian Systems (Code: SS 63A), **Wilhelm Schlag**, University of Chicago, and **Gene Wayne**, Boston University.

Stochastic Analysis (in honor of Hui-Hsiung Kuo) (Code: SS 1A), **Julius Esunge**, University of Mary Washington, and **Aurel Stan**, Ohio State University.

Tensor Categories and Representation Theory (Code: SS 22A), **Deepak Naidu**, Northern Illinois University, and **Dmitri Nikshych**, University of New Hampshire.

Theory and Applications of Stochastic Differential and Partial Differential Equations (Code: SS 15A), **Edward Allen**, Texas Tech University, **Mahmoud Anabtawi**, American University of Sharjah, **Armando Arciniega**, University of Texas at San Antonio, **Gangaram S. Ladde**, University of South Florida, and **Sivapragasam Sathananthan**, Tennessee State University.

Topological Graph Theory: Structure and Symmetry (Code: SS 20A), **Jonathan L. Gross**, Columbia University, and **Thomas W. Tucker**, Colgate University.

Trends in Representation Theory (Code: SS 2A), **Donald King**, Northeastern University, and **Alfred Noel**, University of Massachusetts, Boston.

Uniformly and Partially Hyperbolic Dynamical Systems (Code: SS 53A), **Todd Fisher**, Brigham Young University, and **Boris Hasselblatt**, Tufts University.

AMS Contributed Paper Sessions

There will be sessions of ten-minute contributed talks. Although an individual may present only one contributed paper at a meeting, any combination of joint authorship may be accepted, provided no individual speaks more than once on the program. Contributed papers will be grouped together by related subject classifications into sessions.

Submission of Abstracts for AMS Sessions

Authors must submit abstracts of talks through <http://jointmathematicsmeetings.org/meetings/>

abstracts/abstract.pl?type=jmm. Indicate the number of authors for the paper, click on the “submit” button, and you will be taken to the submission form. Simply follow the step-by-step instructions (read them carefully) until you receive your unique abstract number. No submission is complete until you receive your abstract receipt number. **The deadline for all submissions is September 22, 2011.** Late papers cannot be accommodated. Please email abs-coord@ams.org if you have questions. If you make an inquiry about your specific abstract, please include your abstract number.

Other AMS Sessions

Administrative Strategies for Dealing with Budget Cuts, organized by **Al Boggess**, **Don Allen**, and **Jill Zarrestky**, Texas A&M University; Wednesday, 2:15 p.m.–3:35 p.m. This panel will give chairs of mathematics departments the opportunity to share strategies for dealing with budget cuts. Topics covered include: the effect of increasing class size on student learning, balancing teaching and research, differential teaching loads, the changing role of teaching assistants, the appropriate use of technology as an alternative or supplement to lecture, and the use of electronic textbooks. Our target audience will be public universities that have both teaching and research missions. We will first develop a survey of baseline data regarding responses to current budget cuts well before the meeting. The panel (members to be announced) will begin with a presentation of survey results. This will be followed by a discussion on the above topics with heavy participation by members in the audience. Sponsored by the AMS and the MAA.

Supply, Demand, and the Math Ph.D. Program, Wednesday, 4:30 p.m.–6:00 p.m. Is there an oversupply of Ph.D. mathematicians? What effect should hiring patterns have on Ph.D. programs in term of size, curriculum, or advising? These and other contentious questions will be addressed during this panel discussion with audience participation. Sponsored by the Committee on the Profession.

Conversation on Nonacademic Employment, Thursday, 10:30 a.m.–noon. This session will concentrate on how to find nonacademic positions, types of jobs, the interview process, work environments, and advancement opportunities. The discussion will be led by a panel of mathematical scientists working in government and industry.

Summer Math Camps: The AMS (and Mathematician’s) Role, organized by **Glenn Stevens**, Boston University, and **Irwin Kra**, SUNY at Stony Brook; Thursday, 1:00 p.m.–2:30 p.m. The AMS Epsilon Fund, endowed by contributions from mathematicians, supports summer mathematics camps for mathematically talented high school (including junior high school) students. The Young Scholars Awards Committee (YSAC) is sponsoring this event and allocates roughly US\$100,000 per year to about ten applicants representing about 3% of the total budgets of these summer programs. Panelists **Moon Duchin**, Tufts University, representing the Canada/USA Mathcamp; **Glenn Stevens**, and **Max Warshauer**, Texas State University, representing Texas Mathworks, will give short presentations on their successful programs and discuss the main features,

recruiting and selecting students and faculty/mentors, and budgets and funding. We hope these presentations will generate interest among the mathematical community to get involved in starting and supporting such activities. Ample time will be available for audience participation, including a question and answer period.

Report on the Findings of the 2010 CBMS Survey of Undergraduate Mathematical and Statistical Sciences in the U.S., organized by **Ellen J. Kirkman**, Wake Forest University, and **James W. Maxwell**, AMS; Thursday, 11:15 a.m.–12:15 p.m. A comprehensive survey of undergraduate programs in the mathematical sciences, sponsored by the Conference Board of the Mathematical Sciences, was conducted with funding from the National Science Foundation during fall 2010; a similar survey has been conducted every five years since 1965. The survey requested data including: detailed enrollments, the demographics of majors and faculty, the mathematical preparation of teachers, the major, dual enrollment and distance learning, and how college algebra and elementary statistics are taught. The report will be published in the spring 2012. This presentation will preview the interesting findings of this survey.

Who Wants to Be a Mathematician—National Contest, organized by **Michael A. Breen**, AMS, and **William T. Butterworth**, DePaul University; Friday, 9:30 a.m.–11:00 a.m. See ten of the nation's best high school students compete for a US\$5,000 first prize for themselves and US\$5,000 for their school's math department. Semifinals are at 9:30 a.m. and finals at 10:30 a.m. You are invited to come and take part in this educational and fun presentation.

Current Events Bulletin, organized by **David Eisenbud**, University of California, Berkeley; Friday, 1:00 p.m.–5:00 p.m. Speakers in this session follow the model of the Bourbaki Seminars in that mathematicians with strong expository skills speak on work not their own. Written versions of the talks will be distributed at the meeting and also be available on line at www.ams.org/ams/current-events-bulletin.html after the conclusion of the meeting.

Grad School Fair, Friday, 8:30 a.m.–10:30 a.m. Here is the opportunity for undergrads to meet representatives from mathematical sciences graduate programs from universities all over the country. January is a great time for juniors to learn more, and college seniors may still be able to refine their search. This is your chance for one-stop shopping in the graduate school market. At last year's meeting about 300 students met with representatives from 50 graduate programs. If your school has a graduate program and you are interested in participating, a table will be provided for your posters and printed materials for US\$65 (registration for this event must be made by a person already registered for the JMM), and you are welcome to personally speak to interested students. Complimentary coffee will be served. Cosponsored by the AMS and MAA.

The Changing Landscape of Research Funding, organized by **David Manderscheid**, University of Nebraska-Lincoln; Friday, 2:30 p.m.–4:00 p.m. Sponsored by the Committee on Science Policy.

Congressional Fellowship Session, organized by **Samuel M. Rankin III**, AMS; Friday, 4:30 p.m.–6:30 p.m. Learn

about this program and speak with current and former AMS Fellows. The application deadline for the 2012–13 AMS Congressional Fellowship is February 15, 2012.

Models for Engaging Undergraduate Students in Research, moderated by **David Damiano**, College of the Holy Cross. This panel of faculty and students, including **Dean M. Evasius**, NSF; **Joseph Gallian**, University of Minnesota-Duluth; **Steven J. Miller**, Williams College; **Ivelisse Rubio**, University of Puerto Rico, Rio Piedras; and others, will discuss various types of research experience available to undergraduates. Sponsored by the Committee on Education.

Other AMS Events

Council: Tuesday, 1:30 p.m.

Business Meeting: Saturday, 11:45 a.m. The secretary notes the following resolution of the Council: Each person who attends a business meeting of the Society shall be willing and able to identify himself as a member of the Society. In further explanation, it is noted that each person who is to vote at a meeting is thereby identifying himself as and claiming to be a member of the American Mathematical Society. The Society has a Committee on the Agenda for Business Meetings. The purpose is to make business meetings orderly and effective. The committee does not have legal or administrative power. It is intended that the committee consider what may be called "quasipolitical" motions. The committee has several possible courses of action on a proposed motion, including but not restricted to:

- (a) doing nothing,
- (b) conferring with supporters and opponents to arrive at a mutually accepted amended version to be circulated in advance of the meeting,
- (c) recommending and planning a format for debate to suggest to a business meeting,
- (d) recommending referral to a committee, and
- (e) recommending debate followed by referral to a committee.

There is no mechanism that requires automatic submission of a motion to the committee. However, if a motion has not been submitted through the committee, it may be thought reasonable by a business meeting to refer it rather than to act on it without benefit of the advice of the committee.

In order that a motion for this business meeting receive the service offered by the committee in the most effective manner, it should be in the hands of the AMS Secretary by **December 7, 2011**.

AMS Short Courses

There will be two, two-day Short Courses which will take place on Monday and Tuesday, January 2 and 3, before the meeting actually begins. Titles and organizers are *Random Fields and Random Geometry*, organized by **Robert Adler**, Technion–Israel Institute of Technology, and **Jonathan Taylor**, Stanford University; and *Computing with Elliptic Curves Using Sage*, organized by **William Stein**, University of Washington. There are separate registration fees to participate in these courses. See the complete article

beginning on page 1345 of this issue or at <http://www.ams.org/meetings/short-courses/short-course-general>.

Department Chairs Workshop

This annual one-day workshop for chairs and leaders of departments of mathematical sciences will be held a day before the start of the Joint Meetings on Tuesday, January 3, 8:00 a.m.–6:30 p.m. The workshop format is intended to stimulate discussion among attending chairs and workshop leaders. Sharing ideas and experiences with peers provides a form of department chair therapy, creating an environment that enables attending chairs to address departmental matters from new perspectives.

Past workshop sessions have focused on a range of issues facing departments today, including personnel issues (staff and faculty), long-range planning, hiring, promotion and tenure, budget management, assessments, outreach, stewardship, junior faculty development, communication, and departmental leadership.

There is a separate registration fee to participate. For further information please contact the AMS Washington Office at 202-588-1100 or amsdc@ams.org.

95th Meeting of the MAA

MAA Invited Addresses

Jennifer Quinn, University of Washington Tacoma, *Mathematics to DIE for: The battle between counting and matching*; 2:15 p.m. on Wednesday.

Seth M. Sullivant, North Carolina State University, *Phylogenetic algebraic geometry*; 3:20 p.m. on Wednesday.

Carolyn S. Gordon, Dartmouth College, *The sound of geometry*; 9:00 a.m. on Thursday.

Rekha R. Thomas, University of Washington, *Sum of squares polynomials in optimization*; 9:00 a.m. on Friday.

Mary Lou Zeeman, Bowdoin College, *Mathematical challenges in climate and sustainability*; 10:05 a.m. on Saturday.

Presentations by Teaching Award Recipients

Friday, 2:30 p.m.–3:50 p.m., organized by MAA Secretary **Barbara J. Faires**, Westminster College, and MAA President, **Paul Zorn**, St. Olaf College. Winners of the Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching will give presentations on the secrets of their success.

MAA Invited Paper Sessions

Algebraic Statistics, organized by **Seth Sullivant**, North Carolina State University. Speakers are **Elizabeth Allman**, University of Alaska Fairbanks; **Dustin Cartwright**, Yale University; **Alex Engstrom**, University of California, Berkeley; **Luis Garcia Puente**, Sam Houston State University; **Jason Morton**, Pennsylvania State University; and **Bernd Sturmfels**, University of California Berkeley; Saturday morning.

Applications of Dynamical Systems, organized by **Gene Wayne**, Boston University, Saturday morning.

The Beauty and Power of Number Theory, organized by **Thomas Koshy**, Framingham State University. Speakers are **Amanda Folsom**, Yale University; **Ken Ono**, University of Wisconsin-Madison; **Joseph Silverman**, Brown University; and **Frank Thorne**, Stanford University; Thursday morning.

Clever Counting or Beautiful Bijection?, organized by **Jennifer Quinn**, University of Washington, Tacoma. Speakers are **Richard Brualdi**, University of Wisconsin-Madison; **David Bressoud**, Macalester College; **Georgia Benkhart**, University of Wisconsin-Madison; **James Propp**, University of Massachusetts, Lowell; and **Tom Roby**, University of Connecticut; Thursday afternoon.

Climate Change and Sustainability, organized by **Mary Lou Zeeman**, Bowdoin College; and **Chris Danforth**, University of Vermont; Saturday afternoon.

Contemporary Unsolved Problems, organized by **Ellen Kirkman** and **Jeremy Rouse**, Wake Forest University. Speakers are **Joel Hass**, University of California, Davis; **Mike Sipser**, Massachusetts Institute of Technology; **William Stein**, University of Washington, Seattle; and **Gene Wayne**, Boston University; Friday morning.

Knot Theory Untangled, organized by **Rolland Trapp**, California State University, San Bernardino; Wednesday morning.

Semidefinite Optimization and Nonnegative Polynomials, organized by **Rekha R. Thomas**, University of Washington. Speakers are **Greg Blekherman**, Georgia Institute of Technology; **Amirali Ahmadi**, Massachusetts Institute of Technology; **Steven Gortler**, Harvard University; and **Russ Tedrake**, MIT; Friday afternoon.

Decoding Geometry, organized by **Carolyn S. Gordon** and **David Webb**, Dartmouth College; Thursday afternoon.

MAA-AMS Invited Paper Session

Recent Developments in the Philosophy of Mathematics, organized by **Bonnie Gold**, Monmouth University, and **Daniel Slougher**, Furman University. Speakers are **Arthur Jaffe**, Harvard University; **Charles Parsons**, Harvard University Philosophy Department; **Agustin Rayo** and **Stephen Yablo**, MIT Department of Linguistics and Philosophy; **Juliet Floyd**, Boston University Philosophy Department; and **Jody Azzouni**, Tufts University Philosophy Department; Wednesday afternoon.

MAA Minicourses

MAA Minicourses are open only to persons who register for the Joint Meetings and pay the Joint Meetings registration fee in addition to the appropriate minicourse fee. The MAA reserves the right to cancel any minicourse that is undersubscribed. Participants in minicourses 10–14 are required to bring their own laptop computer equipped with appropriate software. Instructions on how to download any data files needed for those courses will be provided by the organizers. All minicourses will be held in the fourth floor salons in the Marriott Hotel. The enrollment in each minicourse is limited to 50; the cost is US\$77.

Minicourse #1: Mathematics and backgammon, presented by **Arthur Benjamin**, Harvey Mudd College, and **Robert Koca**, Community College of Baltimore County. Part A: Thursday, 9:00 a.m.–11:00 a.m.; Part B: Saturday,

9:00 a.m.–11:00 a.m. The game of backgammon is great fun, but it also leads to some interesting mathematical questions. We will explore these questions and see how a little knowledge of backgammon reasoning can make you a better decision maker. Conversely, we'll see how a little knowledge of mathematics can make you a much better backgammon player. There are no mathematical prerequisites beyond high school algebra, and no prior experience with backgammon is assumed. Since other backgammon experts will assist in the course, participants will get hands-on experience playing with top-notch players.

Minicourse #2: *A dynamical systems approach to the differential equations course*, presented by **Paul Blanchard** and **Robert Devaney**, Boston University. Part A: Thursday, 1:00 p.m.–3:00 p.m.; Part B: Saturday, 1:00 p.m.–3:00 p.m. This minicourse will give an overview of the Boston University Differential Equations Project, originally funded by the National Science Foundation. The BU project involves a complete redesign of the sophomore-level ODE course. It includes more emphasis on qualitative and geometric methods as well as the incorporation of technology and numerical methods throughout. This minicourse will be useful to college instructors wishing to restructure their ODE courses. Participants who bring a laptop can load software and follow the demos, but bringing a laptop isn't necessary.

Minicourse #3: *Problem-based courses for teachers, future teachers, and math majors*, presented by **Gail Burrill**, Michigan State University; **Darryl Yong**, Harvey Mudd College; **Bowen Kerins**, Education Development Center; and **James King**, University of Washington. Part A: Wednesday, 2:15 p.m.–4:15 p.m.; Part B: Friday, 1:00 p.m.–3:00 p.m. A math course can simultaneously engage a broad range of students and enlarge their understanding of what it means to do math. This minicourse—based on a decade of experience at the Park City Mathematics Institute—will illustrate a problem-based approach for doing just that. Participants will spend most of the time in an interactive, collaborative environment, working on problems connecting algebra, number theory and geometry, involving Pythagorean triples, Gaussian integers, lattice geometry, polynomials with special properties, and complex numbers, which will be central to the investigations. We will discuss issues of teaching such a course, originally developed for teachers at the Park City Mathematics Institute, for undergraduate majors, prospective teachers, or as part of continuing education programs for experienced teachers.

Minicourse #4: *Elementary mathematics in architecture*, presented by **Alexander J. Hahn**, University of Notre Dame. Part A: Thursday, 9:00 a.m.–11:00 a.m.; Part B: Saturday, 9:00 a.m.–11:00 a.m. This minicourse will give examples of basic mathematics, chiefly elementary geometry, algebra, and trigonometry, properties of vectors, coordinate geometry in two and three dimensions, and calculus that arise from and inform aspects of architecture. The architecture that is informed includes that of the classical Greeks and Romans; the domes of the Pantheon, the Hagia Sophia, the Cathedral of Florence, and St. Peter's Basilica; the designs of the vaults of the Sagrada Familia;

the concourse beams and roof vaults of the Sydney Opera; as well as the St. Louis Gateway Arch.

Minicourse #5: *Dance and mathematics*, presented by **Leon Harkleroad**, Bowdoin College, and **Karl Schaffer**, De Anza College. Part A: Wednesday, 4:45 p.m.–6:45 p.m.; Part B: Friday, 3:30 p.m.–5:30 p.m. Many dances literally embody mathematical ideas from group theory, graph theory, number theory, combinatorics, topology, and other areas. In this “feet-on” minicourse, participants will learn many such examples, ranging from traditional folk dances to modern dance. No prior experience or ability in dancing will be assumed!

Minicourse #6: *Getting students involved in undergraduate research*, presented by **Aparna Higgins**, University of Dayton, and **Joseph A. Gallian**, University of Minnesota-Duluth. Part A: Wednesday, 9:00 a.m.–11:00 a.m.; Part B: Friday, 9:00 a.m.–11:00 a.m. This minicourse will cover many aspects of facilitating research by undergraduates, such as getting students involved in research, finding appropriate problems, deciding how much help to provide, and presenting and publishing the results. Similarities and differences between research conducted during summer programs and research that can be conducted during the academic year will be discussed. Although the examples used will be primarily in the area of discrete mathematics, the strategies discussed can be applied to any area of mathematics.

Minicourse #7: *Study the masters: Using primary historical sources in mathematics teaching*, presented by **Daniel Otero**, Xavier University, and **David Pengelley**, New Mexico State University. Part A: Wednesday, 2:15 p.m.–4:15 p.m.; Part B: Friday, 1:00 p.m.–3:00 p.m. This minicourse will familiarize participants with the use of primary historical sources as a way to engage mathematics students across a variety of courses. In the first session the organizers will share their experiences with this pedagogy. Participants will discuss in groups how one such unabridged text can be used to teach the relevant mathematics contained therein. In the second session already-developed classroom modules will be examined to illustrate how others have implemented this practice. Participants will also discuss their responses to two articles reflecting on this methodology. Finally we share resources for locating primary historical texts.

Minicourse #8: *Preparing to serve as an outside consultant in the mathematical sciences*, presented by **Kyle Riley**, South Dakota School of Mines and Technology, and **Nancy Baxter Hastings**, Dickinson College. Part A: Wednesday, 9:00 a.m.–11:00 a.m.; Part B: Friday, 9:00 a.m.–11:00 a.m. The goal of this minicourse is to help colleagues prepare to serve as outside consultants. The course will use case studies, role-playing, and discussion sessions to explore answers to questions such as the following: What do consultants need to know? What should they do to prepare for a site visit? What can consultants do to help strengthen a department's self-study process? How can they make the most of the on-campus visit? What difficulties might they encounter and how might they respond? How can they provide constructive feedback? What role might they play following the site visit? This course is sponsored by the

MAA Committee on Departmental Review (formerly known as the MAA Committee on Consultants).

Minicourse #9: *Reading original sources in Latin for the historian and mathematician*, organized by **Amy Shell-Gellasch**, Beloit College, and **Dominic Klyve**, Central Washington University; and presented by **Kim Plofker**, Union College, and **Stacy Langton**, University of San Diego. Part A: Thursday, 1:00 p.m.–3:00 p.m.; Part B: Saturday, 1:00 p.m.–3:00 p.m. Historians of mathematics as well as mathematicians often find it important to their research to read original mathematical and scientific sources in Latin. Technical Latin of the late medieval, the Renaissance, and post-renaissance periods is slightly different from the classical Latin taught in schools. In this minicourse participants will learn of these differences, and will receive direct instruction in the reading of original sources in Latin from these time periods. Specialists from the field of the history of mathematics will facilitate the readings. Attendees should have a basic knowledge of Latin; review material can be acquired from the organizers in advance.

Minicourse #10: *Geometry and art: A Liberal arts mathematics course*, presented by **Anneke Bart**, Saint Louis University. Part A: Thursday, 1:00 p.m.–3:00 p.m.; Part B: Saturday, 1:00 p.m.–3:00 p.m. Motivating mathematical concepts through art is a useful tool. Students are more likely to understand concepts such as symmetry, tessellations, or non-Euclidean geometry if they are shown prints by artists such as Escher that illustrate these topics. The challenge is to connect the art to real mathematical concepts and guide the students through the necessary steps, which takes them from observing patterns to doing real mathematics. During the minicourse we will look at examples from <http://mathcs.slu.edu/escher>, adapt existing explorations, and create new ones. We will discuss possible grading rubrics and explore possibilities for doing projects and field trips. In order to take full advantage of the course, participants should bring their own laptops.

Minicourse #11: *Teaching differential equations with modeling*, presented by **Michael Huber**, Muhlenberg College; **Dan Flath**, Macalester College; and **Tom LoFaro**, Gustavus Adolphus College. Part A: Wednesday, 2:15 p.m.–4:15 p.m.; Part B: Friday, 1:00 p.m.–3:00 p.m. Participants will learn about incorporating modeling into their differential equations courses and will do some modeling themselves using technology. The workshop will have three segments: (1) a short overview of curricular goals, what is modeling and why it is important, how modeling benefits student learning in differential equations; (2) activities and discussions in small groups on specific projects, to include modeling the dynamics of flight, stochastic population growth models, modeling malaria outbreaks, deflection in steel beams, and others; and (3) a wrap-up with references, sharing of best practices, and resources that are available to instructors and students. In order to take full advantage of the course, participants should bring their own laptops.

Minicourse #12: *Using randomization methods to build conceptual understanding of statistical inference*, presented by **Robin Lock**, St. Lawrence University; **Patti Frazer Lock**, St. Lawrence University; **Kari F. Lock**, Harvard

University/Duke University; **Eric F. Lock**, University of North Carolina; and **Dennis F. Lock**, Iowa State University. Part A: Wednesday, 4:45 p.m.–6:45 p.m.; Part B: Friday, 3:30 p.m.–5:30 p.m. The goal of this minicourse is to demonstrate how computer simulation techniques, such as bootstrap confidence intervals and randomization tests, can be used to introduce students to fundamental concepts of statistical inference in an introductory statistics course. Simulation methods are becoming increasingly important in statistics, and can be effective tools for building student understanding of inference. Through easy to use online tools and class activities, participants will see how to engage students and make these methods readily accessible. In order to take full advantage of the course, participants should bring their own laptops.

Minicourse #13: *Interactive applets for calculus and differential equations*, presented by **Haynes Miller**, Massachusetts Institute of Technology. Part A: Thursday, 9:00 a.m.–11:00 a.m.; Part B: Saturday, 9:00 a.m.–11:00 a.m. For the past ten years the basic calculus and differential equations courses at MIT have made extensive use of a suite of highly interactive JAVA applets, both for classroom demonstrations and for use in homework assignments. They can be accessed at <http://math.mit.edu/mathlets>. This course will introduce this set of tools, illustrate how they can be used in a variety of contexts, and encourage the creation of new assignments using them and of variants of them for future development. In order to take full advantage of the course, participants should bring their own laptops.

Minicourse #14: *Teaching introductory statistics (for instructors new to teaching intro stats)*, presented by **Michael Posner**, Villanova University, and **Carolyn Cuff**, Westminster College. Part A: Wednesday, 9:00 a.m.–11:00 a.m.; Part B: Friday, 9:00 a.m.–11:00 a.m. This minicourse exposes participants to the big ideas of statistics and the ASA-endorsed “Guidelines for Assessment and Instruction in Statistics Education” report. It considers ways to engage students in statistical literacy and thinking and contrast conceptual and procedural understanding in the first statistics course. Participants will engage in many of the classic activities that all statistics instructors should know. Internet sources of real data, activities, and best practices articles will be examined. Participants will find out how they can continue to answer the three questions by becoming involved in statistics education related conferences, newsletters, and groups. In order to take full advantage of the course, participants should bring their own laptops.

MAA Contributed Papers

The MAA Committee on Contributed Paper Sessions solicits contributed papers pertinent to the sessions listed below. Contributed Paper Session presentations are limited to fifteen minutes, except in the general session where they are limited to ten minutes. Each session room is equipped with a computer projector, an overhead projector, and a screen. Please note that the dates and times scheduled for these sessions remain tentative. Full descriptions of these sessions may be found at

http://jointmathematicsm meetings.org/meetings/national/jmm2012/2138_maacall.

Arts and Mathematics, Together Again, organized by **Douglas E. Norton**, Villanova University; Thursday morning and afternoon. Sponsored by SIGMAA ARTS.

The Capstone Course: Innovations and Implementations, organized by **Kathryn Weld**, Manhattan College, and **Agnes Rash**, St. Joseph's College; Wednesday morning.

Developmental Mathematics Education: Helping Under-Prepared Students Transition to College-Level Mathematics, organized by **Kimberly Presser** and **J. Winston Crawley**, Shippensburg University; Friday afternoon.

Early Assessment: Find Out What Your Students Understand (and Don't Understand) Before They Take the Test, organized by **Miriam Harris-Botzum**, Lehigh Carbon Community College, and **Bonnie Gold**, Monmouth University; Saturday afternoon.

Effective Use of Dynamic Mathematical Software in the Classroom, organized by **M. E. Waggoner**, Simpson College, and **Therese Shelton**, Southwestern University; Wednesday morning.

The History of Mathematics and Its Uses in the Classroom, organized by **Amy Shell-Gellasch**, Beloit College; Saturday morning. Sponsored by the HOM SIGMAA.

Innovations in Teaching Statistics in the New Decade, organized by **Andrew Zieffler**, University of Minnesota; **Brian Gill**, Seattle Pacific University; and **Nancy Boynton**, SUNY Fredonia; Friday afternoon. Sponsored by the SIGMAA STAT-ED.

Innovative and Effective Ways to Teach Linear Algebra, organized by **David Strong**, Pepperdine University; **Gil Strang**, Massachusetts Institute of Technology; and **David Lay**, University of Maryland; Wednesday afternoon.

The Mathematical Preparation of Teachers: The Impact of the Common Core State Standards Initiative, organized by **Kenneth C. Millett**, University of California Santa Barbara; **Elizabeth Burroughs**, Montana State University; **Holly Peters Hirst**, Appalachian State University; and **William McCallum**, University of Arizona; Saturday morning.

Mathematics and Sports, organized by **R. Drew Pasteur**, College of Wooster; Wednesday morning.

Mathematics Experiences in Business, Industry and Government, organized by **Carla D. Martin**, James Madison University; **Phil Gustafson**, Mesa State College; and **Michael Monticino**, University of North Texas; Thursday morning. Sponsored by the BIG SIGMAA.

Mathematics of Sudoku and Other Pencil Puzzles, organized by **Laura Taalman** and **Jason Rosenhouse**, James Madison University; Wednesday and Thursday afternoons.

Mathematics of Sustainability, organized by **Elton Graves**, Rose-Hulman Institute of Technology, and **Peter Otto**, Willamette University; Friday afternoon.

Modeling Across the Mathematics Curriculum, organized by **Benjamin Galluzzo**, Shippensburg University; **Mariah Birgen**, Wartburg College; and **Joyati Debnath**, Winona State University; Friday morning.

Motivating Statistical and Quantitative Learning through Social Engagement, organized by **Brian Gill**, Seattle Pacific University; **Eric Gaze**, Bowdoin College; **Andrew Zieffler**, University of Minnesota; and **Stuart Boersma**, Central

Washington University; Saturday morning and afternoon. Sponsored by the SIGMAA STAT-ED and the QL SIGMAA.

My Most Successful Math Club Activity, organized by **Jacqueline Jensen**, Slippery Rock University, and **Deanna Haunsberger**, Carleton College; Thursday morning. Sponsored by the MAA Committee on Undergraduate Student Activities and Chapters.

Philosophy of Mathematics and Mathematical Practice, organized by **Dan Sloughter**, Furman University, and **Bonnie Gold**, Monmouth University; Friday afternoon. Sponsored by the POM SIGMAA.

Preparing College Students for Calculus, organized by **Andrew Bennett**, Kansas State University; Thursday morning. Sponsored by the CUPM Subcommittee on Curriculum Renewal Across the First Two Years (CRAFTY).

Projects, Demonstrations, and Activities that Engage Liberal Arts Mathematics Students, organized by **Sarah Mabrouk**, Framingham State University; Thursday afternoon.

Quantitative Literacy and Decision Making, organized by **Eric Gaze**, Bowdoin College; **Cinnamon Hillyard**, University of Washington, Bothell; and **Semra Kilic-Bahi**, Colby Sawyer College; Friday morning. Sponsored by the QL SIGMAA.

Research on the Teaching and Learning of Undergraduate Mathematics, organized by **Sean Larsen**, Portland State University; **Stacy Brown**, Pitzer College; and **Karen Mar-ronnelle**, Portland State University; Thursday morning and afternoon. Sponsored by the SIGMAA RUME.

The Scholarship of Teaching and Learning in Collegiate Mathematics, organized by **Jackie Dewar**, Loyola Marymount University; **Thomas Banchoff**, Brown University; **Pam Crawford**, Jacksonville University; and **Edwin Herman** and **Nathan Wodarz**, University of Wisconsin-Stevens Point; Wednesday morning and afternoon.

Topics and Techniques for Teaching Real Analysis, organized by **Paul Musial**, Chicago State University; **James Peterson**, Benedictine College; **Erik Talvila**, University of the Fraser Valley; and **Robert Vallin**, Slippery Rock University of Pennsylvania; Friday morning.

Touch it, Feel it, Learn it: Tactile Learning Activities in the Undergraduate Mathematics Classroom, organized by **Jessica Mikhaylov**, U.S. Military Academy, and **Julie Barnes**, Western Carolina University; Wednesday afternoon.

Trends in Teaching Mathematics Online, organized by **Michael B. Scott**, California State University, Monterey Bay; Saturday afternoon. Sponsored by the Committee on Technologies in Mathematics Education (CTiME) and the WEB SIGMAA.

Trends in Undergraduate Mathematical Biology Education, organized by **Timothy D. Comar**, Benedictine University; Thursday morning and afternoon. Sponsored by the BIO SIGMAA.

Wavelets in Undergraduate Education, organized by **Caroline Haddad**, SUNY Geneseo; **Catherine Beneteau**, University of South Florida; **David Ruch**, Metropolitan State College of Denver; and **Patrick Van Fleet**, University of St. Thomas; Friday afternoon.

Writing the History of the MAA, organized by **Victor J. Katz**, University of the District of Columbia; **Janet Beery**, University of Redlands; and **Amy Shell-Gellasch**, Beloit College; Friday morning. Sponsored by the History Subcommittee of the MAA Centennial Committee.

General Contributed Paper Session, organized by **Jennifer Beineke**, Western New England College; **Lynnette Boos**, Providence College; and **Aliza Steurer**, Dominican University; Wednesday, Thursday, Friday, and Saturday mornings and afternoons.

Submission Procedures for MAA Contributed Paper Abstracts

Abstracts must be submitted electronically at <http://jointmathematicsmeetings.org/meetings/abstracts/abstract.pl?type=jmm>. Simply fill in the number of authors, and then follow the step-by-step instructions. **The deadline for abstracts is Thursday, September 22, 2011.**

Participants may submit at most **one abstract** for MAA contributed paper sessions at this meeting. If your paper cannot be accommodated in the session in which it is submitted, it will automatically be considered for the general session.

The organizer(s) of your session will automatically receive a copy of the abstract, so it is not necessary for you to send it directly to the organizer. All accepted abstracts are published in a book that is available to registered participants at the meeting. Questions concerning the submission of abstracts should be addressed to abs-coord@ams.org.

MAA Panels, Posters, and Other Sessions

National Science Foundation Programs Supporting Learning and Teaching in the Mathematical Sciences, organized by **Dean Evasius**, Division of Mathematical Sciences, National Science Foundation; and **Richard Alo**, **Ron Buckmire**, and **Lee Zia**, Division of Undergraduate Education, National Science Foundation; Wednesday, 9:00 a.m.–10:20 a.m. A number of NSF divisions offer a variety of grant programs that support innovations in learning and teaching in the mathematical sciences. The organizers will discuss these programs along with examples of successful projects. Anticipated budget highlights and other new initiatives for the next fiscal year will also be presented.

Quantitative Support Center: Common Themes, organized by **Michael E. Schuckers**, St. Lawrence University; Wednesday, 9:00 a.m.–10:20 a.m. Quantitative Support Centers (QSCs) have arisen in the last 20 to 30 years and nearly every academic institution has some form of mathematics help or tutoring. Each QSC has some characteristics that are specific to its particular institution but there are some commonalities. Some QSCs simply provide drop-in help; others play specific roles in support of quantitative initiatives on their campuses. This panel will bring together the directors of several QSCs from a variety of institutions, including **Grace Coulombe**, Bates College; **Cat McCune**, Smith College; **Tom Roby**, University of Connecticut; and **Michael Schuckers**. Discussion will center on

the issues that often arise in leading a QSC. These include staffing, training, scheduling, interactions with faculty and administrators, etc. There will also be a discussion of resources that are available for QSC directors.

Why is Transition from High School to College Important? Issues and Next Steps, organized by **Gail Burrill**, Michigan State University, Wednesday, 9:00 a.m.–10:20 a.m. What high school mathematics prepares which students for what courses at colleges/universities has been of concern in the past. Recent evidence indicates that transition from high school to post-secondary mathematics is becoming even more problematic. Panelists **David Bressoud**, Macalester College; **Dan Teague**, North Carolina School for Science and Mathematics; **Art Benjamin**, Harvey Mudd College; **William McCallum**, University of Arizona; **Paul Zorn**, St. Olaf College; and the session organizer will discuss this evidence, implications for transition policies and practices in light of the Common Core State Standards (CCSS), rethinking the goals of entry-level calculus courses, offer a spirited debate on whether statistics is more appropriate than calculus as an entry-level course for most students, and present recommendations from the Joint MAA/NCTM Mutual Concerns Committee related to these issues. Questions posed for the audience will include 1) Should the focus and goals of introductory calculus change? 2) Are current entry-level courses for potential STEM majors appropriate for all students given the foundation prescribed in the CCSS; and 3) What are your comments and input on the next steps proposed by the Joint Committee? Sponsored by the MAA/NCTM Mutual Concerns Committee.

Administrative Strategies for Dealing with Budget Cuts, organized by **Al Boggess**, **Don Allen**, and **Jill Zarestky**, Texas A&M University; Wednesday, 2:15 p.m.–3:35 p.m. This panel will give chairs of mathematics departments the opportunity to share strategies for dealing with budget cuts. Topics covered include: the effect of increasing class size on student learning, balancing teaching and research, differential teaching loads, the changing role of teaching assistants, the appropriate use of technology as an alternative or supplement to lecture, and the use of electronic textbooks. Our target audience will be public universities that have both teaching and research missions. We will first develop a survey of baseline data regarding responses to current budget cuts well before the meeting. The panel (members to be announced) will begin with a presentation of survey results. This will be followed by a discussion on the above topics with heavy participation by members in the audience. Sponsored by the MAA and the AMS.

Reporting Progress: A Mini-Symposium of Projects from the NSF Mathematics and Science Partnership Program, organized by **Richard Alo**, **Ron Buckmire**, and **Lee Zia**, Division of Undergraduate Education, National Science Foundation; and **Dan Maki**, Indiana University; Wednesday, 2:15 p.m.–3:35 p.m. In this session selected projects from the NSF Division of Undergraduate Education's Mathematics and Science Partnership Program will provide project updates and present major outcomes. A moderated discussion among principal Investigators from selected MSP projects of common development and implementation

issues will follow with an emphasis on opportunities for increasing the involvement of mathematical scientists.

Statistics and Probability in the Common Core State Standards, organized by **Nancy Boynton**, SUNY Fredonia; **Gail Burrill**, Michigan State University; and **Ann Watkins**, California State University Northridge; Wednesday, 2:15 p.m.–3:35 p.m. The Common Core State Standards for mathematics in grades K–12 have been adopted by 41 states and the District of Columbia. The standards for the teaching of statistics and probability range from counting the number in each category to determining statistical significance. Soon, and for the first time, most of our entering students will have been taught some statistics and probability, so our introductory statistics course will have to change. In addition, we must prepare future K–12 teachers to teach this curriculum. Panelists **Christine Franklin**, University of Georgia; **Joan Garfield**, University of Minnesota; **Roxy Peck**, California Polytechnic State University San Luis Obispo; **J. Michael Shaughnessy**, National Council of Teachers of Mathematics; and **Andrew Zieffler**, University of Minnesota, will give an overview of the statistics and probability content of these standards, discuss how the research on learning statistics and probability relates to these standards, consider what should change in our introductory statistics course, and describe the knowledge needed by the future K–12 teachers who will be teaching using these standards. Sponsored by the SIGMAA STAT-ED and the ASA-MAA Joint Committee on Statistics Education

YMN/Project NEXt Poster Session, organized by **Mike Axtell**, University of St. Thomas, and **Kim Roth**, Juniata College; Wednesday, 2:15 p.m.–4:15 p.m. This session is intended to highlight the research activities, both mathematical and pedagogical, of recent or future Ph.D.s in mathematics and related fields. The organizers seek to provide an open venue for people who are near completion, or have finished their graduate studies in the last five years, to present their work and make connections with other same-stage professionals, in much the same spirit as YMN and Project NEXt. The poster size will be 48" wide by 36" high. Posters and materials for posting pages on the posters will be provided onsite. We expect to accept about forty posters from different areas within the mathematical sciences. To apply, send a poster abstract, when and where you have or will receive your Ph.D., and your current college or university affiliation to one of the organizers, **Mike Axtell** (maxtell@stthomas.edu) or **Kim Roth** (roth@juniata.edu). Sponsored by the Young Mathematicians Network and Project NEXt.

Reporting Progress: A Minisymposium of Projects from the NSF Course, Curriculum, and Laboratory Improvement/Transforming Undergraduate Education in STEM Program, organized by **Richard Alo**, **Ron Buckmire**, and **Lee Zia**, Division of Undergraduate Education, National Science Foundation; Wednesday, 3:50 p.m.–5:10 p.m. In this session selected projects from the NSF Division of Undergraduate Education's Course, Curriculum, and Laboratory Improvement/Transforming Undergraduate Education in STEM Program will provide project updates and present major outcomes. A moderated discussion of

common development and implementation issues will follow with an emphasis on scaling up impact.

MAA Session for Chairs: Timely and Timeless Aspects of Chairing a Mathematical Sciences Department, organized by **Daniel Maki**, Indiana University, and **Catherine M. Murphy**, Purdue University Calumet; Thursday, 9:00 a.m.–10:20 a.m. Some roles of chairs of mathematical sciences departments are timeless. However, how they are implemented is affected by the mission of the college/university and time-dependent financial and political pressures. Panelists **Richard Cleary**, Bentley University; **Dennis Luciano**, Western New England College; **Catherine Roberts**, College of the Holy Cross; and **Sheryl Stump**, Ball State University, will share their experiences, which range from a few years to a few decades. One will reflect on how his experience as chair will make him a better faculty member as he returns to the faculty. The Session for Chairs is a great social networking experience. Please participate by attending and contributing to the conversation.

Graduate School: Choosing One, Getting In, Staying In, organized by **Aaron Luttmann**, Clarkson University, and **Kristi Meyer**, Wisconsin Lutheran College; Thursday, 9:00 a.m.–10:20 a.m. With so much information about graduate schools available how do you narrow down your list of schools to apply to? How do you get into a program? How do you successfully complete a program? Panelists **Richard McGehee**, University of Minnesota; **Kim Ruane**, Tufts University; and **Bogdan Vernescu**, Worcester Polytechnic Institute, will discuss these and other important issues for those choosing a graduate school or considering switching graduate programs. Sponsored by the Young Mathematicians Network and the MAA Committee on Graduate Students

Mathematical Outreach Programs for Underrepresented Populations, organized by **Elizabeth Yanik**, Emporia State University; Thursday, 9:00 a.m.–11:00 a.m. This poster session is designed to highlight special programs which have been developed to encourage students from underrepresented populations to maintain an interest in and commitment to succeeding in mathematics. These programs might include such activities as after school clubs, weekend activities, one day conferences, mentoring opportunities, summer camps, etc. In particular, recipients of Tensor and SUMMA grants will find this an ideal venue in which to share the progress of their funded projects. We encourage everyone involved with offering outreach activities to consider submitting an abstract to the session organizer at eyanik@emporia.edu.

Improving College Mathematics Teaching Through Faculty Development, organized by **Jerry Kobylski**, **Alex Heidenberg**, **Hilary Fletcher**, and **Howard McInvale**, U.S. Military Academy; Thursday, 10:35 a.m.–11:55 a.m. From 12–17 June 2011, the Department of Mathematical Sciences at West Point hosted the second annual "Improving College Mathematics Teaching Through Faculty Development" workshop for collegiate educators from across the country. The workshop attendees were professors and leaders in faculty development at their respective schools. This one-week workshop, funded by a grant from the National Science Foundation and also sponsored by

the MAA's PREP program, provided a framework that can be used for faculty members to create/improve faculty development and mentorship programs within their own departments/schools. The purpose of this panel session is to facilitate a discussion in a broader forum about effective faculty development programs. Panelists **Molli Jones**, Immaculata College; **Laurice Garrett**, Edison State College; **Cindy Soderstrom**, Salt Lake Community College; and **Philip Darcy**, Dutchess Community College, will share some of the best teaching practices from the two workshops and participants' lessons learned in developing effective faculty development programs. The panel session is relevant to two-year and four-year programs, as well as developmental and traditional student populations.

Proposal Writing Workshop for Grant Applications to the NSF Division of Undergraduate Education, presented by **Richard Alo**, **Ron Buckmire**, and **Lee Zia**, Division of Undergraduate Education, National Science Foundation; Thursday, 10:35 a.m.–11:55 a.m. The presenters will describe the general NSF grant proposal process and consider particular details relevant to programs in the Division of Undergraduate Education. This interactive session will feature a mock panel review using a series of short excerpts from sample proposals.

Summer Research Programs, organized by **William Hawkins Jr.**, MAA and University of the District of Columbia, and **Robert Megginson**, University of Michigan; Thursday, 1:00 p.m.–2:20 p.m. The MAA has sponsored Summer Research Programs with funding from NSF and NSA since 2003. Each program consists of a small research group of at least four minority undergraduates mentored by a faculty member. About 85 sites will have been funded as of summer 2011. Panelists **Min-Lin Lo**, California State University San Bernardino, and **Asamoah Nkwanta**, Morgan State University, will discuss their programs. There will be ample time for questions and discussion. Funding will be available for summer 2012. Additional information can be found on the NREUP website at www.maa.org/nreup. The session is sponsored by MAA Committee on Minority Participation (CMPM) and the Office of Minority Participation.

What Can Colleges and Universities Do to Increase Student Success in Calculus?, organized by **James R. Choike**, Oklahoma State University, and **Carl C. Cowen**, Indiana University Purdue University Indianapolis; Thursday, 1:00 p.m.–2:20 p.m. Many colleges and universities experience DWF rates of 40% or higher in Calculus I [Bressoud, MAA Retiring Presidential Address, 2011]. In addition, AP Calculus AB scores over the last six AP exams show that 40.9% of the AB test takers score less than 3, the equivalent of a D or F [AP Report to the Nation, 2005–2011]. These data have a direct influence on the numbers of students that ultimately will major in the STEM areas in college. The fair assumption is that students enroll in calculus, in college or in AP, because they have the appropriate transcript prerequisites for calculus. But transcript prerequisites, as these data suggest, do not automatically translate into being ready for success in calculus. Panelists **Alison Ahlgren**, University of Illinois Urbana-Champaign; **David Bressoud**, Macalester College; **Marilyn Carlson**, Arizona

State University; and **Bernard Madison**, University of Arkansas, will discuss what the indicators of readiness for calculus are and what colleges and universities can do to increase student success in calculus. Sponsored by The College Board-MAA Committee on Mutual Concerns.

Career Options for Undergraduate Mathematics Majors, organized by **Raluca Gera**, Naval Postgraduate School, and **Nyles Breecher**, Hamline University; Thursday, 1:00 p.m.–2:20 p.m. There are a vast amount of options available for students in today's global market. A degree in mathematics continues to be a desirable asset, yet a common question for students to ask is "What options are available for someone with a math degree?". This panel will showcase several options for career paths for students with an undergraduate degree in mathematics. A variety of panelists, including **Emily Kessler**, Society of Actuaries; **Michael Dorff**, Brigham Young University; and **Erin Corman**, National Security Agency, will speak on their own experiences of finding a job. Sponsored by the Young Mathematicians Network,

Projects Supported by the NSF Division of Undergraduate Education, organized by **Jon Scott**, Montgomery College; Thursday, 2:00 p.m.–4:00 p.m. This session will feature principal investigators (PIs) presenting progress and outcomes from various NSF funded projects in the Division of Undergraduate Education. The poster session format will permit ample opportunity for attendees to engage in small group discussions with the PIs and to network with each other. Information about presenters and their projects will appear in the meeting program.

Successful and Diverse Models for Mentoring Research by Undergraduates, organized by **Sarah Spence Adams**, Franklin W. Olin College of Engineering, and **Angel R. Pineda**, California State University, Fullerton; Thursday, 2:40 p.m.–4:00 p.m. As the popularity of undergraduate research in mathematics has grown over the last several years, interesting and successful models for mentoring research by undergraduates have emerged. The models include short-term (summer) through multi-year programs, those which are targeted to attract underrepresented students and those in a range of mathematical fields (including pure mathematics, applied mathematics and statistics). In this moderated discussion panelists **James Davis**, University of Richmond; **Gary P. Gordon**, Lafayette College; **Kathryn Leonard**, California State University Channel Islands; **Herbert A. Medina**, Loyola Marymount University; **Alison A. Motsinger-Reif**, North Carolina State University; and **Suzanne L. Weekes**, Worcester Polytechnic Institute, will describe and compare a variety of models for mentoring undergraduate students in research. Sponsored by the MAA Subcommittee on Research by Undergraduates.

Hit the Ground Running! Interview Like a Pro and Land the Job, organized by **Kristine Roinestad**, Georgetown College, and **Nick Scoville**, Ursinus College; Thursday, 2:40 p.m.–4:00 p.m. Your job applications are in and soon invitations for interviews will follow. Make the most of these opportunities by doing your homework. How do you prepare differently for an interview with a liberal arts school than for an interview with a research university?

What about phone and short-list interviews? Our panelists, **Eric Grinberg**, University of Massachusetts Boston; **David Cox**, Amherst College; **Betty Mayfield**, Hood College; and **Paul Dupuis**, Brown University, representing schools that recently conducted job searches, will share what they look for in a candidate and discuss the differences in how to interview at primarily a teaching school versus primarily a research school. They will also discuss how to score well during a phone interview, a Joint Mathematics Meetings interview, and an on-campus interview. Also on the agenda will be the best ways to prepare for different types of interviews and “what not to do, but what many applicants do anyway”. Copponsored by the Young Mathematicians Network.

Publishing with the MAA, organized by **Zaven A. Karian**, Denison University; Thursday, 2:40 p.m.–4:00 p.m. Since it began publishing books in 1925, the MAA has been dedicated to quality exposition. Today the MAA has nine book series that encompass wide areas of mathematics (textbooks, classroom resource materials, history, biography, recreational mathematics, problems, advanced monographs and notes on pedagogy). The MAA publishes about 20 new books each year. Panelists **Don Albers**, MAA, and **Jerry Bryce**, Hampden-Sydney College, will describe MAA's book publications, both traditional and e-publications. The discussion will include a description of the various book series that the MAA publishes, what prospective authors need to know to publish with the MAA, and the advantages of doing so. Time will be set aside for questions from the audience.

Getting Your Textbook Published, organized by **James Hamblin**, Shippensburg University; Friday, 9:00 a.m.–10:20 a.m. With the rising costs of textbooks and higher education in general, many faculty are considering their own low-cost alternatives to existing textbooks. However, many of these would-be authors will never get started simply because they think the publishing process is too difficult. Is working through a big publisher the only option? How much creative control do you have when working with a publisher? How difficult is it to publish a book on your own? How do open-source textbooks work? Panelists **Doug Ensley**, Shippensburg University; **Thomas W. Judson**, Stephen F. Austin State University; and **Sheldon Gordon**, Farmingdale State College, will answer these questions and discuss the advantages and disadvantages of each publishing method. Sponsored by the MAA Professional Development Committee.

Using Data from the Registrar's Office to Better Understand, Plan, and Change Your Undergraduate Mathematics Program, organized by **Jack Bookman**, Duke University; Friday, 9:00 a.m.–10:20 a.m. Gathering useful data for assessment purposes can often be a daunting and time-consuming task but the answers to many questions we may have about our undergraduate mathematics programs, such what is the first math course that our majors take or what is the persistence rate from Calculus I to Calculus II, are readily available from data that can be provided by the registrar's office at each of our institutions. In this panel discussion including **Bill Martin**, North Dakota State University; **Amy Cohen**, Rutgers University; **Jack**

Bookman; and **Mary Callahan**, Massachusetts Institute of Technology, we will hear from a registrar who will discuss what kinds of information the registrar's office can provide and how to clearly present your questions. We will also hear from mathematics faculty who have used registrar data to assess their program and to make better informed decisions about their department's course offerings. Sponsored by the MAA Committee on Assessment.

Incorporation of the Mathematics of Climate Change and Sustainability into our Undergraduate Courses, organized by **Robert E. Megginson**, University of Michigan at Ann Arbor; Friday, 9:00 a.m.–10:20 a.m. The growing interest by undergraduates in climate change and sustainability presents a challenge to our mathematics courses and curricula, because we will be called upon increasingly to provide students with the mathematical background needed for careers in these fields that our courses have not traditionally addressed. However, with that challenge also comes the opportunity to bring more undergraduates into contact with interesting mathematics through their attraction to this subject matter. Panelists **Mary Lou Zee-man**, Bowdoin College; **Thomas J. Pfaff**, Ithaca College; **Martin E. Walter**, University of Colorado at Boulder; and **Christopher Jones**, University of North Carolina at Chapel Hill, will address the possibilities for our leveraging this interest in climate change and sustainability, and describe some of the mathematical materials already available.

A New Look at Math for the Non-STEM Students, organized by **Joanne Peeples**, El Paso Community College; Friday, 1:00 p.m.–2:20 p.m. The Carnegie Foundation for the Advancement of Teaching, the Dana Center, and AMATYC are creating new math pathways for non-STEM majors. Statway (a statistics pathway) and Quantway (a quantitative literacy pathway) are currently being piloted. Both pathways focus on the math that the students see in everyday life, active student learning, and reducing the number of “exit points” where students abandon their pursuit of a college degree. Panelists **Bruce Yoshiwara**, Los Angeles Pierce College (moderator); **Kris Bishop**, University of Texas Austin; and **Karon Klipple** and **Jane Muhich**, Carnegie Foundation, will give an overview of processes used in developing these courses, and share preliminary results. There will be time for discussion at the end of the panel's presentation. Sponsored by the MAA Committee on Two-Year Colleges.

Engaging Secondary Teachers in Doing Mathematics, organized by **Gail Burrill**, Michigan State University; Friday, 2:40 p.m.–4:00 p.m. Park City Mathematics Institute's Professional Development and Outreach (PDO) groups and other PCMI affiliated groups, organized by mathematicians for local teachers in a variety of locations around the nation, provide opportunities for teachers to investigate mathematical ideas and solve mathematical problems, often related to a real context. Each group is organized differently with different activities, but one commonality is a focus on mathematics. Panelists **James King**, University of Washington; **Brian Hopkins**, St. Peters College; **Brynja Kohler**, Utah State University; **Roger Knobel**, University of Texas Pan America; and **Glenn Stevens**, Boston University, will each present an interesting problem they have

used with their teachers, discuss how the work is carried out, and what the mathematical “take-aways” are for the teachers. Participants and the panelists will discuss what is necessary in order to attract and retain teachers’ interests in attending sessions and doing mathematics, what kind of problems seem to be the most successful, and what connections with the work in the PDOs, if any, might be made by the teachers to their own practice of teaching. Sponsored by the Park City Mathematics Institute.

Poetry Reading, organized and hosted by **JoAnne Growney**, Silver Spring, MD; **Mark Huber**, Claremont McKenna College; and **Gizem Karaali**, Pomona College; Friday, 5:00 p.m.–7:00 p.m. All mathematical poets and those interested in mathematical poetry are invited. Share your poetry or simply enjoy the company of like-minded poetic-math people! If you who wish to contact the organizers ahead of time to inquire about the session and/or to add your name to the program, please email Gizem Karaali (gizem.karaali@pomona.edu); other interested meeting participants may simply come to the reading and share as they like. Sponsored by the Journal of Humanistic Mathematics (<http://scholarship.claremont.edu/jhm>).

Mathematically Bent Theater, presented by **Colin Adams**, Mobisubanda Theater Company, Friday, 6:00 p.m.–7:00 p.m. What’s funny about math? Come view these short, original, and humorous mathematical pieces and you will see.

Math Circle Poster and Activity Session, organized by **Philip B. Yasskin**, Texas A&M University; **James Tanton**, St. Mark’s School; **Tatiana Shubin**, San Jose State University; and **Sam Vandervelde**, St. Lawrence University; Saturday, 1:00 p.m.–4:00 p.m. Come join us for the chance to experience a math circle firsthand. Math circles vary widely in format and frequency, but they all bring groups of interested students or teachers together with professional mathematicians to investigate and discover mathematics. About ten math circles from around the country will display a poster describing that circle along with a live activity to try out. These activities are intended to provide ideas for lessons to use at your own circle or school. Activities will be designed to either restart every 30 minutes or run continuously.

Potential presenters should send the organizers (yasskin@math.tamu.edu) an electronic file (or files) of the sample lesson plan and handouts for their activity. The SIGMAA MCST will post those which are accepted at its website. Those that are not accepted will be automatically considered for future meetings. Sponsored by the SIGMAA MCST.

Special Interest Groups of the MAA (SIGMAAs)

SIGMAAs are Special Interest Groups of the MAA. SIGMAAs will be hosting a number of activities, sessions, and guest lectures. There are currently twelve such focus groups in the MAA offering members opportunities to interact, not only at meetings, but throughout the year, via newsletters and email-based communications. For more information visit <http://www.maa.org/sigmaa/>.

SIGMAA Officers Meeting, Thursday, 10:30 a.m.–noon, chaired by **Amy Shell-Gellasch**, Beloit College.

Mathematics and the Arts: SIGMAA ARTS

Arts and Mathematics, Together Again, Thursday morning and afternoon (see MAA Contributed Paper Sessions).

Mathematical and Computational Biology: BIO SIGMAA

Trends in Undergraduate Mathematical Biology Education, Thursday morning and afternoon (see MAA Contributed Paper Sessions).

Reception and Business Meeting, Friday, 6:00 p.m.–7:00 p.m.

Guest Lecture, Friday, 7:00 p.m.–8:00 p.m., **Edward Goldstein**, Department of Epidemiology, Harvard School of Public Health, *Epidemiology of influenza strains: Competition, prediction, and associated mortality*.

Mathematicians in Business, Industry and Government: BIG SIGMAA

Mathematics Experiences in Business, Industry and Government, Thursday morning (See MAA Contributed Paper Sessions).

Guest Lecture, Thursday, 6:00 p.m.–7:00 p.m., **Sommer Gentry**, U.S. Naval Academy, *Rational rationing in health-care: Observations from organ allocation*.

Reception, Thursday, 7:15 p.m.–8:00 p.m.

Business Meeting, Thursday, 8:00 p.m.–8:45 p.m.

History of Mathematics: HOM SIGMAA

The History of Mathematics and Its Uses in the Classroom, Saturday morning (see MAA Contributed Paper Sessions).

Reception and Business Meeting, Wednesday, 5:30 p.m.–6:30 p.m.

Guest Lecture, Wednesday, 6:30 p.m.–7:30 p.m., **William Dunham**, Muhlenberg College, *Title to be announced*.

Math Circles for Students and Teachers: SIGMAA MCST

Math Circle Poster and Activity Session, Saturday, 1:00 p.m.–4:00 p.m. (see MAA Panels, et al).

Philosophy of Mathematics: POM SIGMAA

Invited Paper Session cosponsored by the AMS on *Recent Developments in the Philosophy of Mathematics*, Wednesday afternoon (see MAA-AMS Invited Paper Sessions).

Business Meeting, Thursday, 5:45 p.m.–6:15 p.m.

Guest Lecture, Thursday, 6:15 p.m.–7:15 p.m., by **Barry Mazur**, Harvard University, *What is a heuristic?*

The Philosophy of Mathematics and Mathematical Practice, Friday afternoon (see MAA Contributed Paper Sessions).

Quantitative Literacy: SIGMAA QL

Quantitative Literacy and Decision Making, Friday morning (see MAA Contributed Paper Sessions).

Business Meeting, Friday, 5:00 p.m.–6:00 p.m.

Motivating Statistical and Quantitative Learning through Social Engagement, Saturday morning and afternoon (see MAA Contributed Paper Sessions).

Research in Undergraduate Mathematics Education: SIGMAA RUME

Research on the Teaching of Learning of Undergraduate Mathematics, Thursday morning and afternoon (see MAA Contributed Paper Sessions).

Statistics Education: SIGMAA STAT-ED

Motivating Statistical and Quantitative Learning through Social Engagement, Saturday morning and afternoon (see MAA Contributed Paper Sessions).

Statistics and Probability in the Common Core State Standards, Wednesday afternoon (see MAA panels et al).

Business Meeting and Reception, Thursday, 5:45 p.m.–7:15 p.m.

Mathematics Instruction Using the Web: WEB SIGMAA

Trends in Teaching Mathematics Online, Saturday morning (see MAA Contributed Paper Sessions).

Business Meeting and Reception, Friday, 5:00 p.m.–5:30 p.m.

Guest Lecture, Friday, 5:30 p.m.–6:30 p.m., **Frank Wattenberg**, U.S. Military Academy, *Examples of how mobile/web technologies can impact how, when, where, what, and why students learn*.

MAA Sessions for Students

Grad School Fair, Friday, 8:30 a.m.–10:30 a.m. Here is the opportunity for undergrads to meet representatives from mathematical sciences graduate programs from universities all over the country. January is a great time for juniors to learn more, and college seniors may still be able to refine their search. This is your chance for one-stop shopping in the graduate school market. At last year's meeting about 300 students met with representatives from 50 graduate programs. If your school has a graduate program and you are interested in participating, a table will be provided for your posters and printed materials for US\$65 (registration for this event must be made by a person already registered for the JMM), and you are welcome to personally speak to interested students. Complimentary coffee will be served. Cosponsored by the AMS and MAA.

MAA Lecture for Students, Friday, 1:00 p.m.–1:50 p.m., will be given by **Steve Abbott**, Middlebury College, on *Turning theorems into plays*.

Undergraduate Student Poster Session, Friday, 4:00 p.m.–5:30 p.m., organized by **Joyati Debnath**, Winona State University. The session is reserved to undergraduates and first-year graduate students submitting posters on work done while undergraduates. Abstracts are accepted on a first-come basis. Space is limited and students are encouraged to apply early. See <http://www.maa.org/students/undergrad/jmmposterindex.html> for pertinent details, including a link to the abstracts submission form. Examples of poster topics include a new result, a different proof of a known theorem, an innovative solution of a Putnam problem, a new mathematical model, or method

of solution of an applied problem. Purely expository posters cannot be accepted. Prizes will be awarded to the top-rated posters with money provided by the AMS, MAA, AWM, CUR, PME, the Educational Advancement Foundation, and the MAA Committee on Undergraduate Student Activities and Chapters (CUSAC). Trifold, self-standing 48" by 36" tabletop posterboards will be provided. Additional material or equipment is the responsibility of the presenters. Participants must be available for setting up their posters from noon to 1:00 p.m. and then from 2:30 p.m. to 4:00 p.m. to answer questions from the judges. The general public will be allowed in from 4:00 p.m. to 5:30 p.m. Questions regarding this session should be directed to the session organizer at jdebnath@winona.edu. The deadline for proposals is **October 28, 2011**.

Some more advanced students might be interested in these sessions listed elsewhere in this announcement: **Graduate School: Choosing One, Getting In, Staying In**, Thursday at 9:00 a.m.; **Career Options for Undergraduate Mathematics Majors**, Thursday at 1:00 p.m.; **Hit the Ground Running! Interview Like a Pro and Land the Job**, Thursday at 2:40 p.m.; see the full descriptions in the "MAA Panels..." section. You may also be interested in the **AMS-MAA-SIAM Special Session on Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs** on Friday and Saturday mornings and afternoons, listed in the "AMS Special Sessions" section.

Also see the "Social Events" section for the open hours of the **Student Hospitality Center, Reception for Undergraduates**, and **Reception for Graduate Students and First-Time Participants**.

MAA Short Course

This two-day Short Course on *Discrete and Computational Geometry* is organized by **Satyan L. Devadoss**, Williams College, and **Joseph O'Rourke**, Smith College, and will take place on Monday and Tuesday, January 2 and 3, before the annual meeting begins.

Although geometry is as old as mathematics itself, discrete geometry only fully emerged in the 20th century, and computational geometry was only christened in the late 1970s. The terms "discrete" and "computational" fit well together as the geometry must be discretized in preparation for computations. "Discrete" here means concentration on finite sets of points, lines, triangles, and other geometric objects, and is used to contrast with "continuous" geometry, for example, smooth manifolds. Although the two endeavors were growing naturally on their own, it has been the interaction between discrete and computational geometry that has generated the most excitement, with each advance in one field spurring an advance in the other. The interaction also draws upon two traditions: theoretical pursuits in pure mathematics and applications-driven directions often arising in computer science. The confluence has made the topic an ideal bridge between mathematics and computer science. It is precisely to bridge that gap that we hope to accomplish with this short course.

The material that will be covered is accessible to faculty and scholars at several different levels, whether they are interested in teaching or research: whether teaching students at an advanced high school level, a collegiate setting, or at the graduate level, and research specifically on the topics covered or in allied fields. A solid understanding of proofs is all that is needed to tackle some of the most beautiful and intriguing questions in this field. Moreover, a strong intuition of this subject can be obtained and developed through visualization. Due to the relative youth of the field, there are many accessible unsolved problems, which we highlight throughout the course. We hope this course can serve to open the door on this rich and fascinating subject.

This Short Course is broken into eight lectures, all given by the two organizers. The topics covered include *Polygons: Building blocks of discrete and computational geometry*; *Convex hulls: Computing in 2D and 3D*; *Triangulations: Flip graphs and Delaunay triangulations*; *Voronoi Diagrams: Geometry, duality, and hulls revisited*; *Curves: Medial axes, origami crease lines, and the Poincaré conjecture*; *Polyhedra: From Euler to Gauss to Cauchy*; and *Configuration Spaces: Locked polygonal chains and particle collisions*. The concluding session will discuss undergraduate research.

See a longer description at http://jointmathematicsmeetings.org/2138_maasc.html. There are separate registration fees to participate in this Short Course. See the fee schedule on the registration form at the back of this issue or visit jointmathematicsmeetings.org/2138_regfees.html.

Other MAA Events

Board of Governors, Tuesday, 9:00 a.m.–5:00 p.m.

Section Officers, chaired by **Rick Gillman**, Valparaiso University; Wednesday, 2:30 p.m.–5:00 p.m.

Business Meeting, Saturday, 11:10 a.m.–11:40 a.m., chaired by MAA President **Paul Zorn**, Saint Olaf College.

Department Liaisons Meeting, Wednesday, 9:30 a.m.–11:00 a.m.

Joint PME and MAA Student Chapter Advisors' Meeting, day and time to be determined.

Minority Chairs Meeting, day and time to be determined.

See the listings for various receptions in the “Social Events” section.

MAA Ancillary Workshops

Three ancillary workshops have been scheduled for Tuesday, January 3, the day before the Joint Meetings actually begins, cosponsored by the MAA and the Consortium for the Advancement of Undergraduate Statistics Education (CAUSE). There is no workshop registration fee and advance registration is required through www.causeweb.org/workshop/jmm12_projects/. You will receive notification of acceptance. Please note that walk-ins cannot be accommodated.

Facilitating Student Projects in Elementary Statistics, Tuesday, 8:30 a.m.–4:30 p.m., presented by **Brad Bailey**,

Sherry L. Hix, and **Dianna Spence**, North Georgia College & State University. Research suggests that having students complete statistics projects which entail identifying a research question, collecting and analyzing the necessary data and interpreting the results leads to deeper student understanding of statistics and fuller appreciation for the usefulness of statistics. Successful such student projects encompass a number of key tasks that students must carry out with guidance from their instructor. These tasks include defining appropriate variables, constructs, and research questions; locating authentic data; designing and implementing a sampling strategy; collecting the data; organizing and analyzing the data; and interpreting and presenting the results. Participants will have the opportunity to become more effective project facilitators by carrying out these key tasks in accelerated projects, using both t-tests and linear regression as contexts for the projects. In addition to providing participant hands-on experience with each of the project tasks, we will review methods for guiding students through these tasks. Finally, we will focus on details of facilitating the overall project, including project phases and organization, assessment methods, and best practices for implementation.

Participants should bring a laptop computer to the workshop, if possible. Participants will be on their own for lunch, suggestions for nearby options will be provided.

Teaching Modeling-Based Calculus, Tuesday, 9:00 a.m.–4:30 p.m., presented by **Daniel Kaplan** and **Dan Flath**, Macalester College, **Randall Pruim**, Calvin College, and **Eric Marland**, Appalachian State University. The MAA/CRAFTY reports recommended a strong emphasis on modeling in early university-level math courses, as well as much greater attention to statistics and computing. This workshop will show some techniques for teaching an introductory calculus course that is genuinely based on the process of modeling. By this, we mean using the concepts of calculus to help develop and interpret models of diverse phenomena in biology, economics, physics, etc. There will be a strong link made between calculus and statistical models. And, rather than using technology to carry out traditional symbolic calculus operations, we'll show how technology can be used to aid the modeling process. The workshop will include a general introduction to teaching modeling, several examples of classroom activities and homework projects that help develop modeling concepts and skills, and a broad introduction to the use of computing to support modeling. Participants should bring their laptops with the software they would like to use in their teaching. Recognizing that the choice of software is often determined by external factors including the preferences of colleagues and budgets, we will be ecumenical about software. In addition to providing a basic introduction to two free mathematical software systems—R and Sage—we'll try to support participants who would rather work with Mathematica, Maple, and Matlab. The workshop is an outreach activity of Project MOSAIC (NSF DUE-0920350) as well as CAUSE.

Participants should bring a laptop computer to the workshop, if possible. Lunch will be provided.

Identifying and Addressing Difficult Concepts for Students in the Introductory Statistics Course, Tuesday, 8:30 a.m.–4:30 p.m., presented by **Deborah Rumsey**, The Ohio State University. We know that students have difficulty with certain topics in statistics such as sampling distributions, and it can be difficult to determine the best approach to take to help our students work through these topics. In this workshop we take a selection of difficult concepts, zoom in on exactly what the problems are from the student's point of view, and examine where, when, and how to address them in our course. Along the way we will examine these difficult statistical concepts in detail, and look for common threads that may even lead us back to issues from Chapter 1. The workshop is particularly geared toward instructors at two-year colleges.

Participants should bring a laptop computer to the workshop, if possible. Participants will be on their own for lunch, suggestions for nearby options will be provided.

Activities of Other Organizations

This section includes scientific sessions. Several organizations or special groups are having receptions or other social events. Please see the “Social Events” section of this announcement for details.

Association for Symbolic Logic (ASL)

This two-day program on Friday and Saturday will include sessions of contributed papers as well as Invited Addresses by **John Baldwin**, University of Illinois at Chicago; **Johanna Franklin**, University of Connecticut; **C. Ward Henson**, University of Illinois at Urbana-Champaign; **Julia Knight**, University of Notre Dame; **Roman Kossak**, CUNY Graduate Center; and **Dima Sinapova**, University of California Irvine.

See also the session cosponsored by the ASL, **On the Life and Legacy of Alan Turing**, on Wednesday and Thursday in the “AMS Special Sessions” listings.

Association for Women in Mathematics (AWM)

Thirty-Third Annual Emmy Noether Lecture, Thursday, 10:05 a.m., will be given by **Barbara Lee Keyfitz**, Ohio State University, *Conservation laws—Not exactly à la Noether*.

Also see the session on **Nonlinear Hyperbolic Partial Differential Equations**, jointly sponsored by the AWM, in the “AMS Special Sessions” listings.

Maintaining an Active Research Career Through Collaboration, Wednesday, 2:15 p.m.–3:40 p.m. This panel discussion is organized by **Christina Sormani**, CUNY and Lehman College, and **Ami Radunskaya**, Pomona College. Just before the panel, AWM will recognize the honorees of the Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman. Note that formal prizewinner announcements are made at the Joint Prize Session on Thursday afternoon.

AWM Business Meeting, Thursday, 3:45 p.m.–4:15 p.m.

Workshop, Saturday, 8:30 a.m.–4:30 p.m. With funding from the National Security Agency, AWM will conduct its workshop for women graduate students and women who have received the Ph.D. within the last five years. Twenty

women mathematicians are selected in advance of this workshop to present their research; graduate students will present posters, and the recent Ph.D.s will give 20-minute talks. At 1:00 p.m. there is a panel discussion on *Career Options: Industry, Government, and Academic*, moderated by **Alissa Crans**, Loyola Marymount University, with panelists **Jennifer Chayes**, Microsoft Research; **Melissa Choi**, MIT Lincoln Laboratory; **Navah Langmeyer**, National Security Agency, and **Peter March**, Ohio State University. All mathematicians (female and male) are invited to attend the entire program. Departments are urged to help graduate students and recent Ph.D.s who do not receive funding to obtain some institutional support to attend the workshop and other meeting sessions. Updated information about the workshop is available at www.awm-math.org/workshops.html. AWM seeks volunteers to lead discussion groups and act as mentors for workshop participants. If you are interested, please contact the AWM office; inquiries regarding future workshops may be made to the office at awm@awm-math.org.

Reception, Wednesday, 9:30 p.m.–11:00 p.m. See the listing in the “Social Events,” section of the announcement.

National Association of Mathematicians (NAM) Granville-Brown-Haynes Session of Presentations by Recent Doctorial Recipients in the Mathematical Sciences, Friday, 1:00 p.m.–4:00 p.m.

Cox-Talbot Address, to be given Friday after the banquet by **Sylvia Bozeman**, Spellman University, *Title to be announced*.

Panel Discussion, Saturday, 9:00 a.m.–9:50 a.m., *Title to be announced*.

Business Meeting, Saturday, 10:00 a.m.–10:50 a.m.

Claytor-Woodward Lecture, Saturday, 1:00 p.m., Speaker and title to be announced.

See details about the banquet on Friday in the “Social Events” section.

National Science Foundation (NSF)

The NSF will be represented at a booth in the exhibit area. NSF staff members will be available to provide counsel and information on NSF programs of interest to mathematicians. The booth is open the same days and hours as the exhibits. Times that staff will be available will be posted at the booth.

Pi Mu Epsilon (PME)

Council Meeting, Friday, 8:00 a.m.–11:00 a.m.

Rocky Mountain Mathematics Consortium (RMMC)

Board of Directors Meeting, Friday, 2:15 p.m.–4:10 p.m.

Society for Industrial and Applied Mathematics (SIAM)

This program consists of an Invited Address at 11:10 a.m. on Thursday given by **Edriss S. Titi**, University of California Irvine and Weizmann Institute, *Navier-Stokes, Euler, and other relevant equations*, and a series of Minisymposia on these topics by these organizers:

Sparsity in Inverse Problems and Signal Processing, **Otmar Scherzer**, University of Vienna, Wednesday, morning.

Vistas in Applied, Computational, and Discrete Mathematics, **Zuhair Nashed**, University of Central Florida, and **Luminita Vese**, University of California Los Angeles; Wednesday afternoon.

Computational Geometry, **Suresh Venkatasubramanian**, University of Utah; Thursday morning.

Probabilistic Combinatorics, **Jacob Fox**, Massachusetts Institute of Technology, and **Poh-She Loh**, Carnegie Mellon University; Thursday afternoon.

Applied, Computational, and Discrete Mathematics at National Laboratories and Federal Research Agencies, **Luminita Vese**, University of California Los Angeles, and **Zuhair Nashed**, University of Central Florida, Friday, afternoon.

Recent Advances in Fluid Dynamics and Turbulence Models, **Edriss Titi**, University of California Irvine, Saturday morning.

Variational and PDE Methods in Imaging Science, **Luminita Vese**, University of California Los Angeles; **Otmar Scherzer**, University of Vienna; and **Alexandru Tamasan**, University of Central Florida; Saturday afternoon

Young Mathematicians Network (YMN)

Open Forum, Thursday, 7:30 p.m.–8:30 p.m., organized by **Joshua D. Laison**, Willamette University, and **Thomas Wakefield**, Youngstown State University. All meeting participants, especially undergraduates and graduate students, and early career mathematicians are invited to discuss topics and issues affecting young mathematicians.

Also see other details about other sessions cosponsored by the YMN under these headings: **MAA Panels, et al: Project NExT-YMN Poster Session**, Wednesday, 2:15 p.m.; **Graduate School: Choosing One, Getting In, Staying In**, Thursday, 9:00 a.m.; **Career Options for Undergraduate Mathematics Majors**, Thursday, 1:00 p.m.; and **Hit the Ground Running! Interview Like a Pro and Land the Job**, Thursday at 2:40 p.m.

Others

Mathematical Art Exhibition, organized by **Robert Fathauer**, Tessellations Company; **Nathaniel A. Friedman**, ISAMA and SUNY Albany, **Anne Burns**, Long Island University and C. W. Post University, **Reza Sarhangi**, Towson University, and **Nathan Selikoff**, Digital Awakening Studios. A popular feature at the Joint Mathematics Meetings, this exhibition provides a break in your day. On display are works in various media by artists who are inspired by mathematics and by mathematicians who use visual art to express their findings. Fractals, symmetry, and tiling are some of the ideas at play here. Don't miss this unique opportunity for a different perspective on mathematics. The exhibition will be located inside the Joint Mathematics Exhibits and open during the same exhibit hours.

Summer Program for Women in Mathematics (SPWM) Reunion, Thursday, 1:00 p.m.–4:00 p.m., organized by **Murli M. Gupta**, George Washington University. This is a reunion of the participants from our past 17 years who

are in various states in their mathematical careers: some are students (undergraduate or graduate), others are in various jobs, both in academia as well as government and industry. The participants will describe their experiences relating to all aspects of their careers, and a few will give talks on the research areas they are exploring. See <http://www.gwu.edu/~spwm>.

Social Events

All events listed are open to all registered participants. It is strongly recommended that for any event requiring a ticket, tickets should be purchased through advance registration. Only a very limited number of tickets, if any, will be available for sale on site. If you must cancel your participation in a ticketed event, you may request a 50% refund by returning your tickets to the Mathematics Meetings Service Bureau (MMSB) by **December 27**. After that date no refunds can be made. Special meals are available at banquets upon advance request, but this must be indicated on the Advanced Registration/Housing Form.

AMS Banquet: As a fitting culmination to the Meetings, the AMS banquet provides an excellent opportunity to socialize with fellow participants in a relaxed atmosphere. The participant who has been a member of the Society for the greatest number of years will be recognized and will receive a special award. The banquet will be held on Saturday evening, with dinner served at 7:30 p.m. Tickets are US\$58 including tax and gratuity. The banquet will be preceded by a reception at 6:30 p.m.

Association of Christians in the Mathematical Sciences (ACMS) Reception and Banquet, Friday, 6:00 p.m.–8:00 p.m. This annual dinner at 6:30 p.m. is preceded by a reception at 6:00 p.m. and will be followed by a talk at 7:30 p.m. by **Rosalind Picard**, Massachusetts Institute of Technology Media Lab, *Robots, autism, and God*, presenting her work on affective computing, an interdisciplinary field that explores new systems that recognize and respond to human emotions. See <http://www.acmsonline.org> for details.

Annual Association of Lesbian, Gay, Bisexual, and Transgendered Mathematicians Reception, Thursday, 6:00 p.m.–8:00 p.m. All are welcome to attend this open reception affiliated with NOGLSTP, the National Organization of Gay and Lesbian Scientists and Technical Professionals, Inc.

AWM Reception: There is an open reception on Wednesday at 9:30 p.m. after the AMS Gibbs Lecture. This year reception attendees are invited to participate in a networking activity based on the game SET which will provide opportunities to meet new people and have added fun at the reception.

Budapest Semesters in Mathematics Annual Alumni Reunion, Thursday, 5:30 p.m.–7:00 p.m. All alumni, family, and spouses are welcome to attend.

University of Chicago Mathematics Alumni Reception, Thursday, 6:00 p.m.–7:00 p.m.

Claremont Colleges Alumni Reception, Thursday, 7:00 p.m.–9:00 p.m. The Claremont Colleges invite alumni,

students, faculty and friends to join us for our annual reception. Drinks and hors d'oeuvres will be served and guests are welcome.

Reception for Graduate Students and First-Time Participants, Wednesday, 5:30 p.m.–6:30 p.m. The AMS and MAA cosponsor this social hour. Graduate students and first-timers are especially encouraged to come and meet some old-timers to pick up a few tips on how to survive the environment of a large meeting. Light refreshments will be served.

University of Illinois at Urbana Champaign, Department of Mathematics Alumni Reception, Friday, 5:30 p.m.–7:30 p.m. Everyone ever connected with the department is encouraged to get together for conversation and to hear about mathematics at the University of Illinois. For more information please visit <http://www.math.illinois.edu/jmm-reception.html>.

Knitting Circle, Thursday, 8:15 p.m.–9:45 p.m. Bring a project (knitting/crochet/tatting/beading/ect.) and chat with other mathematical crafters!

Reception in Honor of Retiring MAA Executive Director Tina Straley, Friday, 5:00 p.m.–6:30 p.m. Join the MAA and your colleagues in wishing Tina well as we thank her for her leadership and for her wonderful spirit that has enriched the mathematical community. Tickets are US\$25 each, including tax and gratuity. There will be a cash bar and light hors d'oeuvres will be served.

MAA/Project NExT Reception, Friday, 8:30 p.m.–10:30 p.m.; organized by **Judith Covington**, Louisiana State University Shreveport; **Joseph A. Gallian**, University of Minnesota Duluth; **Aparna W. Higgins**, University of Dayton; and **P. Gavin LaRose**, University of Michigan. All Project NExT Fellows, consultants, and other friends of Project NExT are invited.

MAA Two-Year College Reception, Wednesday, 5:45 p.m.–7:00 p.m., is open to all meeting participants, particularly two-year faculty members. This is a great opportunity to meet old friends and make some new ones. There will be hot and cold refreshments and a cash bar.

Mathematical Reviews Reception, Friday, 6:00 p.m.–7:00 p.m. All friends of the *Mathematical Reviews* (MR) are invited to join reviewers and MR editors and staff (past and present) for a reception in honor of all of the efforts that go into the creation and publication of the *Mathematical Reviews* database. Refreshments will be served.

Mathematical Institutes Open House, Wednesday, 5:30 p.m.–8:00 p.m. Participants are warmly invited to attend this open house which is co-sponsored by several of the Mathematical Institutes in North America. This reception precedes the Gibbs Lecture. Come find out about the latest activities and programs at each of the institutes that may be suited to your own research.

MER/IME Banquet, Thursday, 6:30 p.m.–9:30 p.m. The Mathematicians and Education Reform (MER) Forum and the Institute for Mathematics and Education (IME) welcome all mathematicians who are interested in precollege, undergraduate, and/or graduate educational issues to attend the MER/IME banquet on Thursday evening. This is an opportunity to make or renew contacts with other mathematicians who are involved in education projects

and to engage in lively conversation about educational issues. The after-dinner discussion is an open forum for participants to voice their impressions, observations, and analyses of the current education scene. There will be a cash bar beginning at 6:30 p.m.; dinner will be served at 7:30 p.m. Tickets are US\$60 each, including tax and gratuity.

National Association of Mathematicians Banquet, Friday, 6:00 p.m.–8:40 p.m. A cash bar reception will be held at 6:00 p.m., and dinner will be served at 6:30 p.m. Tickets are US\$58 each, including tax and gratuity. The Cox-Talbot Invited Address will be given after the dinner.

NSA Women in Mathematics Society Networking Session, Thursday, 6:00 p.m.–8:00 p.m. All participants are welcome to this annual event. Please stop by the NSA booth in the exhibit hall for the exact location.

Pennsylvania State University Mathematics Alumni Reception, Wednesday, 6:30 p.m.–8:15 p.m. Please join us for hors d'oeuvres and beverages and mingle with math alumni, faculty, and College of Science representatives.

Student Hospitality Center, Wednesday–Friday, 9:00 a.m.–5:00 p.m., and Saturday, 9:00 a.m.–3:00 p.m., organized by **Richard** and **Araceli Neal**, American Society for the Communication of Mathematics.

Reception for Undergraduates, Wednesday, 4:00 p.m.–5:00 p.m.

Other Events of Interest

AMS Information Booth: All meetings participants are invited to visit the AMS Information Booth during the meetings. A special gift will be available for participants, compliments of the AMS. AMS staff will be at the booth to answer questions about AMS programs and membership.

Book Sales and Exhibits: All participants are encouraged to visit the book, education media, and software exhibits from 12:15 p.m.–5:30 p.m. on Wednesday, 9:30 a.m.–5:30 p.m. on Thursday and Friday, and 9:00 a.m.–noon on Saturday. Books published by the AMS and MAA will be sold at discounted prices somewhat below the cost for the same books purchased by mail. These discounts will be available only to registered participants wearing the official meetings badge. Participants visiting the exhibits are required to display their meetings badge in order to enter the exhibit area.

The MAA and the AMS cordially invite all registered participants to enjoy complimentary tea and coffee while perusing the associations' booths.

Mathematical Sciences Employment Center: Those wishing to participate in the Mathematical Sciences Employment Center should read carefully the important article about the center beginning on page 1343 in this issue of *Notices* or at www.ams.org/profession/employment-services/employment-services. Employers should pay the appropriate fees; there are no fees for applicants to participate, except that all Employment Center participants must also register for the Joint Mathematics Meetings (JMM). Official meeting badges are required to enter the Employment Center.

Networking Opportunities: There are many opportunities to meet new friends and greet old acquaintances in addition to the vast array of scientific sessions offered at these meetings. These opportunities are listed on the networking page at jointmathematicsm meetings.org/2138_newcomers.html.

First-Time Participants: A special welcome is extended to all new participants of these meetings. For your convenience tips on how to GET AROUND at these meetings are found at the newcomers page at jointmathematicsm meetings/2138_newcomers.html. You may want to investigate the many receptions listed in the "Social Events" section, the Student Hospitality Center, and the Employment Center. On site you will find a Networking Center featuring casual seating, and lists of registered participants sorted by school and math subject classification will be available for your perusal. This is a great place to relax between sessions and forge new friendships.

Registering in Advance and Obtaining Hotel Accommodations

The MAA and the AMS make every effort to keep participant expenses at meetings and registration fees for meetings as low as possible. We work hard to negotiate the best hotel rates and to make the best use of your registration dollars to keep the meetings affordable for you. The AMS and the MAA encourage all participants to register for the meeting. When you pay the registration fee, you are helping to support a wide range of activities associated with planning, organizing, and running a major meeting of this size.

How to Register in Advance: The importance of advance registration cannot be overemphasized. Advance registration fees are considerably lower than the fees that will be charged for registration at the meetings. Participants registering by **November 18** may receive their badges, programs, and tickets (where applicable) in advance by mail approximately three weeks before the meetings. Those who do not want their materials mailed should check the box on the form. Because of delays that occur in U.S. mail to Canada, advance registrants from Canada must pick up their materials at the meetings. Because of delays that occur in U.S. mail to overseas, materials are never mailed overseas. There will be a special Registration Assistance Desk at the Joint Meetings to assist individuals who either did not receive this mailing or who have a problem with their registration. Please note that a US\$5 replacement fee will be charged for programs and badges that are mailed but not taken to Boston. Acknowledgments of registrations will be sent by email to the email addresses given on the Advance Registration/Housing Form. If you do not wish your registration acknowledged by email, please mark the appropriate box on the form.

Internet Advance Registration: This service is available for advance registration and hotel reservations at jointmathematicsm meetings.org/2138_reg.html. VISA, MasterCard, Discover, and American Express are the only methods of payment which are accepted for Internet advance registration, and charges to credit cards will be

made in U.S. funds. All Internet advance registrants will receive acknowledgment of payment upon submission of this completed form.

Cancellation Policy: Those who cancel their advance registration for the meetings, minicourses, or short courses by **December 30** will receive a 50% refund of fees paid. Those who cancel their banquet tickets by **December 27** will receive a 50% refund of monies paid. No refunds can be issued after these dates.

Joint Mathematics Meetings Registration Fees

	by Dec. 15	at meeting
Member of AMS, ASL, CMS, MAA, SIAM	US\$228	US\$300
Emeritus Member of AMS, MAA; Unemployed; High School Teacher; Developing Countries Special Rate; Librarian	50	60
Graduate Student Member of AMS, MAA	50	60
Graduate Student Nonmember	78	88
Undergraduate Student	50	60
High School Student	5	10
Temporarily Employed Nonmember	185	214
One-Day Member of AMS, ASL, CMS, MAA, SIAM	N/A	163
One-Day Nonmember	N/A	255
Nonmathematician Guest	15	15
MAA Minicourses *if space is available	US\$77	77*
Grad School Fair Table (table/posterboard/electricity)	US\$65	65
AMS Short Course		
Member of AMS or MAA	US\$102	US\$136
Nonmember	145	175
Student/Unemployed/Emeritus	50	71
MAA Short Course		
MAA or AMS Member	US\$153	US\$163
Nonmember	204	214
Student/Unemployed/Emeritus	77	87

Full-Time Students: Those currently working toward a degree or diploma. Students are asked to determine whether their status can be described as graduate (working toward a degree beyond the bachelor's), undergraduate (working toward a bachelor's degree), or high school (working toward a high school diploma) and to mark the Advance Registration/Housing Form accordingly.

Graduate Student: The member status refers to any graduate student who is a member of the AMS or MAA. These students should check with their department administrator to check their membership status.

Emeritus: Any person who has been a member of the AMS or MAA for twenty years or more and who retired because of age or long-term disability from his or her latest position.

Librarian: Any librarian who is not a professional mathematician.

Unemployed: Any person currently unemployed, actively seeking employment, and not a student. It is not intended to include any person who has voluntarily resigned or retired from his or her latest position.

Developing Country Participant: Any person employed in developing countries where salary levels are radically noncommensurate with those in the U.S.

Temporarily Employed: Any person currently employed but who will become unemployed by June 1, 2012, and who is actively seeking employment.

Nonmathematician Guest: Any family member or friend who is not a mathematician and who is accompanied by a participant in the meetings. These official guests will receive a badge and may attend all sessions and the exhibits.

Participants Who Are Not Members of the AMS or MAA and register for the meetings as a nonmember will receive mailings after the meetings are over with special membership offers.

Advance registration and on-site registration fees only partially cover the expenses of holding meetings. All mathematicians who wish to attend sessions are expected to register and should be prepared to show their badges if so requested. Badges are required to enter the exhibit area, to obtain discounts at the AMS and MAA Book Sales, and to cash a check with the Joint Meetings cashier.

Advance registration forms accompanied by insufficient payment will be returned, thereby delaying the processing of any housing request; a US\$5 charge will be assessed if an invoice must be prepared to collect the delinquent amount. Overpayments of less than US\$5 will not be refunded.

For each invalid check or credit card transaction that results in an insufficient payment for registration or housing, a US\$5 charge will be assessed. Participants should check with their tax preparers for applicable deductions for education expenses as they pertain to these meetings.

If you wish to be included in a **list of individuals sorted by mathematical interest**, please provide the one mathematics subject classification number of your major area of interest on the Advance Registration/Housing Form. (A list of these numbers is available by sending an empty email message to abs-submit@ams.org; include the number 1067 as the subject of the message.) Copies of this list will be available for your perusal in the Networking Center.

If you do not wish to be included in any mailing list used for promotional purposes, please indicate this in the appropriate box on the Advance Registration/Housing Form.

Advance Registration Deadlines

There are three separate advance registration deadlines, each with its own advantages and benefits.

EARLY meetings advance registration
(room drawing) **November 4**

ORDINARY meetings advance registration
(hotel reservations, materials
mailed) **November 18**

FINAL meetings advance registration

(advance registration, short courses,
Employment Center, minicourses,
banquets)

December 15

Early Advance Registration: Those who register by the early deadline of **November 4** will be included in a random drawing to select winners of complimentary hotel rooms in Boston. Multiple occupancy is permissible. The location of rooms to be used in this drawing will be based on the number of complimentary rooms available in the various hotels. Therefore, the free room may not necessarily be in the winner's first-choice hotel. The winners will be notified by mail prior to **December 24**. So register early!

Ordinary Advance Registration: Those who register after **November 4** and by the ordinary deadline of **November 18** may use the housing services offered by the MMSB but are not eligible for the room drawing. You may also elect to receive your badge and program by mail in advance of the meetings.

Final Advance Registration: Those who register after **November 19** and by the final deadline of **December 15** must pick up their badges, programs, and any tickets for social events at the meetings. Unfortunately, it is sometimes not possible to provide final advance registrants with housing, so registrants are strongly urged to make their hotel reservations by **November 18**. Please note that the **December 15** deadline is firm; any forms received after that date will be returned and full refunds issued. To pick up your materials, please come to the Meetings Registration Desk located on the second floor of the Hynes Convention Center.

Special Assistance

We strive to take the appropriate steps required to ensure that no individual with a disability is excluded, denied services, segregated, or otherwise treated differently. Please tell us what you require to help make your participation more enjoyable and meaningful. If you require special assistance, auxiliary aids or other reasonable accommodations to fully participate in this event, please check off the appropriate box on the Registration/Housing Form or email the MMSB at mmsb@ams.org. All requests for special accommodations under the Americans with Disabilities Act of 1990 (ADA) must be made allowing enough time for evaluation and appropriate action by the JMM. Any information received about a disability will remain confidential.

Hotel Reservations

The AMS and MAA contract only with facilities who are working toward being in compliance with the public accommodations requirements of ADA. Participants requiring hotel reservations should read the instructions on the following hotel pages. Participants who did not reserve a room during advance registration and would like to obtain a room at one of the hotels listed on the following pages should call the hotels directly after **December 15**. However, the MMSB can no longer guarantee availability of rooms or special convention rates after that date.

How to Obtain Hotel Accommodations – 2012 Joint Mathematics Meetings

General

Participants must register in advance in order to obtain hotel accommodations through the Mathematics Meetings Service Bureau (MMSB). Special rates have been negotiated exclusively for this meeting at the following hotels: Marriott Cop-ley Place Boston, Sheraton Boston, Boston Park Plaza Hotel & Towers, Boston Omni Parker House, Hilton Back Bay, and The Colonnade Hotel. **Reservations can only be made for these hotels through the MMSB to receive JMM rates.**

The hotels will not be able to accept reservations directly until after **December 14**. At that time, rooms and rates will be based on availability. Higher rates may be applied to any rooms reserved directly with the hotels before **December 14**.

To reserve a room, please complete the housing section of the Advanced Registration/Housing (ARH) Form (via paper or the web) by **November 18**. All reservations must be guaranteed by either credit card or check deposit in the total amount of your first night stay. If you use the online form, a credit card number will be required for guarantee. If you use the paper form, a credit card number or check may be given for guarantee. For your security, credit card numbers will not be accepted by postal mail, e-mail, or fax. If you wish to guarantee your room by credit card and are submitting a paper form, the MMSB will call you at the number you provided. The online form is located at <https://www.jointmathematicsmeetings.org/meetreg?meetnum=2138>. The paper form is located at the back of this announcement. Participants interested in suites should contact the MMSB at mmsb@ams.org or 1-800-321-4267 ext. 4137 or 4144 for further information. **Sorry, reservations cannot be taken over the phone.**

Confirmations

All hotels will be sending e-mail confirmations if e-mail addresses are provided. Please contact the MMSB after **December 14** if you did not receive a confirmation number.

ADA Accessibility

We strive to take the appropriate steps required to ensure that no individual with a disability is excluded, denied services, segregated or otherwise treated differently. Please tell us what you require to help make your participation more enjoyable

Deadlines

- Complimentary Room Drawing: **November 4**
- Reservations through MMSB: **November 18**
- Changes/Cancellations through MMSB: **December 6**

Complimentary Room Drawing

Anyone who reserves a room through the MMSB by **November 4** is eligible for a drawing to receive complimentary room nights during the meeting. See *How to Register in Advance* for details. Good luck!

Looking for a Roommate?

For your convenience, a search board has been set up at jointmathematicsmeetings.org/jmm-bboards to help you find a roommate.

and meaningful. If you require special assistance, auxiliary aids or other reasonable accommodations to fully participate in this meeting, please check off the appropriate box on the ARH Form or e-mail the MMSB at mmsb@ams.org. All requests for special accommodations under the Americans with Disabilities Act of 1990 (ADA) must be made allowing enough time for evaluation and appropriate action by the AMS and MAA. Any information obtained about a disability will remain confidential.

Environmental Policies

All of the hotels have successful “green” programs in place. The Marriott is the recipient of more ENERGY STAR labels than any other hotel company since 2004. In addition, the Sheraton has numerous guest reward programs in place, including the “Green Guest Linen and Terry Program”.

Rates

- All rates are subject to applicable local and state taxes in effect at time of check-in; currently 14.45%.

- Only certified students or unemployed mathematicians qualify for student rates.
- See the ARH Form for a detailed breakdown of rates for each hotel.

Cancellation Policies

- The Omni Parker House and the Sheraton have a 72-hour cancellation policy prior to check-in. The other four hotels have a 24-hour cancellation policy prior to check-in.

Guarantee Requirements

- One night deposit by check, or
- Credit cards (online only): Visa, MC, AMEX, Diners, and Discover. For your security, we do not accept credit card numbers by postal mail, e-mail or fax. If you reserve a room by paper form and want to guarantee by credit card, the MMSB will contact you at the phone number you provided.

Check-in/Check-out

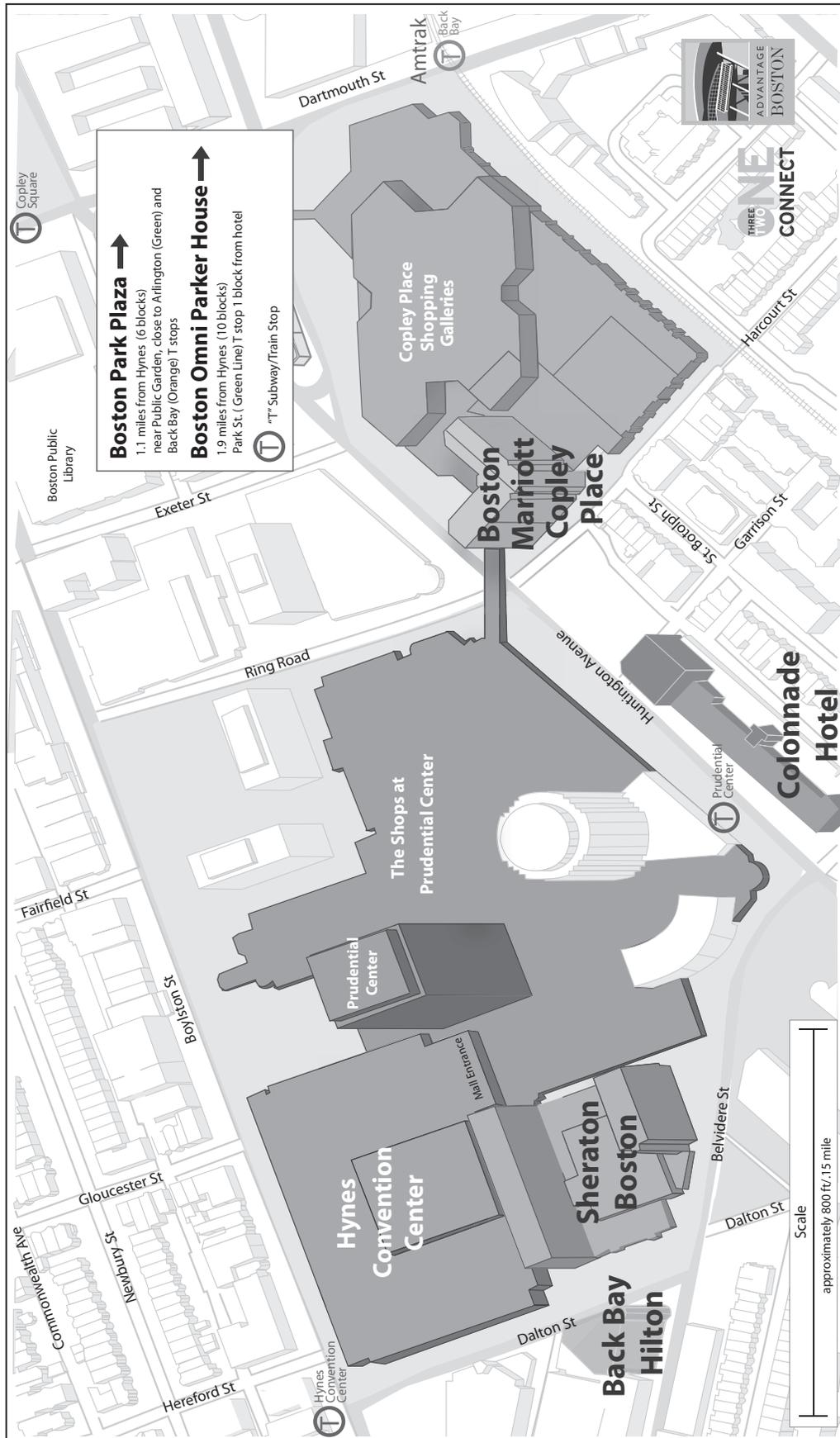
Check-in at the Marriott is 4:00 p.m. Check-in at the other five hotels is 3:00 p.m. Check-out at each hotel is noon.

Internet Access/Wireless

- **Marriott Copley Place:** Complimentary wireless available in the lobby and public areas; wired and wireless in guest rooms for a daily rate of US\$12.95
- **Sheraton Boston:** Complimentary wireless available in the lobby and public areas; wired and wireless in the guest rooms for a daily rate of US\$9.95
- **Boston Omni Parker House:** Wireless is offered in the lobby, restaurants, and all of the guest rooms to hotel guests **ONLY** for a daily rate of US\$9.95.
- **Hilton Back Bay:** Complimentary wireless available in the lobby and public areas; wired **ONLY** in guest rooms for a daily rate of US\$14.95
- **The Colonnade Hotel:** Complimentary wireless available in the lobby and public areas; wired and wireless in guest rooms for a daily rate of US\$13.95
- **Boston Park Plaza Hotel & Towers:** Complimentary wireless available in the lobby and mezzanine level; wired **ONLY** in the guest rooms for a daily rate of US\$10.45

<p>Marriott Copley Place Boston (Co-Headquarters)</p>	<p>Marriott Copley Place Boston (Co-Headquarters)</p> <p>.25 miles, connected to the Hynes Convention Center</p> <p>110 Huntington Avenue Boston, MA 02116 Single/Double Rate: US\$159.00 Student Single/Double: US\$149.00</p> <p>Smoke-free hotel. Restaurants: Champions, Connexion Lounge, and Starbucks; Fitness center; Indoor heated pool; Spa services; Business center; Full amenities in guest rooms; Laptop-sized safes in guest rooms; Windows do not open; Children under 15 free in room with an adult; Cribs available upon request at no charge; Rollaways no charge; No pets allowed except service animals; Valet parking or self-parking US\$44.00 + tax per day; See the travel section of this announcement for other parking options. Confirmations sent by e-mail only.</p>	<p>Sheraton Boston (Co-Headquarters)</p>	<p>Sheraton Boston (Co-Headquarters)</p> <p>Next door, connected to the Hynes Convention Center</p> <p>39 Dalton Street Boston, MA 02199 Single/Double Rate: US\$159.00 Student Single/Double: US\$149.00</p> <p>Smoke-free hotel. Restaurants: Café Apropos, Sidebar & Grille, and Starbucks; Fitness center; Indoor heated pool; Spa services; Business center; Full amenities in guest rooms; Laptop-sized safes in guest rooms; Windows do not open; Children under 18 free in room with an adult; Cribs available upon request at no charge; Rollaways no charge; Pets allowed (under 80 pounds only); Valet parking US\$44.00 + tax per day; Self-parking US\$39.00 + tax per day; See the travel section of this announcement for other parking options. Confirmations sent by e-mail only.</p>	<p>Boston Omni Parker House</p>	<p>Boston Omni Parker House</p> <p>10 blocks from the Hynes Convention Center Green Line (Park Street stop) - "The T" located 1 block from hotel</p> <p>60 School Street Boston, MA 02108 Single/Double: US\$149.00 Student Single/Double: US\$129.00 (single/double only)</p> <p>Smoke-free hotel. Restaurants: Parker's Restaurant and The Last Hurray; Spa services; Business center; Full amenities in guest rooms; Safe deposit boxes available at front desk; Windows open in all rooms, including suites; Pets allowed (under 25 pounds); Children under 12 free in room with an adult; Cribs available upon request at no charge; Rollaways no charge; Valet parking ONLY for US\$42.00 + tax per day. See the travel section of this announcement for other parking options. Confirmations sent by e-mail only.</p>
<p>Hilton Back Bay</p>	<p>Hilton Back Bay</p> <p>3 blocks from the Hynes Convention Center</p> <p>40 Dalton Street Boston, MA 02115 Single/Double Rate: US\$129.00 Student Single/Double US\$119.00</p> <p>Smoke-free hotel. Restaurants: Forty Dalton and Starbucks; Fitness center; Spa services; Business center; Full amenities in guest rooms; Laptop-sized safes in guest rooms; Windows open in all rooms, including suites; Children under 16 free in room with an adult; Cribs available upon request at no charge; Rollaways available US\$25 per night; Pets allowed; Self parking ONLY for US\$41.00 + tax per day; See the travel section of this announcement for other parking options. Confirmations sent by e-mail only.</p>	<p>The Colonnade Hotel</p>	<p>The Colonnade Hotel</p> <p>3 blocks from the Hynes Convention Center</p> <p>120 Huntington Avenue Boston, MA 02116 Single/Double Rate: US\$124.00 Student Single/Double: US\$114.00</p> <p>Smoke-free hotel. Restaurant: Brasserie Jo; Fitness center; Spa services; Business center; Full amenities in guest rooms; Laptop-sized safes in guest rooms; Windows open in all rooms, including suites; Children under 16 free in room with an adult; Cribs available upon request at no charge; Rollaways no charge; Pets allowed; Self-parking ONLY for US\$38.00 per day; See the travel section of this announcement for other parking options. Confirmations sent by e-mail only.</p>	<p>Boston Park Plaza Hotel & Towers</p>	<p>Boston Park Plaza Hotel & Towers</p> <p>6 blocks from the Hynes Convention Center - Green line (Arlington stop) or Orange line (Back Bay stop) - "The T" located on same block as hotel</p> <p>50 Park Plaza at Arlington Boston, MA 02116 Single/Double Rate: US\$122.00 Student Single/Double: US\$112.00</p> <p>Smoke-free hotel. Restaurants: McCormick & Schmick's, Grand Lobby and Pairing Lounge; Spa services; Business center; Full amenities in guest rooms; Safe deposit boxes available at front desk; Windows open in all rooms, including suites; Pets allowed; Children under 18 free in room with an adult; Cribs available upon request at no charge; Rollaways available US\$25 per stay; Valet parking ONLY for US\$44.00 + tax per day. See the travel section of this announcement for other parking options. Confirmations sent by e-mail only.</p>

2012 Joint Mathematics Meetings Hotel Map



Participants should be aware that most hotels are starting to charge a penalty fee to guests for departure changes made before or after guests have checked into their rooms. These hotels are indicated on the hotel page at jointmathematicsmetings.org/2138_hotelpage.html. Participants should also inquire about this at check-in and make their final plans accordingly.

Participants should also be aware that it is general hotel practice in most cities to hold a nonguaranteed reservation until 6:00 p.m. only. When one guarantees a reservation by paying a deposit or submitting a credit card number as a guarantee in advance, however, the hotel will usually honor this reservation until checkout time the following day. If the individual holding the reservation has not checked in by that time, the room is then released for sale, and the hotel retains the deposit or applies a room charge to the credit card number submitted equivalent to a one-night stay.

If you hold a guaranteed reservation at a hotel but are informed upon arrival that there is no room for you, there are certain things you can request the hotel do. First, they should provide for a room at another hotel in town for that evening at no charge. (You already paid for the first night when you made your deposit.) Second, they should pay for taxi fares to the other hotel that evening and back to the hotel the following morning, assuming a room is available. Third, they should pay for one telephone call so that you can notify people of where you are staying. The hotel should make every effort to find a room for you in their hotel the following day and, if successful, pay your taxi fares to and from the second hotel so that you can pick up your baggage and bring it to the first hotel. Not all hotels in all cities follow this practice, so your request for these services may bring mixed results or none at all. If you did not receive satisfactory service in this regard, please inform the Housing Coordinator for this meeting.

Importance of Staying in the Official Meetings Hotels: Your patronage of the official Meetings hotels enables the JMM to secure the meeting space at a greatly reduced cost which helps to keep the cost of the meeting and your registration fees down.

Room Drawing: Win FREE room nights at our official hotels as listed on the hotel pages. Multiple winners! Participants who register and reserve a room at any of the listed meetings hotels by **November 4**, will automatically be included in a random drawing to select a winner of free room nights in that hotel. The number of drawings to be made will be based on the number of complimentary room nights available in the various hotels. Multiple occupancy is permissible. The winners will be drawn at random from the hotel reservation lists and notified by email or phone prior to **December 24**.

Miscellaneous Information

Audio-Visual Equipment: Standard equipment in all session rooms is one overhead projector and screen. Invited 50-minute speakers are automatically provided with an ELMO visual presenter (document camera/projector), one overhead projector, and a laptop projector; AMS Spe-

cial Sessions and Contributed Papers, and MAA Invited and Contributed Paper Sessions, are provided with the standard equipment and a laptop projector. Blackboards are not available, nor are Internet hookups in session rooms. Any request for additional equipment should be sent to meet@ams.org and **received by November 1**.

Equipment requests made at the meetings most likely will not be granted because of budgetary restrictions. Unfortunately no audio-visual equipment can be provided for committee meetings or other meetings or gatherings not on the scientific program.

Childcare: The AMS and the MAA will again offer childcare services for the Joint Mathematics Meetings to registered participants.

The childcare will be offered through KiddieCorp Children's Program. KiddieCorp is an organization that has been providing high-quality programs for children of all ages at meetings throughout the United States and Canada since 1986. Read all about them at www.kiddiecorp.com/.

The childcare services provided at the JMM are for children ages 6 months through 12 years old. Space per day will be limited and is on a space available basis. The dates and times for the program are January 4-7, 2012, 8:00 a.m.-5:00 p.m. each day. It will be located at the Sheraton Boston. If you would like to know how many children will be in the same age group as your child's, please call KiddieCorp. Parents are encouraged to bring snacks and beverages for their children but items such as juice boxes, Cheerios, and crackers will be provided. KiddieCorp can arrange meals for children at cost plus 15% or parents can be responsible for meals for their children. Parents who have questions about specific programs that will be offered or special requests, rules, or needs for their children must call KiddieCorp ahead of time.

Registration starts on **September 1**. The registration fee is US\$30 per family (nonrefundable). Additional cost will be US\$12 per hour per child or US\$9 per hour per child for graduate students. These reduced child care rates are made possible to the meetings participant by the MAA and the AMS, who heavily subsidize the cost of this service, thus keeping this program affordable for families. Parents must be registered for the JMM to participate. Full payment is due at the time of registration with KiddieCorp. Deadline for registering is **December 9, 2011**.

If parents do not pick up their children at the time scheduled or by the end of the day (no later than 5:00 p.m.), they will be charged a late fee of US\$5 per child for every 15 minutes thereafter.

Cancellations must be made to KiddieCorp prior to December 9, 2011, for a full refund. Cancellations made after that date will be subject to a 50% cancellation fee. Once the program has begun, no refunds will be issued.

To register, go to <https://www.kiddiecorp.com/jmmkids.htm> or jointmathematicsmetings.org/2138_daycare.html, or call KiddieCorp at 858-455-1718 to request a form.

Email Services: Limited email access for all Joint Meetings participants will be available in an email center located near the JMM Registration Desk. The hours of

operation will be published in the program. Participants should be aware that **complimentary Internet access** will be available in the public areas of the Hynes Convention Center.

Information Distribution: Tables are set up in the exhibit area for dissemination of general information of possible interest to the members and for the dissemination of information of a mathematical nature not promoting a product or program for sale. Information must be approved by the director of meetings prior to being placed on these tables.

If a person or group wishes to display information of a mathematical nature promoting a product or program for sale, they may do so in the exhibit area at the Joint Books, Journals, and Promotional Materials exhibit for a fee of US\$50 (posters are slightly higher) per item. Please contact the exhibits manager, MMSB, P.O. Box 6887, Providence, RI 02940, or by email at cpd@ams.org for further details.

The administration of these tables is in the hands of the AMS-MAA Joint Meetings Committee, as are all arrangements for Joint Mathematics Meetings.

Local Information: For information about the city see www.bostonusa.com/visit.

Petition Table: At the request of the AMS Committee on Human Rights of Mathematicians, a table will be made available in the exhibit area at which petitions on behalf of named individual mathematicians suffering from human rights violations may be displayed and signed by meetings participants acting in their individual capacities. For details contact the director of meetings in the Providence office at 401-455-4145 or by email at pop@ams.org.

Signs of moderate size may be displayed at the table but must not represent that the case of the individual in question is backed by the Committee on Human Rights unless it has, in fact, so voted. Volunteers may be present at the table to provide information on individual cases, but notice must be sent at least seven days in advance of the meetings to the director of meetings in the Providence office. Since space is limited, it may also be necessary to limit the number of volunteers present at the table at any one time. The AMS Committee on Human Rights may delegate a person to be present at the table at any or all times, taking precedence over other volunteers.

Any material that is not a petition (e.g., advertisements, résumés) will be removed by the staff. At the end of the exhibits on Saturday, any material on the table will be discarded, so individuals placing petitions on the table should be sure to remove them prior to the close of exhibits.

Telephone Messages: The most convenient method for leaving a message is to do so with the participant's hotel. Another method would be to leave a message at the meetings registration desk from January 4 through 7 during the hours that the desk is open. These messages will be posted on the Mathematics Meetings Message Board; however, staff at the desk will try to locate a participant in the event of a bona fide emergency. The telephone number will be published in the program and daily newsletter.

Travel/Transportation

Boston is on Eastern Standard Time. Boston's Logan International Airport (BOS) is located within 10 miles of the John B. Hynes Veterans Memorial Convention Center (Hynes) and is served by all major airlines. For more information about Logan Airport, see www.massport.com.

The **official airline** for the meeting is **United Airlines**. Participants are encouraged to book their flights for the meeting, where possible, with United or United Express and receive special pricing on scheduled service to Boston on applicable carriers. Book your airline reservation with United by calling the toll free reservation line (1-800-521-4041), through www.united.com, or going through your preferred travel professional. Please be sure to reference the Meeting ID **Tour Code 587FL**. Reservation agents are available Monday thru Friday from 8:00 a.m. to 10:00 p.m. (ET) at 1-800-521-4041. The specialized meeting reservations center will be closed on all major holidays.

There is special discounted pricing on published fares for qualifying travel in or between the domestic 48 States, Hawaii, and Canada when the tickets are purchased subject to all restrictions and rules applicable to the fare purchased and issued in the United States. Discounted rates are

Domestic 48 states, Hawaii, Canada	
classes F, J, A, C, D, and Y—L	5%
Over 30 days advance ticketing	
classes A, Q, V, and W	7%
classes M, E, U, H, F, J, C, D, Y, B	10%
Bookings through www.united.com	5%

This special discount pricing is not applicable to Internet-only fares. Mileage Plus members will receive full credit to their account for all their miles flown when attending this meeting.

Special Discounts on Car Rentals with Hertz: Participants of the Joint Mathematics Meetings are eligible for discounts of up to 20% off the applicable rental rates plus unlimited mileage when reservations are made in conjunction with United Airlines air reservations. To take advantage of this discount, call 888-444-1074 or to go www.Hertz.com. Please make sure you reference use **Hertz Discount number CV# 02R30006**. To make reservations with Hertz without using United Airlines, see below.

Car Rental: Hertz is the official car rental company for the meeting. To make a reservation using the special meeting rates, please provide the convention number **CV# 04N30002** when making reservations. Details on rates and general instructions can be found at <http://jointmathematicsm meetings.org/meetings/national/jmm2012/04N30002.bos12.pdf>. You can make reservations online at http://link.hertz.com/link.html?id=23051&LinkType=HZLK&TargetType=Homepage&ret_url=www.ams.org or call Hertz directly at 800-654-2240 (U.S. and Canada) or 405-749-4434 (other countries). At the time of reservation, the meeting rates will be automatically compared to other

Hertz rates and you will be quoted the best comparable rate available.

Traveling from the Airport

Taxi Service: Taxis are available outside the baggage claim areas at all terminals 24 hours a day. The fares currently range from US\$25–30 (for the Omni Parker House) to US\$35–40 for the hotels close to the Hynes (Sheraton and Marriott). Travel time will be approximately 15–20 minutes. It is recommended that you ask the taxi driver for a receipt showing the driver's name, company, and amount paid.

Airport Shuttle: Service is available through GOBostonShuttle (formerly Ultimate Shuttle), 888-437-4379, or www.gobostonshuttle.com/; reservations are required. The shuttle operates 24 hours/seven days a week. Fees are currently US\$17 per person each way for the Hynes and all meeting hotels except the Colonnade, which is US\$21 per person each way. If you have more than two bags per person, an additional US\$5 per bag fee applies. There is no charge for children under three years. Please check the <http://jointmathematicsm meetings.org> website for information on how to receive a discount on GoBostonShuttle. To find the shuttles, exit the terminals from the baggage claim area and look for signs that say "Shared and Scheduled Vans".

Driving Directions to the Hynes Convention Center: The Hynes Convention Center is located at 900 Boylston Street, Boston, MA 02115. Please see the hotel pages for the specific addresses of the meeting hotels. Also see the map online at http://jointmathematicsm meetings.org/meetings/national/jmm2012/google_map_bos. This map gives the option of directions from Google maps when you click on a meeting hotel. The Sheraton Boston and the Marriott Copley Place are connected to the Hynes/Prudential Center complex, which includes the Convention Center, the Prudential Center, the Prudential Center Mall and the Copley Place Shopping Galleries. The Colonnade Hotel and the Hilton Back Bay Hotel are adjacent to the complex.

From Logan International Airport and I-90 Westbound: Merge onto I-90 West/Mass Pike/Ted Williams tunnel and take exit 24 toward I-93. Merge onto I-93 South via exit on the left. Take the Massachusetts Avenue exit, Exit 18. Take a slight right onto the Massachusetts Avenue Connector and take your next right onto Massachusetts Avenue. Follow Massachusetts Avenue 1.4 miles and take a right onto Boylston Street. The Hynes Convention Center is on the right.

From I-90 (Mass Pike) Eastbound: Take Exit 22 (Prudential/Copley Place). Stay left and take the ramp toward the Prudential Center as you exit onto Huntington Avenue. Stay right while on Huntington Avenue, and at the next set of lights turn right onto Belvidere Street, then take a right onto Dalton Street. At the first set of lights on Dalton Street take a right onto Boylston Street. The Hynes Convention Center's main entrance and driveway will be immediately on the right.

From I-93 Southbound: Follow I-93 South, staying to the far right as you approach Boston. Take Exit 26 (Stor-

row Drive). Follow Storrow Drive for approximately two miles to the Fenway/Kenmore Exit, which is the first exit after Massachusetts Avenue, on the left. Stay left as you exit Storrow Drive, going toward the Fenway. Continue to the first set of lights, staying left, onto Boylston Street. Go through four sets of lights on Boylston Street. The Hynes Convention Center's main entrance and driveway will be immediately on the right.

From I-93 Northbound: Take Exit 18 (Mass Avenue/Roxbury). At the third set of lights, turn left onto the Massachusetts Avenue Connector, then turn right onto Massachusetts Avenue. Follow Massachusetts Avenue for 1.4 miles, and take a right onto Boylston Street. The Hynes Convention Center's main entrance and driveway will be on the right.

Public Transportation

The Massachusetts Bay Transportation Authority (MBTA, known locally as the "T") is Boston's public transit system. It includes the subway system, buses, boat/ferries, and the commuter rail. Please refer to www.mbta.com for information, schedules and maps. All subway trips are US\$2; the senior/disabled fare is US\$0.60. Bus fare is US\$1.50 per trip; the senior/disabled rate is US\$0.40. The commuter rail fares range from US\$1.70 to US\$8.25.

From Logan Airport to the Hynes Convention Center by Public Transportation

Via the MBTA (subway): Board the complimentary Massport shuttle bus which stops outside the baggage claim area of all terminals, and get off at the Airport "T" station. Take an inbound Blue Line train (marked Bowdoin Station) to Government Center. Change at Government Center to an outbound Green Line. Follow the signs to board either the Green Line "B", "C", or "D" trains to the Hynes Convention Center stop. Turn left as you leave the subway, and left again at Boylston Street. The Hynes (and the Prudential Tower) will be straight ahead. An alternative route is to board the Green Line "E" train ("Arborway/Heath Street") and exit at Prudential Station. Enter the Prudential Center Mall, go up the escalator, turn left and proceed down the Belvidere Arcade to the end where you will see a Dunkin Donuts. There will be a garden on your right most of the way. Go past Dunkin Donuts (turning slightly left) into Hynes Court. The entrance to the Hynes is just past Dunkin Donuts. The entrance to the Sheraton is to the left of the entrance to the Hynes.

Via MBTA (bus): Take the Silver Line Bus (SL1) which stops at Logan Airport's Terminals A, B, C, and E. There are signs directing you to the Silver Line bus as you leave the baggage claim areas. Take this bus to South Station. See below for directions to the Hynes from South Station.

From the Boston Train Stations to the Hynes/Prudential Center Complex

There are usually taxis waiting near the train stations. To take public transportation, please refer to the following directions.

Back Bay Station (Amtrak's Acela and Regional trains, MBTA Commuter Rail and the "T" Orange Line): Exit the Back Bay station onto Dartmouth Street. Cross Dartmouth Street and enter the Copley Place Mall (to the left of Neiman Marcus entrance). Go up the escalator and walk

straight through the Copley Place Mall to the Marriott Copley Place. To get to the Hynes Convention Center, cross the glass footbridge connecting the Marriott to the Prudential Center Mall, and walk through to the Center Court. Go straight through the Center Court down the Prudential Arcade and turn right at the end of the arcade at the Dunkin Donuts as you enter Hynes Court. The entrance to the Hynes is to the left of the Dunkin Donuts. The entrance to the Sheraton is near the entrance to the Hynes.

North Station (Amtrak's Downeaster trains, the MBTA Commuter Rail, "T" station for Orange and Green Lines): Take the outbound Green Line "B", "C", or "D" trains to the Hynes Convention Center stop. Once you get off the subway, go toward Boylston Street. Turn left at Boylston Street and the Hynes will be straight ahead. It is also possible to take the Green Line "E" train ("Arborway/Heath Street") to Prudential station, and enter the Hynes through the Prudential Center Mall. When you enter the mall, take the escalator up and at the top turn left into Belvidere Arcade. Go straight to the end until you see Dunkin Donuts. The entrance to the Hynes is just past Dunkin Donuts.

South Station (Amtrak's Acela and Regional trains, MBTA Commuter Rail and the "T" Red Line, also the bus terminal): From the South Station bus terminal or train station, go to the Red Line subway "T" entrance. Take an outbound Red Line train toward "Alewife" to the Park Street station. At Park Street, change to the outbound Green line "B", "C", or "D" trains to the Hynes Convention Center stop. Exit the subway turning left, and turn left again at Boylston Street. The Hynes will be straight ahead. You can also take the outbound Green Line "E" train to Prudential Station. (See directions from North Station.)

Parking

See hotel pages for parking information and rates at the meeting hotels. Parking at the Hilton, Marriott Copley Place, Sheraton Boston, and the Colonnade Hotels is convenient to the Hynes. Additional information on parking can be found at www.celebrateboston.com/parking.htm. All rates are subject to change. Other parking options include:

Auditorium Parking Garage, 50 Dalton St., 617-247-8006, pilgrimparking.com/boston-parking-garages/hynes-auditorium-garage.htm. Rates: US\$5 each ½ hour; US\$25 maximum up to 6:00 p.m.; US\$30 maximum up to 24 hours. Early Bird Special is US\$18 (arrive 3:00 a.m. to 9:00 a.m. and leave by 6:00 p.m.).

Belvidere Street Lot, 53 Belvidere St, Boston, 617-536-0910, www.celebrateboston.com/parking.53-belvidere-street-parking-lot.htm (only 50 parking spaces in lot). Rates: up to 1 hour: US\$12; up to 2 hours: US\$20; 2-3 hours: US\$24; 3-12 hours: US\$26; 24 hours: US\$29. Early Bird Special is US\$19 (in before 9:00 a.m. and out before 7:00 p.m.).

Copley Place Parking Garage, 100 Huntington Ave. (corner of Huntington Ave. and Dartmouth St.), 617-369-5025. Rates: 1 hour: US\$9; 2 hours: US\$18; 3 hours: US\$25; 3-10 hours: US\$30; 10-20 hours: US\$34; 24 hours: US\$35. Early Bird Special: US\$20 (Monday to Friday, in before 9:00 a.m., leave between 1:00 p.m. and 8:00 p.m.).

Prudential Center Parking Garage, 800 Boylston St., 617-236-3060, <http://www.prudentialcenter.com/parking/rates.php>. Rates: up to 1 hour: US\$9; 1 to 1.5 hours: US\$18; 1.5 to 2 hours: US\$27; 2-10 hours: US\$35; 10-24 hours: US\$39. Early Bird Special: US\$19 (Monday to Friday, arrive between 6:00 a.m. and 9:00 a.m., leave between 3:00 p.m. and 6:00 p.m.).

MotorMart Garage, 201 Stuart St., 617-482-8380, <http://www.motormartgarage.com>. The garage is located across the street from The Boston Park Plaza Hotel & Towers. Rates: up to 1 hour US\$8; up to 2 hours US\$12; 2-3 hours US\$16.00; 3-12 hours US\$20.00; 12-24 hours US\$31.

Boston Common Garage, Zero Charles St., 617-954-2098, www.massconvention.com/bcg.html. This garage is located near the Public Gardens and approximately eight blocks from the Hynes. Rates: up to 1 hour: US\$10; up to 2 hours US\$14; up to 3 hours US\$18; up to 10 hours, US\$23; 24-hour maximum charge: US\$28. Weekend rates: US\$11 (Enter after 6:00 a.m. on Saturday or Sunday and exit by 8:00 a.m. the next morning).

Honolulu, Hawaii

University of Hawaii at Manoa

March 3-4, 2012

Saturday - Sunday

Meeting #1078

Western Section

Associate secretary: Michel L. Lapidus

Announcement issue of *Notices*: October 2012

Program first available on AMS website: January 26, 2012

Program issue of electronic *Notices*: March 2012

Issue of *Abstracts*: Volume 33, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: November 22, 2011

For abstracts: December 13, 2011

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Zhiqin Lu, University of California Irvine, *Title to be announced.*

Peter Schroder, California Institute of Technology, *Title to be announced.*

Pham Tiep, University of Arizona, Tucson, *Title to be announced.*

Lauren Williams, University of California Berkeley, *Title to be announced.*

Special Sessions

Algebraic Number Theory, Diophantine Equations and Related Topics (Code: SS 6A), **Claude Levesque**, Université de Laval, Quebec, Canada.

Applications of Nonstandard Analysis (Code: SS 14A), **Tom Lindstrom**, University of Oslo, Norway, **Peter Loeb**, University of Illinois at Urbana-Champaign, and **David Ross**, University of Hawaii, Honolulu.

Arithmetic Geometry (Code: SS 5A), **Xander Faber**, **Michelle Manes**, and **Gretel Sia**, University of Hawaii.

Asymptotic Group Theory (Code: SS 12A), **Tara Davis**, Hawaii Pacific University, **Erik Guentner**, University of Hawaii, and **Michael Hull** and **Mark Sapir**, Vanderbilt University.

Automorphic and Modular Forms (Code: SS 4A), **Pavel Guerzhoy**, University of Hawaii, and **Zachary A. Kent**, Emory University.

Geometry and Analysis on Fractal Spaces (Code: SS 3A), **Michel Lapidus**, University of California, Riverside, **Hung Lu**, Hawaii Pacific University, **John A. Rock**, California State Polytechnic University, Pomona, and **Machiel van Frankenhuysen**, Utah Valley University.

Holomorphic Spaces (Code: SS 8A), **Hyungwoon Koo**, Korea University, and **Wayne Smith**, University of Hawaii.

Kaehler Geometry and Its Applications (Code: SS 1A), **Zhiqin Lu**, University of California Irvine, **Jeff Streets**, Princeton University, **Li-Sheng Tseng**, Harvard University, and **Ben Weinkove**, University of California San Diego.

Linear and Permutation Representations (Code: SS 2A), **Robert Guralnick**, University of Southern California, and **Pham Huu Tiep**, University of Arizona.

Mathematical Coding Theory and its Industrial Applications (Code: SS 13A), **J. B. Nation**, University of Hawaii, and **Manabu Hagiwara**, National Institute of Advanced Industrial Science and Technology, Japan.

Model Theory (Code: SS 11A), **Isaac Goldbring**, University of California Los Angeles, and **Alice Medvedev**, University of California Berkeley.

Noncommutative Algebra and Geometry (Code: SS 15A), **Jason Bell**, Simon Fraser University, and **James Zhang**, University of Washington.

Nonlinear Partial Differential Equations at the Common Interface of Waves and Fluids (Code: SS 9A), **Ioan Bejenaru** and **Vlad Vicol**, University of Chicago.

Nonlinear Partial Differential Equations of Fluid and Gas Dynamics (Code: SS 7A), **Elaine Cozzi**, Oregon State University, and **Juhi Jang** and **Jim Kelliher**, University of California Riverside.

Universal Algebra and Lattice Theory (Code: SS 10A), **Ralph Freese**, **William Lampe**, and **J. B. Nation**, University of Hawaii.

Tampa, Florida

University of South Florida

March 10–11, 2012

Saturday – Sunday

Meeting #1079

Southeastern Section

Associate secretary: Matthew Miller

Announcement issue of *Notices*: January

Program first available on AMS website: February 2, 2012

Program issue of electronic *Notices*: March 2012

Issue of *Abstracts*: Volume 33, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: November 29, 2011

For abstracts: January 18, 2012

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgsectional.html.

Invited Addresses

Anne Condon, University of British Columbia, *Some why's and how's of programming DNA molecules.*

Mark Ellingham, Vanderbilt University, *Title to be announced.*

Mauro Maggioni, Duke University, *Digital data sets: Geometry, random walks, multiscale analysis, and applications.*

Weiqiang Wang, University of Virginia, *Title to be announced.*

Special Sessions

Algebraic and Combinatorial Structures in Knot Theory (Code: SS 2A), **J. Scott Carter**, University of South Alabama, and **Mohamed Elhamedi** and **Masahico Saito**, University of South Florida.

Analysis in Metric Spaces (Code: SS 3A), **Thomas Bieske**, University of South Florida, and **Jason Gong**, University of Pittsburgh.

Applications of Complex Analysis in Mathematical Physics (Code: SS 9A), **Razvan Teodorescu**, University of South Florida, **Mihai Putinar**, University of California, Santa Barbara, and **Pavel Bleher**, Indiana University-Purdue University Indianapolis.

Complex Analysis and Operator Theory (Code: SS 8A), **Sherwin Koučekian**, University of South Florida, and **William Ross**, University of Richmond.

Discrete Models in Molecular Biology (Code: SS 1A), **Alessandra Carbone**, Université Pierre et Marie Curie and Laboratory of Microorganisms Genomics, **Natasha Jonoska**, University of South Florida, and **Reidun Twarock**, University of York.

Extremal Combinatorics (Code: SS 13A), **Brendan Nagle**, University of South Florida.

Finite Fields and Their Applications (Code: SS 15A), **Xiang-dong Hou**, University of South Florida, and **Gary Mullen**, Pennsylvania State University.

Graph Theory (Code: SS 14A), **Mark Ellingham**, Vanderbilt University, and **Xiaoya Zha**, Middle Tennessee State University.

Hopf Algebras and Galois Module Theory (Code: SS 7A), **James Carter**, College of Charleston, and **Robert Underwood**, Auburn University Montgomery.

Interaction between Algebraic Combinatorics and Representation Theory (Code: SS 4A), **Mahir Can**, Tulane University, and **Weiqiang Wang**, University of Virginia.

Modeling Crystalline and Quasi-Crystalline Materials (Code: SS 5A), **Mile Krjacevski** and **Gregory McColm**, University of South Florida.

Representations of Algebraic Groups and Related Structures (Code: SS 12A), **Joerg Feldvoss** and **Cornelius Pillen**, University of South Alabama.

Solvability and Integrability of Nonlinear Evolution Equations (Code: SS 6A), **Wen-Xiu Ma**, University of South Florida, and **Ahmet Yildirim**, Ege University and University of South Florida.

Spectral Theory (Code: SS 11A), **Anna Skripka** and **Maxim Zinchenko**, University of Central Florida.

Stochastic Analysis and Applications (Code: SS 16A), **Sivapragasam Sathananthan**, Tennessee State University, and **Gangaram Ladde**, University of South Florida.

Stochastic Partial Differential Equations and Random Global Dynamics (Code: SS 10A), **Yuncheng You**, University of South Florida, and **Shanjian Tang**, Fudan University.

Washington, District of Columbia

George Washington University

March 17–18, 2012

Saturday – Sunday

Meeting #1080

Eastern Section

Associate secretary: Steven H. Weintraub

Announcement issue of *Notices*: January 2012

Program first available on AMS website: February 9, 2012

Program issue of electronic *Notices*: March 2012

Issue of *Abstracts*: Volume 33, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: December 6, 2011

For abstracts: January 31, 2012

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtg/section1.html.

Invited Addresses

Jim Geelen, University of Waterloo, *Title to be announced*.

Boris Solomyak, University of Washington, *Title to be announced*.

Gunther Uhlmann, University of Washington, *Title to be announced* (Einstein Public Lecture in Mathematics).

Anna Wienhard, Princeton University, *Title to be announced*.

Special Sessions

Computable Mathematics (in honor of Alan Turing) (Code: SS 8A), **Douglas Cenzer**, University of Florida, **Valentina Harizanov**, George Washington University, and **Russell Miller**, Queens College and Graduate Center-CUNY.

Convex and Discrete Geometry (Code: SS 9A), **Jim Lawrence** and **Valeriu Soltan**, George Mason University.

Dynamics of Complex Networks (Code: SS 7A), **Yongwu Rong**, **Guanyu Wang**, and **Chen Zeng**, George Washington University.

Homology Theories Motivated by Knot Theory (Code: SS 3A), **Jozef H. Przytycki**, George Washington University, **Radmila Sazdanovic**, University of Pennsylvania, and **Alexander N. Shumakovitch** and **Hao Wu**, George Washington University.

Matroid Theory (Code: SS 1A), **Joseph E. Bonin**, George Washington University, and **Sandra Kingan**, Brooklyn College.

Nonlinear Dispersive Equations (Code: SS 10A), **Manoussos Grillakis**, University of Maryland, **Justin Holmer**, Brown University, and **Svetlana Roudenko**, George Washington University.

Optimization: Theory and Applications (Code: SS 2A), **Roman Sznajder**, Bowie State University.

Self-organization Phenomena in Reaction Diffusion Equations (Code: SS 5A), **Xiaofeng Ren**, George Washington University, and **Junping Shi**, College of William and Mary.

Structural and Extremal Problems in Graph Theory (Code: SS 4A), **Daniel Cranston**, Virginia Commonwealth University, and **Gexin Yu**, College of William & Mary.

Tilings, Substitutions, and Bratteli-Vershik Transformations (Code: SS 6A), **E. Arthur Robinson**, George Washington University, and **Boris Solomyak**, University of Washington.

Lawrence, Kansas

University of Kansas

March 30 – April 1, 2012

Friday – Sunday

Meeting #1081

Central Section

Associate secretary: Georgia Benkart

Announcement issue of *Notices*: February 2012

Program first available on AMS website: March 8, 2012

Program issue of electronic *Notices*: March 2012

Issue of *Abstracts*: Volume 33, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: December 20, 2011

For abstracts: February 14, 2012

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Frank Calegari, Northwestern University, *Title to be announced.*

Christopher Leininger, University of Illinois at Urbana-Champaign, *Title to be announced.*

Alina Marian, University of Illinois at Chicago, *Title to be announced.*

Catherine Yan, Texas A&M University, *Title to be announced.*

Special Sessions

Combinatorial Commutative Algebra (Code: SS 1A), **Christopher Francisco** and **Jeffrey Mermin**, Oklahoma State University, and **Jay Schweig**, University of Kansas.

Enumerative and Geometric Combinatorics (Code: SS 5A), **Margaret Bayer**, University of Kansas, **Joseph P. King**, University of North Texas, **Svetlana Poznanovik**, Georgia Institute of Technology, and **Catherine Yan**, Texas A&M University.

Geometric Representation Theory (Code: SS 4A), **Zongzhu Lin**, Kansas State University, and **Zhiwei Yun**, Massachusetts Institute of Technology.

Harmonic Analysis and Applications (Code: SS 6A), **Arpad Benyi**, Western Washington University, **David Cruz-Urbe**, Trinity College, and **Rodolfo Torres**, University of Kansas.

Invariants of Knots (Code: SS 3A), **Heather A. Dye**, McKendree University, and **Aaron Kaestner** and **Louis H. Kauffman**, University of Illinois at Chicago.

Partial Differential Equations (Code: SS 2A), **Milena Stanislavova** and **Atanas Stefanov**, University of Kansas.

Singularities in Commutative Algebra and Algebraic Geometry (Code: SS 7A), **Hailong Dao**, University of Kansas, **Lance E. Miller**, University of Utah, and **Karl Schwede**, Pennsylvania State University.

Topics in Commutative Algebra (Code: SS 8A), **Hailong Dao**, **Craig Huneke**, and **Daniel Katz**, University of Kansas.

Rochester, New York

Rochester Institute of Technology

September 22–23, 2012

Saturday – Sunday

Meeting #1082

Eastern Section

Associate secretary: Steven H. Weintraub

Announcement issue of *Notices*: May 2012

Program first available on AMS website: July 19, 2012

Program issue of electronic *Notices*: September 2012

Issue of *Abstracts*: Volume 33, Issue 3

Deadlines

For organizers: February 22, 2012

For consideration of contributed papers in Special Sessions: May 15, 2012

For abstracts: July 10, 2012

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Steve Gonek, University of Rochester, *Title to be announced.*

James Keener, University of Utah, *Title to be announced.*

Dusa McDuff, Barnard College, *Title to be announced.*

Peter Winkler, Dartmouth College, *Title to be announced.*

New Orleans, Louisiana

Tulane University

October 13–14, 2012

Saturday – Sunday

Meeting #1083

Southeastern Section

Associate secretary: Matthew Miller

Announcement issue of *Notices*: June 2012

Program first available on AMS website: September 6, 2012

Program issue of electronic *Notices*: October 2012

Issue of *Abstracts*: Volume 33, Issue 3

Deadlines

For organizers: March 13, 2012

For consideration of contributed papers in Special Sessions: July 3, 2012

For abstracts: August 28, 2012

The scientific information listed below may be dated.
For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Anita Layton, Duke University, *Title to be announced.*

Lenhard Ng, Duke University, *Title to be announced.*

Henry K. Schenck, University of Illinois at Urbana-Champaign, *From approximation theory to algebraic geometry: The ubiquity of splines.*

Milen Yakimov, Louisiana State University, *Title to be announced.*

Akron, Ohio

University of Akron

October 20–21, 2012

Saturday – Sunday

Meeting #1084

Central Section

Associate secretary: Georgia Benkart

Announcement issue of *Notices*: August 2012

Program first available on AMS website: September 27, 2012

Program issue of electronic *Notices*: October 2012

Issue of *Abstracts*: Volume 33, Issue 4

Deadlines

For organizers: March 22, 2012

For consideration of contributed papers in Special Sessions: July 10, 2012

For abstracts: September 4, 2012

The scientific information listed below may be dated.
For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Tanya Christiansen, University of Missouri, *Title to be announced.*

Tim Cochran, Rice University, *Title to be announced.*

Ronald Solomon, Ohio State University, *Title to be announced.*

Ben Weinkove, University of California San Diego, *Title to be announced.*

Tucson, Arizona

University of Arizona, Tucson

October 27–28, 2012

Saturday – Sunday

Meeting #1085

Western Section

Associate secretary: Michel L. Lapidus

Announcement issue of *Notices*: August 2012

Program first available on AMS website: October 4, 2012

Program issue of electronic *Notices*: October 2012

Issue of *Abstracts*: Volume 33, Issue 4

Deadlines

For organizers: March 27, 2012

For consideration of contributed papers in Special Sessions: July 17, 2012

For abstracts: September 11, 2012

The scientific information listed below may be dated.
For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Michael Hutchings, University of California Berkeley, *Title to be announced.*

Kenneth McLaughlin, University of Arizona, Tucson, *Title to be announced.*

Ken Ono, Emory University, *Title to be announced* (Erdős Memorial Lecture).

Jacob Sterbenz, University of California San Diego, *Title to be announced.*

Goufang Wei, University of California, Santa Barbara, *Title to be announced.*

Special Sessions

Harmonic Maass Forms and q -Series (Code: SS 1A), **Ken Ono**, Emory University, **Amanda Folsom**, Yale University, and **Zachary Kent**, Emory University.

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 9–12, 2013

Wednesday – Saturday

Meeting #1086

Joint Mathematics Meetings, including the 119th Annual Meeting of the AMS, 96th Annual Meeting of the Mathematical Association of America, 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), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Georgia Benkart

Announcement issue of *Notices*: October 2012

Program first available on AMS website: November 1, 2012

Program issue of electronic *Notices*: January 2012

Issue of *Abstracts*: Volume 34, Issue 1

Deadlines

For organizers: April 1, 2012

For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Oxford, Mississippi

University of Mississippi

March 1–3, 2013

Friday – Sunday

Southeastern Section

Associate secretary: Matthew Miller

Announcement issue of *Notices*: To be announced

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 1, 2012

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Chestnut Hill, Massachusetts

Boston College

April 6–7, 2013

Saturday – Sunday

Eastern Section

Associate secretary: Steven H. Weintraub

Announcement issue of *Notices*: To be announced

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 6, 2012

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Ames, Iowa

Iowa State University

April 27–28, 2013

Saturday – Sunday

Central Section

Associate secretary: Georgia Benkart

Announcement issue of *Notices*: To be announced

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: April 2013

Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 27, 2012

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtg/sectional.html.

Special Sessions

Operator Algebras and Topological Dynamics (Code: SS 1A), **Ken Ono**, Emory University, **Amanda Folsom**, Yale University, and **Zachary Kent**, Emory University.

Alba Iulia, Romania

June 27–30, 2013

Thursday – Sunday

First Joint International Meeting of the AMS and the Romanian Mathematical Society, in partnership with the “Simion Stoilow” Institute of Mathematics of the Romanian Academy.

Associate secretary: Steven H. Weintraub

Announcement issue of *Notices*: To be announced

Program first available on AMS website: Not applicable

Program issue of electronic *Notices*: Not applicable

Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Louisville, Kentucky

University of Louisville

October 5–6, 2013

Saturday – Sunday

Southeastern Section

Associate secretary: Matthew Miller

Announcement issue of *Notices*: To be announced

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 5, 2013

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

St. Louis, Missouri

Washington University

October 18–20, 2013

Friday – Sunday

Central Section

Associate secretary: Georgia Benkart

Announcement issue of *Notices*: To be announced

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 20, 2013

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Riverside, California

University of California Riverside

November 2–3, 2013

Saturday – Sunday

Western Section

Associate secretary: Michel L. Lapidus

Announcement issue of *Notices*: To be announced

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 2, 2013

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Baltimore, Maryland

Baltimore Convention Center, Baltimore Hilton, and Marriott Inner Harbor

January 15–18, 2014

Wednesday – Saturday

Joint Mathematics Meetings, including the 120th Annual Meeting of the AMS, 97th Annual Meeting of the Mathematical Association of America, 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, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Matthew Miller

Announcement issue of *Notices*: October 2013

Program first available on AMS website: November 1, 2013

Program issue of electronic *Notices*: January 2013

Issue of *Abstracts*: Volume 35, Issue 1

Deadlines

For organizers: April 1, 2013

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Tel Aviv, Israel

Bar-Ilan University, Ramat-Gan and Tel-Aviv University, Ramat-Aviv

June 16–19, 2014

Monday – Thursday

The 2nd Joint International Meeting between the AMS and the Israel Mathematical Union.

Associate secretary: Michel L. Lapidus

Announcement issue of *Notices*: To be announced

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

San Antonio, Texas

Henry B. Gonzalez Convention Center and Grand Hyatt San Antonio

January 10–13, 2015

Saturday – Tuesday

Joint Mathematics Meetings, including the 121st Annual Meeting of the AMS, 98th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Steven H. Weintraub

Announcement issue of *Notices*: October 2014

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: January 2015

Issue of *Abstracts*: Volume 36, Issue 1

Deadlines

For organizers: April 1, 2014

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Porto, Portugal

University of Porto

June 11–14, 2015

Thursday – Sunday

Associate secretary: Georgia Benkart

Announcement issue of *Notices*: To be announced

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Seattle, Washington

Washington State Convention Center and the Sheraton Seattle Hotel

January 6–9, 2016

Wednesday – Saturday

Joint Mathematics Meetings, including the 122nd Annual Meeting of the AMS, 99th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Michel L. Lapidus

Announcement issue of *Notices*: October 2015

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: January 2016

Issue of *Abstracts*: Volume 37, Issue 1

Deadlines

For organizers: April 1, 2015

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Atlanta, Georgia

Hyatt Regency Atlanta and Marriott Atlanta Marquis

January 4–7, 2017

Wednesday – Saturday

Joint Mathematics Meetings, including the 123rd Annual Meeting of the AMS, 100th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the

National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Georgia Benkart

Announcement issue of *Notices*: October 2016

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: January 2017

Issue of *Abstracts*: Volume 38, Issue 1

Deadlines

For organizers: April 1, 2016

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 10–13, 2018

Wednesday – Saturday

Joint Mathematics Meetings, including the 124th Annual Meeting of the AMS, 101st Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Matthew Miller

Announcement issue of *Notices*: October 2017

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

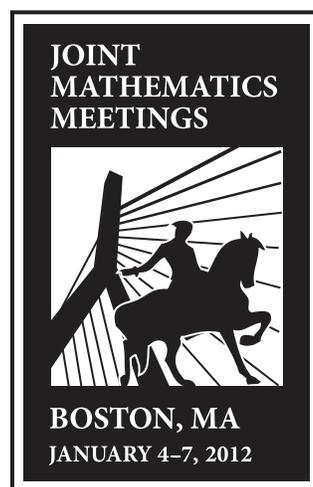
For organizers: April 1, 2017

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Program at a Glance

This document provides a thumbnail sketch of all scientific and social events so you can easily see which events may overlap and better plan your time.



Monday, January 02

- 8:00 a.m.–5:00 p.m. **MAA SHORT COURSE ON DISCRETE AND COMPUTATIONAL GEOMETRY, PART I**
9:00 a.m.–5:00 p.m. **AMS SHORT COURSE ON RANDOM FIELDS AND RANDOM GEOMETRY, PART I**
9:00 a.m.–5:00 p.m. **AMS SHORT COURSE ON COMPUTING WITH ELLIPTIC CURVES USING SAGE, PART I**

Tuesday, January 03

- 8:00 a.m.–6:30 p.m. **AMS DEPARTMENT CHAIRS WORKSHOP**
8:30 a.m.–4:30 p.m. **MAA ANCILLARY WORKSHOP ON STATISTICS: FACILITATING STUDENT PROJECTS IN ELEMENTARY STATISTICS**
8:30 a.m.–4:30 p.m. **MAA ANCILLARY WORKSHOP ON STATISTICS: IDENTIFYING AND ADDRESSING DIFFICULT CONCEPTS FOR STUDENTS IN THE INTRODUCTORY STATISTICS COURSE**
9:00 a.m.–5:00 p.m. **AMS SHORT COURSE ON RANDOM FIELDS AND RANDOM GEOMETRY, PART II**
9:00 a.m.–5:00 p.m. **AMS SHORT COURSE ON COMPUTING WITH ELLIPTIC CURVES USING SAGE, PART II**
9:00 a.m.–5:00 p.m. **MAA SHORT COURSE ON DISCRETE AND COMPUTATIONAL GEOMETRY, PART II**
9:00 a.m.–4:30 p.m. **MAA ANCILLARY WORKSHOP ON STATISTICS: TEACHING MODELING-BASED CALCULUS**
9:00 a.m.–5:00 p.m. **MAA BOARD OF GOVERNORS**
1:30 p.m.–10:00 p.m. **AMS COUNCIL**
3:00 p.m.–7:00 p.m. **JOINT MEETINGS REGISTRATION**, 2nd Floor Corridor, opposite Hall C, Hynes

Wednesday, January 04

- 7:30 a.m.–6:00 p.m. **JOINT MEETINGS REGISTRATION**, 2nd Floor Corridor, opposite Hall C, Hynes

AMS SPECIAL SESSIONS

- 8:00 a.m.–10:50 a.m. *History of Mathematics, I (AMS-MAA)*
8:00 a.m.–10:50 a.m. *Life and Legacy of Alan Turing, I (AMS-ASL)*
8:00 a.m.–10:50 a.m. *Advances in Coding Theory, I*
8:00 a.m.–10:50 a.m. *Dynamical Systems in Algebraic and Arithmetic Geometry, I*
8:00 a.m.–10:50 a.m. *Stochastic Analysis (in honor of Hui-Hsiung Kuo), I*
8:00 a.m.–10:50 a.m. *Topological Graph Theory: Structure and Symmetry, I*
8:00 a.m.–10:50 a.m. *Local Field Properties, Microstructure, and Multiscale Modeling of Heterogeneous Media, I*
8:00 a.m.–10:50 a.m. *Hyperbolicity in Manifolds and Groups, I*
8:00 a.m.–10:50 a.m. *Classical Fourier Analysis and Partial Differential Equations, I*

- 8:00 a.m.–10:50 a.m. *Groups, Algorithms, Complexity, and Theory of Security, I*
 8:00 a.m.–10:50 a.m. *Trends in Representation Theory, I*
 8:00 a.m.–10:50 a.m. *Mathematics in Industry, I*
 8:00 a.m.–10:50 a.m. *Generalized Cohomology Theories in Engineering Practice, I*
 8:00 a.m.–10:50 a.m. *Difference Equations and Applications, I*
 8:00 a.m.–10:50 a.m. *Optimal Control in Applied Mathematical Modeling, I*
 8:00 a.m.–11:50 a.m. *Set-Valued Optimization and Variational Problems, I*
 8:00 a.m.–10:50 a.m. *Arithmetic Geometry, I*
 8:00 a.m.–10:50 a.m. *Mathematics of Decisions, Elections, and Games, I*
 8:00 a.m.–10:50 a.m. *Stability Analysis for Infinite Dimensional Hamiltonian Systems, I*
 8:00 a.m.–10:50 a.m. *Several Complex Variables and Multivariable Operator Theory, I*
 8:00 a.m.–10:50 a.m. *Mathematics in Natural Resource Modeling, I*
- MAA INVITED PAPER SESSION**
 8:00 a.m.–11:00 a.m. *Algebraic Statistics*
- MAA CONTRIBUTED PAPER SESSIONS**
 8:00 a.m.–11:00 a.m. *Scholarship of Teaching and Learning in Collegiate Mathematics, I*
 8:00 a.m.–11:00 a.m. *Mathematics and Sports*
 8:00 a.m.–11:00 a.m. *Effective Use of Dynamic Mathematical Software in the Classroom*
 8:00 a.m.–11:00 a.m. *Capstone Course: Innovations and Implementations*
 8:00 a.m.–11:00 a.m. *General Session, I*
- SIAM MINISYMPOSIUM ON SPARSITY IN INVERSE PROBLEMS AND SIGNAL PROCESSING**
- AMS SESSIONS FOR CONTRIBUTED PAPERS**
- EMPLOYMENT CENTER**
 8:00 a.m.–7:00 p.m.
- MAA MINICOURSE #14: PART A** *Teaching introductory statistics.*
 9:00 a.m.–11:00 a.m.
MAA MINICOURSE #6: PART A *Getting students involved in undergraduate research.*
 9:00 a.m.–11:00 a.m.
MAA MINICOURSE #8: PART A *Preparing to serve as an outside consultant in the mathematical sciences.*
 9:00 a.m.–11:00 a.m.
- MAA PANEL DISCUSSION** *Quantitative support center: Common themes.*
 9:00 a.m.–10:20 a.m.
MAA/NCTM MUTUAL CONCERNS COMMITTEE PANEL DISCUSSION *Why is transition from high school to college important? Issues and next steps.*
 9:00 a.m.–10:20 a.m.
MAA PANEL DISCUSSION *National Science Foundation programs supporting learning and teaching in the mathematical sciences.*
 9:00 a.m.–10:20 a.m.
- STUDENT HOSPITALITY CENTER**
 9:00 a.m.–5:00 p.m.
- MAA DEPARTMENT LIAISONS MEETING**
 9:30 a.m.–11:00 a.m.
- AMS INVITED ADDRESS** *The polynomial method in combinatorial geometry.* Larry Guth
 10:05 a.m.–10:55 a.m.
AMS-MAA INVITED ADDRESS *Title to be announced.* Allen Knutson
 11:10 a.m.–12:00 p.m.
- EXHIBITS AND BOOK SALES**
 12:15 p.m.–5:30 p.m.
- AMS COLLOQUIUM LECTURES: LECTURE I** *Langlands program, trace formulas, and their geometrization, I.* Edward Frenkel
 1:00 p.m.–2:00 p.m.
- MAA INVITED ADDRESS** *Mathematics to DIE for: The battle between counting and matching.* Jennifer Quinn
 2:15 p.m.–3:05 p.m.
- AMS SPECIAL SESSIONS**
 2:15 p.m.–6:05 p.m. *History of Mathematics, II (AMS-MAA)*
 2:15 p.m.–6:05 p.m. *Mathematics of Computation: Differential Equations, Linear Algebra, and Applications, I (AMS-SIAM)*
 2:15 p.m.–6:05 p.m. *Life and Legacy of Alan Turing, II (AMS-ASL)*
 2:15 p.m.–6:05 p.m. *Science for Policy and Policy for Science: Career Opportunities at the Intersection of Science and Policy, I (AMS-AAAS)*
 2:15 p.m.–6:05 p.m. *Advances in Coding Theory, II*
 2:15 p.m.–6:05 p.m. *Dynamical Systems in Algebraic and Arithmetic Geometry, II*
 2:15 p.m.–6:05 p.m. *Stochastic Analysis (in honor of Hui-Hsiung Kuo), II*

- 2:15 p.m.–6:05 p.m. *Topological Graph Theory: Structure and Symmetry, II*
- 2:15 p.m.–6:05 p.m. *Local Field Properties, Microstructure, and Multiscale Modeling of Heterogeneous Media, II*
- 2:15 p.m.–6:05 p.m. *Hyperbolicity in Manifolds and Groups, II*
- 2:15 p.m.–6:05 p.m. *Classical Fourier Analysis and Partial Differential Equations, II*
- 2:15 p.m.–6:05 p.m. *Groups, Algorithms, Complexity, and Theory of Security, II*
- 2:15 p.m.–6:05 p.m. *Trends in Representation Theory, II*
- 2:15 p.m.–6:05 p.m. *Generalized Cohomology Theories in Engineering Practice, II*
- 2:15 p.m.–6:05 p.m. *Difference Equations and Applications, II*
- 2:15 p.m.–6:05 p.m. *Optimal Control in Applied Mathematical Modeling, II*
- 2:15 p.m.–6:05 p.m. *Set-Valued Optimization and Variational Problems, II*
- 2:15 p.m.–6:05 p.m. *Mathematics of Decisions, Elections, and Games, II*
- 2:15 p.m.–6:05 p.m. *Stability Analysis for Infinite Dimensional Hamiltonian Systems, II*
- 2:15 p.m.–6:05 p.m. *Several Complex Variables and Multivariable Operator Theory, II*
- 2:15 p.m.–6:05 p.m. *Mathematics in Natural Resource Modeling, II*
- 2:15 p.m.–4:15 p.m. **MAA MINICOURSE #11: PART A** *Teaching differential equations with modeling.*
- 2:15 p.m.–4:15 p.m. **MAA MINICOURSE #3: PART A** *Problem-based courses for teachers, future teachers, and math majors.*
- 2:15 p.m.–4:15 p.m. **MAA MINICOURSE #7: PART A** *Study the masters: Using primary historical sources in mathematics teaching.*
- MAA CONTRIBUTED PAPER SESSIONS**
- 2:15 p.m.–6:00 p.m. *Scholarship of Teaching and Learning in Collegiate Mathematics, II*
- 2:15 p.m.–6:00 p.m. *Touch it, Feel it, Learn it: Tactile learning Activities in the Undergraduate Mathematics Classroom*
- 2:15 p.m.–6:00 p.m. *Innovative and Effective Ways to Teach Linear Algebra*
- 2:15 p.m.–6:00 p.m. *Mathematics of Sudoku and Other Pencil Puzzles, I*
- 2:15 p.m.–6:00 p.m. *General Session, II*
- MAA-AMS INVITED PAPER SESSION**
- 2:15 p.m.–6:40 p.m. *Philosophy of Mathematics*
- 2:15 p.m.–6:15 p.m. **SIAM MINISYMPOSIUM ON VISTAS IN APPLIED, COMPUTATIONAL, AND DISCRETE MATHEMATICS**
- 2:15 p.m.–3:35 p.m. **AMS-MAA JOINT PANEL DISCUSSION** *Administrative strategies for dealing with budget cuts.*
- 2:15 p.m.–3:35 p.m. **SIGMAA ON STATISTICS EDUCATION/ASA-MAA JOINT COMMITTEE ON STATISTICS EDUCATION PANEL DISCUSSION** *Statistics and probability in the Common Core State Standards.*
- 2:15 p.m.–3:35 p.m. **MAA PANEL DISCUSSION** *Reporting progress: A minisymposium of projects from the NSF Mathematics and Science Partnership program.*
- 2:15 p.m.–4:15 p.m. **YMN/PROJECT NEXT POSTER SESSION**
- 2:15 p.m.–5:55 p.m. **AMS SESSIONS FOR CONTRIBUTED PAPERS**
- 2:15 p.m.–3:40 p.m. **AWM PANEL DISCUSSION** *Maintaining an active research career through collaboration.*
- 2:30 p.m.–5:00 p.m. **MAA SECTION OFFICERS**
- 3:20 p.m.–4:10 p.m. **MAA INVITED ADDRESS** *Phylogenetic algebraic geometry. Seth M. Sullivant*
- 3:45 p.m.–4:15 p.m. **AWM BUSINESS MEETING**
- 3:50 p.m.–5:10 p.m. **MAA PANEL DISCUSSION** *Reporting progress: A minisymposium of projects from the NSF Course, Curriculum, and Laboratory Improvement/Transforming Undergraduate Education in STEM program.*
- 4:00 p.m.–5:00 p.m. **RECEPTION FOR UNDERGRADUATE STUDENTS**
- 4:30 p.m.–6:00 p.m. **AMS COMMITTEE ON THE PROFESSION PANEL DISCUSSION** *Supply, demand, and the math Ph.D. program.*
- 4:45 p.m.–6:45 p.m. **MAA MINICOURSE #12: PART A** *Using randomization methods to build conceptual understanding of statistical inference.*
- 4:45 p.m.–6:45 p.m. **MAA MINICOURSE #5: PART A** *Dance and mathematics.*

5:30 p.m.–7:15 p.m.	SIGMAA ON THE HISTORY OF MATHEMATICS RECEPTION, BUSINESS MEETING, AND GUEST LECTURE
5:30 p.m.–6:30 p.m.	RECEPTION FOR GRADUATE STUDENTS AND FIRST-TIME PARTICIPANTS
5:30 p.m.–8:00 p.m.	MATHEMATICAL INSTITUTES OPEN HOUSE
6:30 p.m.–8:15 p.m.	RECEPTION FOR PENNSYLVANIA STATE UNIVERSITY MATHEMATICS ALUMNI
8:30 p.m.–9:30 p.m.	AMS JOSIAH WILLARD GIBBS LECTURE <i>A 250-year argument: Belief, behavior, and the bootstrap.</i> Bradley Efron
9:30 p.m.–11:00 p.m.	AWM RECEPTION

Thursday, January 05

7:30 a.m.–4:00 p.m.	JOINT MEETINGS REGISTRATION , 2nd Floor Corridor, opposite Hall C, Hynes
	AMS SPECIAL SESSIONS
8:00 a.m.–11:50 a.m.	<i>History of Mathematics, III (AMS-MAA)</i>
8:00 a.m.–11:50 a.m.	<i>Mathematics of Computation: Differential Equations, Linear Algebra, and Applications, II (AMS-SIAM)</i>
8:00 a.m.–11:50 a.m.	<i>Life and Legacy of Alan Turing, III (AMS-ASL)</i>
8:00 a.m.–11:50 a.m.	<i>Knot Theory, I</i>
8:00 a.m.–11:50 a.m.	<i>Theory and Applications of Stochastic Differential and Partial Differential Equations, I</i>
8:00 a.m.–11:50 a.m.	<i>Hyperbolicity in Manifolds and Groups, III</i>
8:00 a.m.–11:50 a.m.	<i>Classical Fourier Analysis and Partial Differential Equations, III</i>
8:00 a.m.–11:50 a.m.	<i>Groups, Algorithms, Complexity, and Theory of Security, III</i>
8:00 a.m.–11:50 a.m.	<i>Rational Points on Varieties, I</i>
8:00 a.m.–11:50 a.m.	<i>Climate Modeling and Geophysical Fluid Dynamics, I</i>
8:00 a.m.–11:50 a.m.	<i>Combinatorial Geometry of Polytopes, I</i>
8:00 a.m.–11:50 a.m.	<i>Optimal Control in Applied Mathematical Modeling, III</i>
8:00 a.m.–11:50 a.m.	<i>Progress in Free Analysis, I</i>
8:00 a.m.–11:50 a.m.	<i>Fractal Geometry in Pure and Applied Mathematics (in memory of Benoit Mandelbrot), I</i>
8:00 a.m.–11:50 a.m.	<i>Some Nonlinear Partial Differential Equations: Theory and Application, I</i>
8:00 a.m.–11:50 a.m.	<i>Geometry of Real Projective Structures (Mathematics Research Communities session), I</i>
8:00 a.m.–11:50 a.m.	<i>Computational and Applied Topology (Mathematics Research Communities session), I</i>
8:00 a.m.–11:50 a.m.	<i>New Perspectives in Multiplicative Number Theory (Mathematics Research Communities session), I</i>
8:00 a.m.–11:50 a.m.	<i>Stability Analysis for Infinite Dimensional Hamiltonian Systems, III</i>
8:00 a.m.–11:50 a.m.	<i>Differential Algebraic Geometry and Galois Theory (in memory of Jerald Kovacic), I</i>
8:00 a.m.–11:50 a.m.	<i>Mathematics in Natural Resource Modeling, III</i>
	MAA CONTRIBUTED PAPER SESSIONS
8:00 a.m.–12:00 p.m.	<i>Preparing College Students for Calculus</i>
8:00 a.m.–12:00 p.m.	<i>Trends in Undergraduate Mathematical Biology Education, I</i>
8:00 a.m.–12:00 p.m.	<i>My Most Successful Math Club Activity</i>
8:00 a.m.–12:00 p.m.	<i>Research on the Teaching and Learning of Undergraduate Mathematics, I</i>
8:00 a.m.–12:00 p.m.	<i>Mathematics Experiences in Business, Industry, and Government</i>
8:00 a.m.–12:00 p.m.	<i>Arts and Mathematics, Together Again, I</i>
8:00 a.m.–12:00 p.m.	<i>General Session, III</i>
8:00 a.m.–11:00 a.m.	SIAM MINISYMPOSIUM ON COMPUTATIONAL GEOMETRY
8:00 a.m.–11:55 a.m.	AMS SESSIONS FOR CONTRIBUTED PAPERS
8:00 a.m.–7:00 p.m.	EMPLOYMENT CENTER
9:00 a.m.–9:50 a.m.	MAA INVITED ADDRESS <i>The sound of geometry.</i> Carolyn Gordon
	MAA INVITED PAPER SESSION
9:00 a.m.–12:00 p.m.	<i>The Beauty and Power of Number Theory</i>

Meetings & Conferences

- 9:00 a.m.–11:00 a.m. **MAA MINICOURSE #13: PART A** *Interactive applets for calculus and differential equations.*
- 9:00 a.m.–11:00 a.m. **MAA MINICOURSE #1: PART A** *Mathematics and backgammon.*
- 9:00 a.m.–11:00 a.m. **MAA MINICOURSE #4: PART A** *Elementary mathematics in architecture.*
- 9:00 a.m.–10:20 a.m. **MAA COMMITTEE ON GRADUATE STUDENTS/YOUNG MATHEMATICIANS NETWORK PANEL DISCUSSION** *Graduate school: Choosing one, getting in, staying in.*
- 9:00 a.m.–10:20 a.m. **MAA SESSION FOR CHAIRS** *Timely and timeless aspects of chairing a mathematical sciences department.*
- 9:00 a.m.–11:00 a.m. **MAA POSTER SESSION ON MATHEMATICAL OUTREACH PROGRAMS FOR UNDERREPRESENTED POPULATIONS**
- 9:00 a.m.–5:00 p.m. **STUDENT HOSPITALITY CENTER**
- 9:30 a.m.–5:30 p.m. **EXHIBITS AND BOOK SALES**
- 10:05 a.m.–10:55 a.m. **AWM EMMY NOETHER LECTURE** *Conservation laws—Not exactly a la Noether.* **Barbara Keyfitz**
- 10:30 a.m.–12:00 p.m. **AMS SPECIAL PRESENTATION** *A conversation on nonacademic employment.*
- 10:30 a.m.–12:00 p.m. **SIGMAA OFFICERS MEETING**
- 10:35 a.m.–11:55 a.m. **MAA WORKSHOP** *Proposal writing for grant applications to the NSF Division of Undergraduate Education.*
- 10:35 a.m.–11:55 a.m. **MAA PANEL DISCUSSION** *Improving college mathematics teaching through faculty development.*
- 11:10 a.m.–12:00 p.m. **SIAM INVITED ADDRESS** *Navier-Stokes, Euler, and other relevant equations.* **Edriss Titi**
- 11:15 a.m.–12:15 p.m. **AMS SPECIAL PRESENTATION** *Report on the findings of the 2010 CBMS survey of undergraduate mathematical and statistical sciences in the U.S.*
- 1:00 p.m.–2:00 p.m. **AMS COLLOQUIUM LECTURES: LECTURE II** *Langlands program, trace formulas, and their geometrization, II.* **Edward Frenkel**
- AMS SPECIAL SESSIONS**
- 1:00 p.m.–3:50 p.m. *History of Mathematics, IV (AMS-MAA)*
- 1:00 p.m.–3:50 p.m. *Life and Legacy of Alan Turing, IV (AMS-ASL)*
- 1:00 p.m.–3:50 p.m. *Nonlinear Hyperbolic Partial Differential Equations, I (AMS-AWM)*
- 1:00 p.m.–3:50 p.m. *Knot Theory, II*
- 1:00 p.m.–3:50 p.m. *Control Theory and Inverse Problems for Partial Differential Equations, I*
- 1:00 p.m.–3:50 p.m. *Dynamical Systems in Algebraic and Arithmetic Geometry, III*
- 1:00 p.m.–3:50 p.m. *Stochastic Analysis (in honor of Hui-Hsiung Kuo), III*
- 1:00 p.m.–3:50 p.m. *Topological Graph Theory: Structure and Symmetry, III*
- 1:00 p.m.–3:50 p.m. *Classical Fourier Analysis and Partial Differential Equations, IV*
- 1:00 p.m.–3:50 p.m. *Trends in Representation Theory, III*
- 1:00 p.m.–3:50 p.m. *Rational Points on Varieties, II*
- 1:00 p.m.–3:50 p.m. *Reaction Diffusion Equations and Applications, I*
- 1:00 p.m.–3:50 p.m. *Mathematics in Industry, II*
- 1:00 p.m.–3:50 p.m. *Climate Modeling and Geophysical Fluid Dynamics, II*
- 1:00 p.m.–3:50 p.m. *Combinatorial Geometry of Polytopes, II*
- 1:00 p.m.–3:50 p.m. *Linear Algebraic Groups: Their Arithmetic, Geometry, and Representations, I*
- 1:00 p.m.–3:50 p.m. *The Geometry of Real Projective Structures (Mathematics Research Communities session), II*
- 1:00 p.m.–3:50 p.m. *Computational and Applied Topology (Mathematics Research Communities session), II*
- 1:00 p.m.–3:50 p.m. *New Perspectives in Multiplicative Number Theory (Mathematics Research Communities session), II*
- 1:00 p.m.–3:50 p.m. *Several Complex Variables and Multivariable Operator Theory, III*
- 1:00 p.m.–3:50 p.m. *Mathematics in Natural Resource Modeling, IV*
- MAA INVITED PAPER SESSIONS**
- 1:00 p.m.–4:00 p.m. *Clever Counting or Beautiful Bijection?*
- 1:00 p.m.–4:00 p.m. *Decoding Geometry*
- 1:00 p.m.–3:00 p.m. **MAA MINICOURSE #10: PART A** *Geometry and art: A liberal arts mathematics course.*

- 1:00 p.m.–3:00 p.m. **MAA MINICOURSE #2: PART A** *A dynamical systems approach to the differential equations course.*
- 1:00 p.m.–3:00 p.m. **MAA MINICOURSE #9: PART A** *Reading original sources in Latin for the historian and mathematician.*
- MAA CONTRIBUTED PAPER SESSIONS**
- 1:00 p.m.–4:00 p.m. *Trends in Undergraduate Mathematical Biology Education, II*
- 1:00 p.m.–4:00 p.m. *Research on the Teaching and Learning of Undergraduate Mathematics, II*
- 1:00 p.m.–4:00 p.m. *Projects, Demonstrations, and Activities that Engage Liberal Arts Mathematics Students*
- 1:00 p.m.–4:00 p.m. *Arts and Mathematics, Together Again, II*
- 1:00 p.m.–4:00 p.m. *Mathematics of Sudoku and Other Pencil Puzzles, II*
- 1:00 p.m.–4:00 p.m. *General Session, IV*
- 1:00 p.m.–3:50 p.m. **SIAM MINISYMPOSIUM ON PROBABILISTIC COMBINATORICS**
- 1:00 p.m.–2:30 p.m. **AMS PANEL DISCUSSION** *Summer math camps: The AMS (and mathematician's) role.*
- 1:00 p.m.–2:20 p.m. **MAA-YOUNG MATHEMATICIANS NETWORK PANEL DISCUSSION** *Career options for undergraduate mathematics majors.*
- 1:00 p.m.–2:20 p.m. **MAA COMMITTEE ON MINORITY PARTICIPATION/MAA OFFICE OF MINORITY PARTICIPATION PANEL DISCUSSION** *Summer research programs.*
- 1:00 p.m.–2:20 p.m. **THE COLLEGE BOARD/MAA COMMITTEE ON MUTUAL CONCERNS PANEL DISCUSSION** *What can colleges and universities do to increase student success in calculus?*
- 1:00 p.m.–4:10 p.m. **AMS SESSIONS FOR CONTRIBUTED PAPERS**
- 2:00 p.m.–4:00 p.m. **MAA POSTER SESSION ON PROJECTS SUPPORTED BY THE NSF DIVISION OF UNDERGRADUATE EDUCATION**
- 2:15 p.m.–3:05 p.m. **AMS INVITED ADDRESS** *Invariant manifolds and dispersive Hamiltonian evolution equations.*
Wilhelm Schlag
- 2:40 p.m.–4:00 p.m. **MAA/YOUNG MATHEMATICIANS NETWORK PANEL DISCUSSION** *Hit the ground running! Interview like a pro and land the job.*
- 2:40 p.m.–4:00 p.m. **MAA SUBCOMMITTEE ON RESEARCH BY UNDERGRADUATES PANEL DISCUSSION** *Successful and diverse models for mentoring research by undergraduates.*
- 2:40 p.m.–4:00 p.m. **MAA PANEL DISCUSSION** *Publishing with the MAA.*
- 3:20 p.m.–4:10 p.m. **AMS RETIRING PRESIDENTIAL ADDRESS** *Title to be announced.* George E. Andrews
- 4:25 p.m.–5:25 p.m. **JOINT PRIZE SESSION**
- 5:30 p.m.–6:30 p.m. **JOINT PRIZE SESSION RECEPTION**
- 5:30 p.m.–7:00 p.m. **BUDAPEST SEMESTERS IN MATHEMATICS ANNUAL ALUMNI REUNION**
- 5:45 p.m.–7:00 p.m. **SIGMAA ON THE PHILOSOPHY OF MATHEMATICS BUSINESS MEETING AND GUEST LECTURE**
- 5:45 p.m.–7:15 p.m. **SIGMAA ON STATISTICS EDUCATION BUSINESS MEETING AND RECEPTION**
- 5:45 p.m.–7:00 p.m. **MAA TWO-YEAR COLLEGE RECEPTION**
- 6:00 p.m.–8:45 p.m. **SIGMAA ON MATHEMATICIANS IN BUSINESS, INDUSTRY, AND GOVERNMENT GUEST LECTURE, RECEPTION, AND BUSINESS MEETING**
- 6:00 p.m.–8:00 p.m. **NSA'S WOMEN IN MATHEMATICS SOCIETY NETWORKING SESSION**
- 6:00 p.m.–7:00 p.m. **UNIVERSITY OF CHICAGO MATHEMATICS ALUMNI RECEPTION**
- 6:00 p.m.–8:00 p.m. **ASSOCIATION OF LESBIAN, GAY, BISEXUAL, AND TRANSGENDERED MATHEMATICIANS RECEPTION**
- 6:00 p.m.–7:00 p.m. **UNIVERSITY OF CHICAGO MATHEMATICS ALUMNI RECEPTION**
- 6:30 p.m.–9:30 p.m. **MER BANQUET**
- 7:00 p.m.–9:00 p.m. **CLAREMONT COLLEGES RECEPTION**
- 7:30 p.m.–8:30 p.m. **YOUNG MATHEMATICIANS' NETWORK OPEN FORUM** *All meeting participants, including undergraduates and graduate students, are welcome to discuss topics and issues affecting young mathematicians.*
- 8:15 p.m.–9:45 p.m. **KNITTING CIRCLE** *Bring a project (knitting/crocheting/tatting/beading/etc.) and chat with other crafters.*

Friday, January 06

7:30 a.m.–4:00 p.m. **JOINT MEETINGS REGISTRATION**, 2nd Floor Corridor, opposite Hall C, Hynes

AMS SPECIAL SESSIONS

- 8:00 a.m.–10:50 a.m. *Mathematics and Education Reform, I* (AMS-MAA-MER)
 8:00 a.m.–10:50 a.m. *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, I* (AMS-MAA)
 8:00 a.m.–10:50 a.m. *Mathematics of Computation: Algebra and Number Theory, I* (AMS-SIAM)
 8:00 a.m.–10:50 a.m. *Nonlinear Hyperbolic Partial Differential Equations, II* (AMS-AWM)
 8:00 a.m.–10:50 a.m. *Calculus of Functors and Its Applications, I*
 8:00 a.m.–10:50 a.m. *Radon Transforms and Geometric Analysis (in honor of Sigurdur Helgason's 85th birthday), I*
 8:00 a.m.–10:50 a.m. *Control Theory and Inverse Problems for Partial Differential Equations, II*
 8:00 a.m.–10:50 a.m. *Recent Advances in Mathematical Biology, Ecology, and Epidemiology, I*
 8:00 a.m.–10:50 a.m. *Recent Trends in Graph Theory, I*
 8:00 a.m.–10:50 a.m. *Enumerative and Algebraic Combinatorics, I*
 8:00 a.m.–10:50 a.m. *Noncommutative Birational Geometry and Cluster Algebras, I*
 8:00 a.m.–10:50 a.m. *Progress in Free Analysis, II*
 8:00 a.m.–10:50 a.m. *Linear Algebraic Groups: Their Arithmetic, Geometry, and Representations, II*
 8:00 a.m.–10:50 a.m. *Fractal Geometry in Pure and Applied Mathematics (in memory of Benoit Mandelbrot), II*
 8:00 a.m.–10:50 a.m. *Arithmetic Geometry, II*
 8:00 a.m.–10:50 a.m. *Uniformly and Partially Hyperbolic Dynamical Systems, I*
 8:00 a.m.–10:50 a.m. *Some Nonlinear Partial Differential Equations — Theory and Application, II*
 8:00 a.m.–10:50 a.m. *Frontiers in Geomathematics, I*
 8:00 a.m.–10:50 a.m. *Advances in Mathematical Biology, I*
 8:00 a.m.–10:50 a.m. *Algebraic and Geometric Aspects of Integrable Systems and Random Matrices, I*
 8:00 a.m.–10:50 a.m. *Homotopy Theory, I*
 8:00 a.m.–10:50 a.m. *Differential Algebraic Geometry and Galois Theory (in memory of Jerald Kovacic), II*

MAA INVITED PAPER SESSIONS

- 8:00 a.m.–11:00 a.m. *Contemporary Unsolved Problems*
 8:00 a.m.–11:00 a.m. *Knot Theory Untangled*

MAA CONTRIBUTED PAPER SESSIONS

- 8:00 a.m.–11:00 a.m. *Modeling Across the Mathematics Curriculum*
 8:00 a.m.–11:00 a.m. *Quantitative Literacy and Decision Making*
 8:00 a.m.–11:00 a.m. *Writing the History of the MAA*
 8:00 a.m.–11:00 a.m. *Topics and Techniques for Teaching Real Analysis*
 8:00 a.m.–11:00 a.m. *General Session, V*

SIAM MINISYMPOSIUM ON EDUCATION

8:00 a.m.–5:00 p.m. **ASL INVITED ADDRESSES AND CONTRIBUTED PAPER SESSIONS**

AMS SESSIONS FOR CONTRIBUTED PAPERS

8:00 a.m.–11:00 a.m. **PME COUNCIL MEETING**

8:00 a.m.–7:00 p.m. **EMPLOYMENT CENTER**

8:30 a.m.–10:30 a.m. **AMS-MAA GRAD SCHOOL FAIR** *Undergrads! Take this opportunity to meet representatives from mathematical sciences graduate programs.*

9:00 a.m.–9:50 a.m. **MAA INVITED ADDRESS** *Sum of squares polynomials in optimization.* **Rekha R. Thomas**

9:00 a.m.–11:00 a.m. **MAA MINICOURSE #14: PART B** *Teaching introductory statistics.*

9:00 a.m.–11:00 a.m. **MAA MINICOURSE #6: PART B** *Getting students involved in undergraduate research.*

9:00 a.m.–11:00 a.m. **MAA MINICOURSE #8: PART B** *Preparing to serve as an outside consultant in the mathematical sciences.*

9:00 a.m.–10:20 a.m. **MAA PROFESSIONAL DEVELOPMENT COMMITTEE PANEL DISCUSSION** *Getting your textbook published.*

- 9:00 a.m.–10:20 a.m. **MAA COMMITTEE ON ASSESSMENT PANEL DISCUSSION** *Using data from the registrar's office to better understand, plan, and change your undergraduate mathematics program.*
- 9:00 a.m.–10:20 a.m. **MAA PANEL DISCUSSION** *Incorporation of the mathematics of climate change and sustainability into our undergraduate courses.*
- 9:00 a.m.–5:00 p.m. **STUDENT HOSPITALITY CENTER**
- 9:30 a.m.–11:00 a.m. **AMS SPECIAL PRESENTATION** *Who wants to be a mathematician—National contest.*
- 9:30 a.m.–5:30 p.m. **EXHIBITS AND BOOK SALES**
- 10:05 a.m.–10:55 a.m. **AMS INVITED ADDRESS** *The Ribe program. Assaf Naor*
- 11:10 a.m.–12:00 p.m. **AMS-MAA INVITED ADDRESS** *Title to be announced. Hee Oh*
- 1:00 p.m.–2:00 p.m. **AMS COLLOQUIUM LECTURES: LECTURE III** *Langlands program, trace formulas, and their geometrization, III. Edward Frenkel*
- 1:00 p.m.–1:50 p.m. **MAA LECTURE FOR STUDENTS** *Turning theorems into plays. Steve Abbott*
- 1:00 p.m.–4:45 p.m. **AMS CURRENT EVENTS BULLETIN**
- AMS SPECIAL SESSIONS**
- 1:00 p.m.–5:50 p.m. *Mathematics and Education Reform, II (AMS-MAA-MER)*
- 1:00 p.m.–5:50 p.m. *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, II (AMS-MAA)*
- 1:00 p.m.–5:50 p.m. *Mathematics of Computation: Algebra and Number Theory, II (AMS-SIAM)*
- 1:00 p.m.–5:50 p.m. *Nonlinear Hyperbolic Partial Differential Equations, III (AMS-AWM)*
- 1:00 p.m.–5:50 p.m. *Knot Theory, III*
- 1:00 p.m.–5:50 p.m. *Calculus of Functors and Its Applications, II*
- 1:00 p.m.–5:50 p.m. *Fractional, Hybrid, and Stochastic Dynamical Systems with Applications*
- 1:00 p.m.–5:50 p.m. *Radon Transforms and Geometric Analysis (in honor of Sigurdur Helgason's 85th birthday), II*
- 1:00 p.m.–5:50 p.m. *Control Theory and Inverse Problems for Partial Differential Equations, III*
- 1:00 p.m.–5:50 p.m. *Recent Trends in Graph Theory, II*
- 1:00 p.m.–5:50 p.m. *Rational Points on Varieties, III*
- 1:00 p.m.–5:50 p.m. *Climate Modeling and Geophysical Fluid Dynamics, III*
- 1:00 p.m.–5:50 p.m. *Enumerative and Algebraic Combinatorics, II*
- 1:00 p.m.–5:50 p.m. *Progress in Free Analysis, III*
- 1:00 p.m.–5:50 p.m. *Linear Algebraic Groups: Their Arithmetic, Geometry, and Representations, III*
- 1:00 p.m.–5:50 p.m. *Uniformly and Partially Hyperbolic Dynamical Systems, II*
- 1:00 p.m.–5:50 p.m. *Some Nonlinear Partial Differential Equations — Theory and Application, III*
- 1:00 p.m.–5:50 p.m. *Advances in Mathematical Biology, II*
- 1:00 p.m.–5:50 p.m. *Algebraic and Geometric Aspects of Integrable Systems and Random Matrices, II*
- 1:00 p.m.–5:50 p.m. *Differential Algebraic Geometry and Galois Theory (in memory of Jerald Kovacic), III*
- MAA INVITED PAPER SESSION**
- 1:00 p.m.–4:00 p.m. *Semidefinite Optimization and Nonnegative Polynomials*
- 1:00 p.m.–3:00 p.m. **MAA MINICOURSE #11: PART B** *Teaching differential equations with modeling.*
- 1:00 p.m.–3:00 p.m. **MAA MINICOURSE #3: PART B** *Problem-based courses for teachers, future teachers, and math majors.*
- 1:00 p.m.–3:00 p.m. **MAA MINICOURSE #7: PART B** *Study the masters: Using primary historical sources in mathematics teaching.*
- MAA CONTRIBUTED PAPER SESSIONS**
- 1:00 p.m.–6:00 p.m. *Mathematics of Sustainability*
- 1:00 p.m.–6:00 p.m. *Wavelets in Undergraduate Education*
- 1:00 p.m.–6:00 p.m. *Developmental Mathematics Education: Helping Under-Prepared Students Transition to College-Level Mathematics*
- 1:00 p.m.–6:00 p.m. *Philosophy of Mathematics and Mathematical Practice*
- 1:00 p.m.–6:00 p.m. *Innovations in Teaching Statistics in the New Decade*

Meetings & Conferences

- 1:00 p.m.–6:00 p.m. *General Session, VI*
- 1:00 p.m.–5:50 p.m. **SIAM MINISYMPOSIUM ON APPLIED, COMPUTATIONAL, AND DISCRETE MATHEMATICS AT NATIONAL LABORATORIES AND FEDERAL RESEARCH AGENCIES**
- 1:00 p.m.–4:00 p.m. **NAM GRANVILLE-BROWN-HAYNES SESSION OF PRESENTATIONS BY RECENT DOCTORAL RECIPIENTS IN THE MATHEMATICAL SCIENCES**
- 1:00 p.m.–2:20 p.m. **MAA COMMITTEE ON TWO-YEAR COLLEGES PANEL DISCUSSION** *A new look at math for the non-STEM students.*
- 1:00 p.m.–5:55 p.m. **AMS SESSIONS FOR CONTRIBUTED PAPERS**
- 2:15 p.m.–4:00 p.m. **ROCKY MOUNTAIN MATHEMATICS CONSORTIUM BOARD OF DIRECTORS MEETING**
- 2:30 p.m.–3:50 p.m. **MAA PRESENTATIONS BY TEACHING AWARD WINNERS**
- 2:30 p.m.–4:00 p.m. **AMS COMMITTEE ON SCIENCE POLICY PANEL DISCUSSION** *The changing landscape of research funding.*
- 2:40 p.m.–4:00 p.m. **MAA/PARK CITY MATHEMATICS INSTITUTE PANEL DISCUSSION** *Engaging secondary teachers in doing mathematics.*
- 3:30 p.m.–5:30 p.m. **MAA MINICOURSE #12: PART B** *Using randomization methods to build conceptual understanding of statistical inference.*
- 3:30 p.m.–5:30 p.m. **MAA MINICOURSE #5: PART B** *Dance and mathematics.*
- 4:00 p.m.–5:30 p.m. **MAA UNDERGRADUATE POSTER SESSION**
- 4:30 p.m.–6:30 p.m. **AMS CONGRESSIONAL FELLOWSHIP SESSION**
- 5:00 p.m.–6:15 p.m. **SIGMAA ON MATHEMATICS INSTRUCTION USING THE WEB BUSINESS MEETING, RECEPTION, AND GUEST LECTURE**
- 5:00 p.m.–7:00 p.m. **MAA SPECIAL PRESENTATION: POETRY READING** *All mathematical poets and those interested in mathematical poetry are invited.*
- 5:00 p.m.–6:00 p.m. **SIGMAA ON QUANTITATIVE LITERACY BUSINESS MEETING**
- 5:00 p.m.–6:30 p.m. **RECEPTION IN HONOR OF RETIRING MAA EXECUTIVE DIRECTOR TINA STRALEY**
- 5:30 p.m.–7:30 p.m. **UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN RECEPTION**
- 6:00 p.m.–7:45 p.m. **SIGMAA ON MATHEMATICAL AND COMPUTATIONAL BIOLOGY BUSINESS MEETING AND GUEST LECTURE**
- 6:00 p.m.–7:00 p.m. **MAA DRAMATIC PRESENTATION** *Mathematically Bent Theater.*
- 6:00 p.m.–7:00 p.m. **AMS MATHEMATICAL REVIEWS RECEPTION**
- 6:00 p.m.–9:30 p.m. **NAM RECEPTION AND BANQUET**
- 6:00 p.m.–8:00 p.m. **ASSOCIATION OF CHRISTIANS IN THE MATHEMATICAL SCIENCES (ACMS) RECEPTION AND BANQUET**
- 7:30 p.m.–8:15 p.m. **NAM COX-TALBOT ADDRESS** *Title to be announced. Sylvia Bozeman*
- 8:30 p.m.–10:00 p.m. **MAA-PROJECT NEXT RECEPTION** *All Project NExT Fellows, consultants, and other friends of Project NExT are invited.*

Saturday, January 07

- 7:30 a.m.–2:00 p.m. **JOINT MEETINGS REGISTRATION**, 2nd Floor Corridor, opposite Hall C, Hynes
- AMS SPECIAL SESSIONS**
- 8:00 a.m.–10:50 a.m. *Mathematics and Education Reform, III (AMS-MAA-MER)*
- 8:00 a.m.–10:50 a.m. *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, III (AMS-MAA)*
- 8:00 a.m.–10:50 a.m. *Mathematics of Computation: Algebra and Number Theory, III (AMS-SIAM)*
- 8:00 a.m.–10:50 a.m. *Geometric Invariants of Groups and Related Topics, I*
- 8:00 a.m.–10:50 a.m. *Theory and Applications of Stochastic Differential and Partial Differential Equations, II*
- 8:00 a.m.–10:50 a.m. *Radon Transforms and Geometric Analysis (in honor of Sigurdur Helgason's 85th birthday), III*
- 8:00 a.m.–10:50 a.m. *Recent Advances in Mathematical Biology, Ecology, and Epidemiology, II*
- 8:00 a.m.–10:50 a.m. *Tensor Categories and Representation Theory, I*
- 8:00 a.m.–10:50 a.m. *My Favorite Graph Theory Conjectures, I*

- 8:00 a.m.–10:50 a.m. *Reaction Diffusion Equations and Applications, II*
- 8:00 a.m.–10:50 a.m. *Control of Biological and Physical Systems, I*
- 8:00 a.m.–10:50 a.m. *Mathematical Theory of Control of Quantum Systems, I*
- 8:00 a.m.–10:50 a.m. *Combinatorial Geometry of Polytopes, III*
- 8:00 a.m.–10:50 a.m. *Operator Theory on Analytic Function Spaces, I*
- 8:00 a.m.–10:50 a.m. *Noncommutative Birational Geometry and Cluster Algebras, II*
- 8:00 a.m.–10:50 a.m. *Nonlinear Analysis of Partial Differential Equation Models in Biology and Chemical Physics, I*
- 8:00 a.m.–10:50 a.m. *Fractal Geometry in Pure and Applied Mathematics (in memory of Benoit Mandelbrot), III*
- 8:00 a.m.–10:50 a.m. *Matrices and Graphs, I*
- 8:00 a.m.–10:50 a.m. *Arithmetic Geometry, III*
- 8:00 a.m.–10:50 a.m. *Uniformly and Partially Hyperbolic Dynamical Systems, III*
- 8:00 a.m.–10:50 a.m. *Frontiers in Geomathematics, II*
- 8:00 a.m.–10:50 a.m. *Homotopy Theory, II*
- MAA INVITED PAPER SESSION**
- 8:00 a.m.–11:00 a.m. *Applications of Dynamical Systems*
- MAA CONTRIBUTED PAPER SESSIONS**
- 8:00 a.m.–11:00 a.m. *Motivating Statistical and Quantitative Learning through Social Engagement, I*
- 8:00 a.m.–11:00 a.m. *Mathematical Preparation of Teachers: The Impact of the Common Core State Standards Initiative*
- 8:00 a.m.–11:00 a.m. *History of Mathematics and Its Uses in the Classroom*
- 8:00 a.m.–11:00 a.m. *General Session, VII*
- 8:00 a.m.–10:50 a.m. **SIAM MINISYMPOSIUM ON RECENT ADVANCES IN FLUID DYNAMICS AND TURBULENCE MODELS**
- 8:00 a.m.–5:00 p.m. **ASL INVITED ADDRESSES AND CONTRIBUTED PAPER SESSIONS**
- 8:00 a.m.–10:55 a.m. **AMS SESSIONS FOR CONTRIBUTED PAPERS**
- 8:25 a.m.–4:30 p.m. **AWM WORKSHOP** *This session has several parts that will be listed separately by time in this program. All presentations are open to all JMM participants.*
- 8:30 a.m.–10:30 a.m. **AWM WORKSHOP: RESEARCH PRESENTATIONS BY RECENT PH.D.S**
- 8:30 a.m.–10:00 a.m. **AMS COMMITTEE ON EDUCATION PANEL DISCUSSION** *Models for engaging undergraduate students in research.*
- 9:00 a.m.–9:50 a.m. **AMS INVITED ADDRESS** *Beyond q : Special functions on elliptic curves.* Eric Rains
- 9:00 a.m.–11:00 a.m. **MAA MINICOURSE #13: PART B** *Interactive applets for calculus and differential equations.*
- 9:00 a.m.–11:00 a.m. **MAA MINICOURSE #1: PART B** *Mathematics and backgammon.*
- 9:00 a.m.–11:00 a.m. **MAA MINICOURSE #4: PART B** *Elementary mathematics in architecture.*
- 9:00 a.m.–9:50 a.m. **NAM PANEL DISCUSSION**
- 9:00 a.m.–2:00 p.m. **STUDENT HOSPITALITY CENTER**
- 9:00 a.m.–12:00 p.m. **EXHIBITS AND BOOK SALES**
- 9:00 a.m.–12:00 p.m. **EMPLOYMENT CENTER**
- 10:00 a.m.–10:50 a.m. **NAM BUSINESS MEETING**
- 10:05 a.m.–10:55 a.m. **MAA INVITED ADDRESS** *Mathematical challenges in climate and sustainability.* Mary Lou Zeeman
- 10:30 a.m.–11:00 a.m. **AWM WORKSHOP: POSTER SESSION WITH PRESENTATIONS FROM WOMEN GRADUATE STUDENTS**
- 11:10 a.m.–11:40 a.m. **MAA BUSINESS MEETING**
- 11:45 a.m.–12:15 p.m. **AMS BUSINESS MEETING**
- 1:00 p.m.–1:50 p.m. **NAM CLAYTOR-WOODARD LECTURE** *Title to be announced.* Aderemi Kuku
- AMS SPECIAL SESSIONS**
- 1:00 p.m.–5:50 p.m. *Research in Mathematics by Undergraduates and Students in Post-Baccalaureate Programs, IV (AMS-MAA)*
- 1:00 p.m.–5:50 p.m. *Geometric Invariants of Groups and Related Topics, II*

Meetings & Conferences

- 1:00 p.m.–5:50 p.m. *Radon Transforms and Geometric Analysis (in honor of Sigurdur Helgason's 85th birthday), IV*
- 1:00 p.m.–5:50 p.m. *Recent Advances in Mathematical Biology, Ecology, and Epidemiology, III*
- 1:00 p.m.–5:50 p.m. *Tensor Categories and Representation Theory, II*
- 1:00 p.m.–5:50 p.m. *My Favorite Graph Theory Conjectures, II*
- 1:00 p.m.–5:50 p.m. *Reaction Diffusion Equations and Applications, III*
- 1:00 p.m.–5:50 p.m. *Global Dynamics of Rational Difference Equations with Applications*
- 1:00 p.m.–5:50 p.m. *Mathematical Principles and Theories of Integrable Systems*
- 1:00 p.m.–5:50 p.m. *Control of Biological and Physical Systems, II*
- 1:00 p.m.–5:50 p.m. *Mathematical Theory of Control of Quantum Systems, II*
- 1:00 p.m.–5:50 p.m. *Enumerative and Algebraic Combinatorics, III*
- 1:00 p.m.–5:50 p.m. *Operator Theory on Analytic Function Spaces, II*
- 1:00 p.m.–5:50 p.m. *Noncommutative Birational Geometry and Cluster Algebras, III*
- 1:00 p.m.–5:50 p.m. *Nonlinear Analysis of Partial Differential Equation Models in Biology and Chemical Physics, II*
- 1:00 p.m.–5:50 p.m. *Fractal Geometry in Pure and Applied Mathematics (in memory of Benoit Mandelbrot), IV*
- 1:00 p.m.–5:50 p.m. *Matrices and Graphs, II*
- 1:00 p.m.–5:50 p.m. *Mathematics and Statistics in Computational Biology.*
- 1:00 p.m.–5:50 p.m. *Frontiers in Geomathematics, III*
- 1:00 p.m.–5:50 p.m. *Algebraic and Geometric Aspects of Integrable Systems and Random Matrices, III*
- 1:00 p.m.–5:50 p.m. *Homotopy Theory, III*
- 1:00 p.m.–5:50 p.m. *Advanced Investigations on Applied Optimization and Multiple Fractional Programming*
- MAA INVITED PAPER SESSION**
- 1:00 p.m.–5:00 p.m. *Climate Change and Sustainability*
- 1:00 p.m.–3:00 p.m. **MAA MINICOURSE #10: PART B** *Geometry and art: A liberal arts mathematics course.*
- 1:00 p.m.–3:00 p.m. **MAA MINICOURSE #2: PART B** *A dynamical systems approach to the differential equations course.*
- 1:00 p.m.–3:00 p.m. **MAA MINICOURSE #9: PART B** *Reading original sources in Latin for the historian and mathematician.*
- MAA CONTRIBUTED PAPER SESSIONS**
- 1:00 p.m.–6:00 p.m. *Motivating Statistical and Quantitative Learning through Social Engagement, II*
- 1:00 p.m.–6:00 p.m. *Early Assessment: Find Out What Your Students Understand (and Don't Understand) before They Take the Test*
- 1:00 p.m.–6:00 p.m. *Trends in Teaching Mathematics Online*
- 1:00 p.m.–6:00 p.m. *General Session, VIII*
- 1:00 p.m.–5:50 p.m. **SIAM MINISYMPOSIUM ON VARIATIONAL AND PDE METHODS IN IMAGING SCIENCE**
- 1:00 p.m.–4:00 p.m. **SIGMAA ON MATH CIRCLES FOR STUDENTS AND TEACHERS POSTER AND ACTIVITY SESSION** *Come join us for the chance to experience a math circle firsthand.*
- 1:00 p.m.–2:15 p.m. **AWN WORKSHOP PANEL DISCUSSION** *Career options: Industry, government, and academia.*
- 1:00 p.m.–5:55 p.m. **AMS SESSIONS FOR CONTRIBUTED PAPERS**
- 3:00 p.m.–4:00 p.m. **AMS-MAA-SIAM GERALD AND JUDITH PORTER PUBLIC LECTURE** *Geometric puzzles: Algorithms and complexity. Erik Demaine*
- 6:30 p.m.–7:30 p.m. **AMS BANQUET RECEPTION**
- 7:30 p.m.–10:00 p.m. **AMS BANQUET**

2012 Joint Mathematics Meetings Advance Registration/Housing Form



Name _____
(please write name as you would like it to appear on your badge)

Mailing Address _____

Telephone _____ Fax: _____

In case of emergency (for you) at the meeting, call: Day # _____ Evening #: _____

E-mail Address _____

Acknowledgment of this registration and any hotel reservations will be sent to the e-mail address given here, unless you check this box: *Send by U.S. Mail*

Affiliation for badge _____ (company/university) Nonmathematician guest badge name: _____ (Note fee of US\$15)

I DO NOT want my program and badge to be mailed to me on 12/12/11. (Materials will be mailed to the address listed above unless you check this box.)

Registration Fees

Membership all that apply. First row is eligible to register as a JMM member.

- AMS MAA ASL CMS SIAM
 ASA AWM NAM YMN

Joint Meetings by Dec 15 at mtg Subtotal

<input type="checkbox"/> Member AMS, MAA, ASL, CMS, SIAM	US\$228	US\$ 300
<input type="checkbox"/> Nonmember	US\$356	US\$ 462
<input type="checkbox"/> Graduate Student (Member of AMS or MAA)	US\$ 50	US\$ 60
<input type="checkbox"/> Graduate Student (Nonmember)	US\$ 78	US\$ 88
<input type="checkbox"/> Undergraduate Student	US\$ 50	US\$ 60
<input type="checkbox"/> High School Student	US\$ 5	US\$ 10
<input type="checkbox"/> Unemployed	US\$ 50	US\$ 60
<input type="checkbox"/> Temporarily Employed	US\$185	US\$214
<input type="checkbox"/> Developing Countries Special Rate	US\$ 50	US\$ 60
<input type="checkbox"/> Emeritus Member of AMS or MAA	US\$ 50	US\$ 60
<input type="checkbox"/> High School Teacher	US\$ 50	US\$ 60
<input type="checkbox"/> Librarian	US\$ 50	US\$ 60
<input type="checkbox"/> Press	US\$ 0	US\$ 0
<input type="checkbox"/> Nonmathematician Guest	US\$ 15	US\$ 15
		\$ _____

AMS Short Course 1: *Random Fields and Random Geometry*(1/2-1/3)

<input type="checkbox"/> Member of AMS or MAA	US\$102	US\$136
<input type="checkbox"/> Nonmember	US\$145	US\$175
<input type="checkbox"/> Student, Unemployed, Emeritus	US\$ 50	US\$ 71
		\$ _____

AMS Short Course 2: *Computing with Elliptic Curves Using Sage* (1/2-1/3)

<input type="checkbox"/> Member of AMS or MAA	US\$102	US\$136
<input type="checkbox"/> Nonmember	US\$145	US\$175
<input type="checkbox"/> Student, Unemployed, Emeritus	US\$ 50	US\$ 71
		\$ _____

MAA Short Course: *Discrete and Computational Geometry* (1/2-1/3)

<input type="checkbox"/> Member of MAA or AMS	US\$ 153	US\$163
<input type="checkbox"/> Nonmember	US\$204	US\$214
<input type="checkbox"/> Student, Unemployed, Emeritus	US\$ 77	US\$ 87
		\$ _____

MAA Minicourses (see listing in text)

I would like to attend: One Minicourse Two Minicourses
 Please enroll me in MAA Minicourse(s) # _____ and/or # _____
 In order of preference, my alternatives are: # _____ and/or # _____
 Price: US\$77 for each minicourse.
 (For more than 2 minicourses call or email the MMSB.) \$ _____

Graduate School Fair

<input type="checkbox"/> Graduate Program Table	US\$ 65	US\$ 65
		\$ _____

Employment Center Please go to <http://www.ams.org/emp-reg> to register. For further information, contact Steve Ferrucci at emp-info@ams.org.

Events with Tickets

Graduate Student/First Time Attendee Reception (1/4) (no charge)
 MER/IME Banquet (1/5) US\$ 60 # _____Chicken # _____Fish # _____Kosher # _____Vegan
 NAM Banquet (1/6) US\$ 58 # _____Chicken # _____Fish # _____Kosher # _____Vegan
 AMS Banquet (1/7) US\$ 58 # _____Chicken # _____Fish # _____Kosher # _____Vegan
 Reception for Tina Straley (1/6) US\$ 28 # _____tickets
 (Additional fees may apply for Kosher meals.) \$ _____

Total for Registrations and Events \$ _____

Payment

Registration & Event Total (total from column on left) \$ _____
 Hotel Deposit (only if paying by check) \$ _____

Total Amount To Be Paid \$ _____

(Note: A US\$5 processing fee will be charged for each returned check or invalid credit card. Debit cards cannot be accepted.)

Method of Payment

Check. Make checks payable to the AMS. Checks drawn on foreign banks must be in equivalent foreign currency at current exchange rates. For all check payments, please keep a copy of this form for your records.

Credit Card. All major credit cards accepted. For your security, we do not accept credit card numbers by postal mail, e-mail or fax. If the MMSB receives your registration form by fax or postal mail, we will contact you at the phone number provided on this form. For questions, contact the MMSB at mmsb@ams.org.

Signature: _____

Purchase Order # _____ (please enclose copy)

Other Information

Mathematical Reviews field of interest # _____

How did you hear about this meeting? Check one:

Colleague(s) Internet Notices Focus Other _____

This is my first Joint Mathematics Meetings.

I am a mathematics department chair.

For planning purposes for the MAA Two-year College Reception, please check if you are a faculty member at a two-year college.

I would like to receive promotions for future JMM meetings.

Please do not include my name on any promotional mailing lists.

Please this box if you have a disability requiring special services. 

Mailing Address/Contact:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887 Fax: 401-455-4004; E-mail: mmsb@ams.org
Telephone: 401-455-4143 or 1-800-321-4267 x4143 or x4144

Deadlines

To be eligible for the complimentary room drawing: **Nov. 4, 2011**
 For housing reservations, badges/programs mailed: **Nov. 18, 2011**
 For housing changes/cancellations through MMSB: **Dec. 6, 2011**
 For advance registration for the Joint Meetings, short courses, minicourses, and tickets: **Dec. 15, 2011**
 For 50% refund on banquets, cancel by: **Dec. 27, 2011***
 For 50% refund on advance registration, minicourses & short courses, cancel by: **Dec. 30, 2011***
***no refunds after this date**

Registration for the Joint Meetings is not required for the short courses but it is required for the minicourses and the Employment Center.

2012 Joint Mathematics Meetings Hotel Reservations – Boston, MA

Please see the hotel page in the announcement or on the web for detailed information on each hotel. To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc. in the column on the left and by circling the requested room type and rate. If the rate or the hotel requested is no longer available, you will be assigned a room at the next available comparable rate. Please call the MMSB for details on suite configurations, sizes, availability, etc. All reservations, including suite reservations, must be made through the MMSB to receive the JMM rates. Reservations made directly with the hotels before **December 14** may be changed to a higher rate. All rates are subject to a 14.45% sales/occupancy tax. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee.**

Deposit enclosed (see front of form) Hold with my credit card. **For your security, we do not accept credit card numbers by postal mail, e-mail or fax.** If the MMSB receives your registration form by postal mail or fax, we will contact you at the phone number provided on the reverse of this form.

Date and Time of Arrival _____ Date and Time of Departure _____
 Name of Other Room Occupant _____ Arrival Date _____ Departure Date _____ Child (give age(s)) _____

Order of choice	Hotel	Single	Double 1 bed	Double 2 beds	Triple 2 beds	Triple 2 beds w/cot	Triple - king or queen w/cot	Quad 2 beds	Quad 2 beds w/cot	Suites Starting rates
	Marriott Copley Place (co-headquarters)									
	Regular Rate	US\$ 159	US\$ 159	US\$ 159	US\$ 179	US\$ 179	US\$ 179	US\$ 199	US\$ 199	US\$ 800
	Student Rate	US\$ 149	US\$ 149	US\$ 149	US\$ 169	US\$ 169	US\$ 169	US\$ 189	US\$ 189	N/A
	Sheraton Boston (Co-headquarters)									
	Regular Rate	US\$ 159	US\$ 159	US\$ 159	US\$ 169	N/A	US\$ 169	US\$ 179	N/A	US\$ 219
	Student Rate	US\$ 149	US\$ 149	US\$ 149	US\$ 159	N/A	US\$ 159	US\$ 169	N/A	N/A
	Boston Omni Parker House									
	Regular Rate	US\$ 149	US\$ 149	US\$ 149	US\$ 179	US\$ 179	US\$ 179	US\$ 209	US\$ 209	N/A
	Student Rate	US\$ 129	US\$ 129	US\$ 129	N/A	N/A	N/A	N/A	N/A	N/A
	Hilton Back Bay									
	Regular Rate	US\$ 129	US\$ 129	US\$ 129	US\$ 149	US\$ 174	N/A	US\$ 169	US\$ 194	US\$ 429
	Student Rate	US\$ 119	US\$ 119	US\$ 119	US\$ 139	US\$ 164	N/A	US\$ 159	US\$ 184	N/A
	The Colonnade Hotel									
	Regular Rate	US\$ 124	US\$ 124	US\$ 124	US\$ 154	US\$ 154	US\$ 154	US\$ 184	US\$ 184	US\$ 424
	Student Rate	US\$ 114	US\$ 114	US\$ 114	US\$ 144	US\$ 144	US\$ 144	US\$ 174	US\$ 174	N/A
	Boston Park Plaza and Towers									
	Regular Rate	US\$ 122	US\$ 122	US\$ 122	US\$ 132	N/A	US\$ 132*	US\$ 142	N/A	US\$ 272
	Student Rate	US\$ 112	US\$ 112	US\$ 112	US\$ 122	N/A	US\$ 122*	US\$ 132	N/A	N/A

* Boston Park Plaza charges an additional US\$25 per stay for a rollaway cot

Special Housing Requests:

I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are: _____

Other requests: _____
 I am a member of a hotel frequent-travel club and would like to receive appropriate credit. The hotel chain and card number are: _____

E-mail confirmations (no paper) will be sent by all hotels if an e-mail address is provided.

If you are not making a reservation, please check one of the following:

- I plan to make a reservation at a later date.
- I will be making my own reservations at a hotel not listed. Name of hotel: _____
- I live in the area or will be staying privately with family or friends.
- I plan to share a room with _____, who is making the reservations.

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

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Central Section: Georgia Benkart, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388; e-mail: benkart@math.wisc.edu; telephone: 608-263-4283.

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Southeastern Section: Matthew Miller, Department of Mathematics, University of South Carolina, Columbia, SC 29208-0001, e-mail: miller@math.sc.edu; telephone: 803-777-3690.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information can be found at www.ams.org/meetings/.**

Meetings:

2011

September 24–25	Winston-Salem, North Carolina	p. 1348
October 14–16	Lincoln, Nebraska	p. 1349
October 22–23	Salt Lake City, Utah	p. 1350
November 29–December 3	Port Elizabeth, Republic of South Africa	p. 1350

2012

January 4–7	Boston, Massachusetts Annual Meeting	p. 1351
March 3–4	Honolulu, Hawaii	p. 1378
March 10–11	Tampa, Florida	p. 1379
March 17–18	Washington, DC	p. 1380
March 30–April 1	Lawrence, Kansas	p. 1380
September 22–23	Rochester, New York	p. 1381
October 13–14	New Orleans, Louisiana	p. 1381
October 20–21	Akron, Ohio	p. 1382
October 27–28	Tucson, Arizona	p. 1382

2013

January 9–12	San Diego, California Annual Meeting	p. 1382
March 1–3	Oxford, Mississippi	p. 1383
April 6–7	Chestnut Hill, Massachusetts	p. 1383
April 27–28	Ames, Iowa	p. 1383
June 27–30	Alba Iulia, Romania	p. 1383

October 5–6	Louisville, Kentucky	p. 1383
October 18–20	St. Louis, Missouri	p. 1384
November 2–3	Riverside, California	p. 1384

2014

January 15–18	Baltimore, Maryland Annual Meeting	p. 1384
June 16–19	Tel Aviv, Israel	p. 1384

2015

January 10–13	San Antonio, Texas Annual Meeting	p. 1384
June 11–14	Porto, Portugal	p. 1385

2016

January 6–9	Seattle, Washington	p. 1385
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2017

January 4–7	Atlanta, Georgia	p. 1385
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2018

January 10–13	San Diego, California	p. 1385
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Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 100 in the January 2011 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of L^AT_EX is necessary to submit an electronic form, although those who use L^AT_EX may submit abstracts with such coding, and all math displays and similarly coded material (such as accent marks in text) must be typeset in L^AT_EX. Visit <http://www.ams.org/cgi-bin/abstracts/abstract.pl>. Questions about abstracts may be sent to abs-info@ams.org. 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.)

March 11–14, 2012: Fourth International Conference on Mathematical Sciences, United Arab Emirates (held in cooperation with the AMS). Please see <http://icm.uaeu.ac.ae/> for more information.

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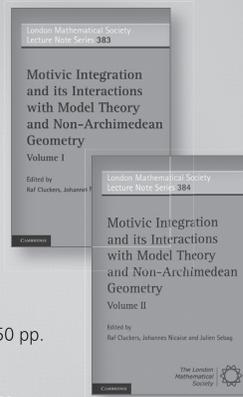
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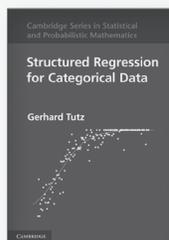


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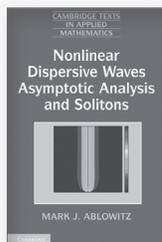


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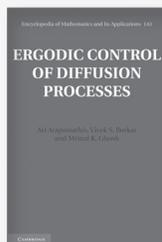
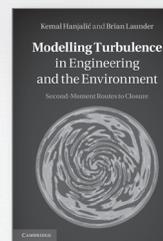
Nonlinear Dispersive Waves Asymptotic Analysis and Solitons

Mark J. Ablowitz
Cambridge Texts in Applied Mathematics
\$115.00; Hardback: 978-1-107-01254-7; 360 pp.
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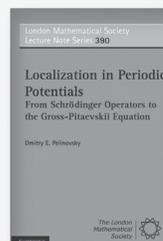
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Kemal Hanjalic and Brian Launder
\$130.00; Hardback: 978-0-521-84575-5; 400 pp.



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Ari Arapostathis, Vivek S. Borkar, and Mrinal K. Ghosh
Encyclopedia of Mathematics and its Applications
\$115.00; Hardback: 978-0-521-76840-5; 335 pp.

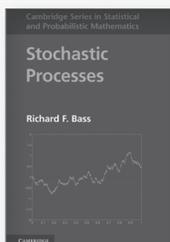


Localization in Periodic Potentials From Schrödinger Operators to the Gross-Pitaevskii Equation

Dmitry E. Pelinovsky
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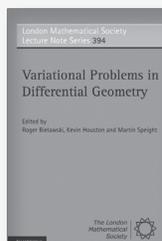
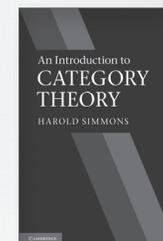
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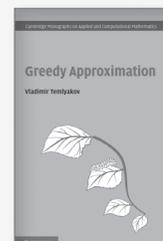
An Introduction to Category Theory

Harold Simmons
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\$29.99; Paperback: 978-0-521-28304-5



Variational Problems in Differential Geometry

Edited by Roger Bielawski, Kevin Houston, and Martin Speight
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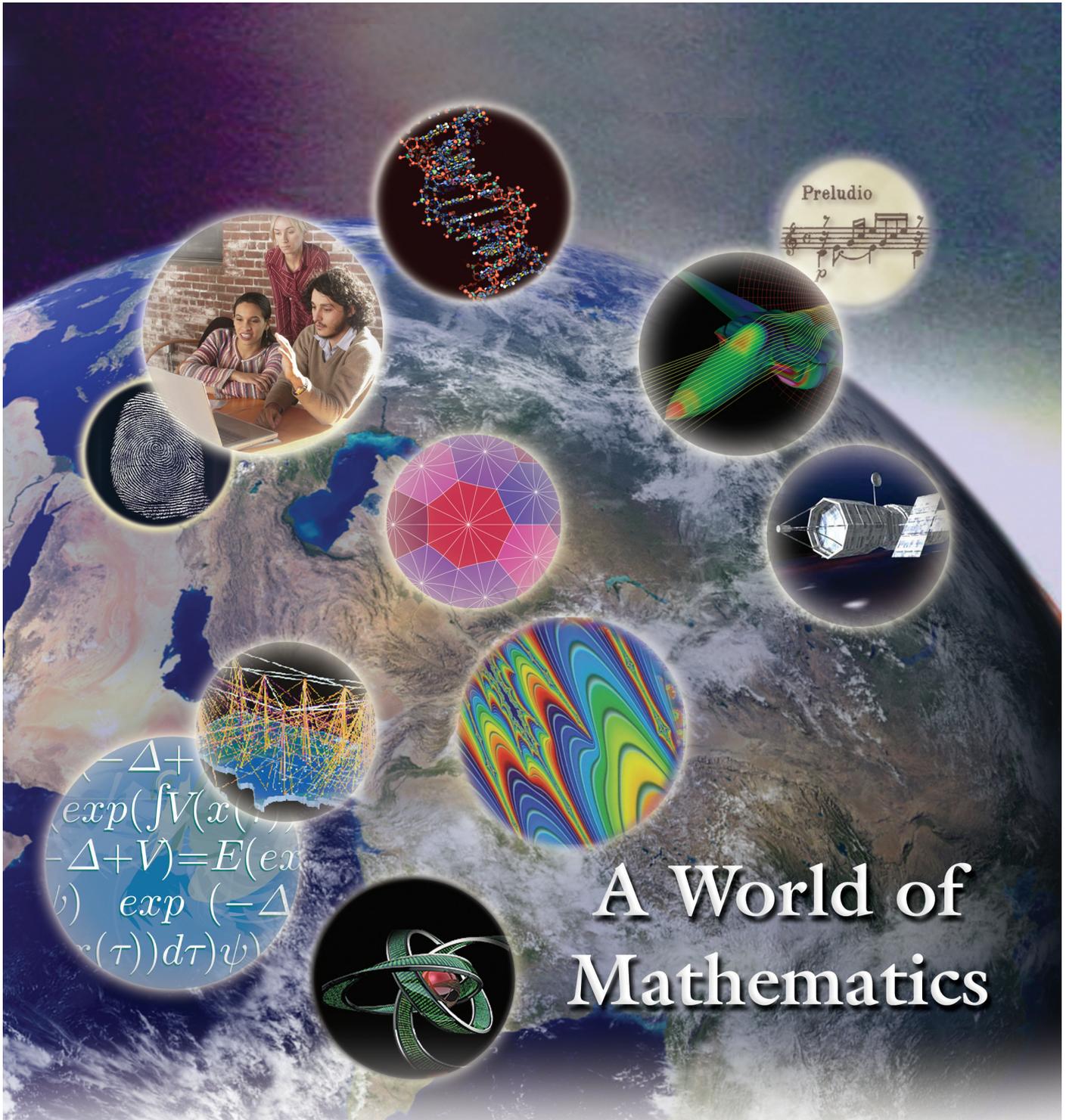


Greedy Approximation

Vladimir Temlyakov
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\$99.00; Hardback: 978-1-107-00337-8; 432 pp.

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Nikolai Chernov, *University of Alabama at Birmingham, AL*, and Roberto Markarian, *Universidad de la República, Montevideo, Uruguay*

Mathematical Surveys and Monographs, Volume 127; 2006; 316 pages; Hardcover; ISBN: 978-0-8218-4096-2; List US\$85.00; **SALE PRICE US\$21.25**; Order code SURV/127

Chiral Algebras

Alexander Beilinson and Vladimir Drinfeld, *University of Chicago, IL*

Colloquium Publications, Volume 51; 2004; 375 pages; Hardcover; ISBN: 978-0-8218-3528-9; List US\$72.00; **SALE PRICE US\$25.20**; Order code COLL/51



Continuous Symmetry

From Euclid to Klein

William Barker, *Bowdoin College, Brunswick, ME*, and Roger Howe, *Yale University, New Haven, CT*

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A Course in Ring Theory

Donald S. Passman, *University of Wisconsin, Madison, WI*

AMS Chelsea Publishing, Volume 348; 2004; 306 pages; Hardcover; ISBN: 978-0-8218-3680-4; List US\$47.00; **SALE PRICE US\$23.50**; Order code CHEL/348.H

Pick Interpolation and Hilbert Function Spaces

Jim Agler, *University of California at San Diego, CA*, and John E. McCarthy, *Washington University, St. Louis, MO*

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CRM Monograph Series, Volume 23; 2004; 215 pages; Hardcover; ISBN: 978-0-8218-3571-5; List US\$62.00; **SALE PRICE US\$21.70**; Order code CRMM/23



Discrete Mathematics

Martin Aigner, *Freie Universität Berlin, Germany*

2007; 388 pages; Hardcover; ISBN: 978-0-8218-4151-8; List US\$59.00; **SALE PRICE US\$20.65**; Order code DISCMAT

Essays in the History of Lie Groups and Algebraic Groups

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An Introduction to Limit Theorems in Probability

Emmanuel Lesigne, *Université François Rabelais, Tours, France*

Student Mathematical Library, Volume 28; 2005; 150 pages; Softcover; ISBN: 978-0-8218-3714-6; List US\$30.00; **SALE PRICE US\$15.00**; Order code STML/28

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