Conformal maps by packing circles (see page 1388)
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In the Monte Carlo simulations that follow, three bandwidth choices were investigated. For parameter combinations, the LSCV bandwidth, the “Stanton” bandwidth, and identical bandwidths (IID) were used. The first choice is the solution to the square root of the bandwidth problem (ref: LSCVfunc). The IID bandwidth is defined as

\[ h_{II} = \hat{\sigma} T^{-\frac{1}{5}} \]

where \( \hat{\sigma} \) is the sample standard deviation and \( T \) is the sample size. The Stanton bandwidth is the one usually used for the entire sample.

The estimators in Stanton (1997) are based directly on equations (6.1) and (6.2), above. In particular, “inverting” these equations yields

\[ \mu(x_t) = \frac{1}{\Delta} \frac{\Delta}{\hat{\sigma}} h_{WW} \left( x_{t+\Delta} - x_t \right) + \frac{\Delta}{\hat{\sigma}} \]

\[ \sigma(x_t) = \sqrt{\frac{\hat{\sigma}^2}{\Delta}} \left( x_{t+\Delta} - x_t \right) \frac{1}{\Delta} \]

The essence of Stanton’s approach is to apply the Nadaraya-Watson estimator to construct nonparametric estimates of the conditional mean (ref: diff2) and (ref: diff2):

\[ \beta(z_t) = \frac{1}{\Delta} \frac{\Delta}{\hat{\sigma}} h_{WW} \left( z_{t+\Delta} - z_t \right) \]

and

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All Write Now

Can a typo send a man to hell? Some authorities claim that such a fate befell Ben Jonson (the Elizabethan dramatist, contemporary of Shakespeare, and convicted murderer), whose grave marker in Westminster Abbey reads, "O RARE BEN JOHNSON". The variation in the spelling of the name is not an issue, but the space after the "O" is. Some argue that the initial word of the inscription should have been the Latin verb "Orare", the intent being to exhort the beholder to pray for Jonson's salvation. Thus an engraver's error may have cheated Jonson out of centuries of prayers for his soul.

Similarly, a mistake in a single character in a mathematics paper can wreak havoc on the reader's comprehension. A wrong minus sign ruins a calculation, and confusing $p$ with $p$ turns the Navier-Stokes equations into nonsense. A discussion about the structure of rings of functions had better not mix up the words "homomorphic" and "holomorphic". Inattention to such details can have catastrophic consequences: the $125$ million Mars Climate Orbiter was lost in September 1999 due to a mix-up concerning the units of measurement of the thrust of the rocket engines.

The moral is the expositor's version of Murphy's Law: namely, anything that can be misunderstood will be misunderstood. This being my last issue as editor of the Notices, I take the opportunity to expound on the principle.

One of the great challenges of writing expository articles about mathematics is that the audience is unknown. Because the printed medium lacks interaction, the author cannot be sure that the reader interprets such terms as "Riesz representation theorem", "harmonic", and even "integer" the same way that the author does. Moreover, the author cannot determine whether the reader knows the Gauss-Bonnet theorem, the definition of the wave-front set, or the proof of Hilbert's Nullstellensatz. Unable to engage readers in a dialogue, authors must design the exposition to give implicit reminders about mathematical topics that may be fuzzy in readers' minds and to bolster readers' confidence that they are following the discussion.

What may authors of Notices articles assume about the readers? The Notices reaches a wide audience that includes graduate students, college and university teachers, and mathematicians working in industry. Readers may be presumed to have an interest in learning about contemporary developments in mathematical research, but not all readers are themselves engaged in research. Thus, an article whose first paragraph expects readers to know about last year's breakthrough in the theory of (say) pseudoplastic prosthaphaeresis is inappropriate for the Notices audience. Indeed, the intersection of the mathematical backgrounds of all the readers of the Notices is a set of measure zero (possibly void). Consequently, authors who hope to reach a substantial fraction of the Notices audience must constantly look for ways to make contact with parts of mathematics likely to be familiar to most readers. Canny authors skip the subtleties and the abstractions; instead they present the simplest nontrivial examples.

Good expositors also take pains to eliminate ambiguities that could cause confusion or uncertainty in the reader's mind. A careful author avoids writing $r^{s+1/2}$, for readers may be in doubt about whether the author is following the convention that treats the exponent as $s + (1/2)$. Similarly, an argument should not depend on a proper interpretation of the relative pronouns "which" and "that", for many readers are unsure about the conventional difference in meaning between these two words. Nor should authors place excessive demands on the acuity of the reader's eyesight: a formula that uses both $\alpha$ and $\beta$ is begging for misinterpretation. One of the reasons I became an analyst rather than an algebraist is that when I was a student, I could not distinguish $\psi$ from $\varphi$ and $\epsilon$ from $\varepsilon$; neither the algebra book nor the teacher provided a chart of the Fraktur letters.

Quality mathematical writing requires not only thoughtful organization, clear explanation, and meticulous attention to detail but also the ability to view the subject from a nonexpert's viewpoint and the willingness to revise and rewrite multiple times. Writing well requires different skills from proving theorems. It is hard work, but I have learned as editor of the Notices that there is an enthusiastic and appreciative audience for good mathematical exposition.

In the year 2000 the AMS established a new prize that recognizes the value and the importance of communicating mathematics to a broad audience. The annual Levi L. Conant prize is awarded for the best expository paper published in either the Notices or the Bulletin of the AMS in the preceding five years. Prospective authors in search of models to emulate might start with the prize-winning papers listed at the Internet address http://www.ams.org/prizes/conant-prize.html.

I am pleased that the Society honors good mathematical writing. It is an activity I hold dear: that is why I devoted the past three years to fostering mathematical exposition. I hope that readers of the Notices will study the masters and then try their own hands at writing papers worthy of a prize.

—Harold P. Boas, Editor
Letters to the Editor

Poor Quality Textbooks
The mathematical community should pay more attention to the quality of textbooks printed in this country. Sometimes it looks as if the author is unfamiliar with the standard terminology or lacks elementary logic.

For the current academic year our department adopted a book on introductory statistics. I became struck by the shortcomings of the book. Here are two examples.

(i) Marginal probability is defined as the probability of a single event without consideration of any other event. Marginal probability is also called simple probability.

Stated in those general terms, without specifying that the word marginal is applicable only in the case of a two-way classification of the outcomes of an experiment, this definition is unscientific and misleading. The term simple probability seems to be the author's invention.

(ii) The author makes several “Important Observations”, and one of them is: Two events are either mutually exclusive or independent.

Is it not amusing? An unqualified reader most likely would conclude that if two events are not mutually exclusive, then they are independent, which is indeed an absurdity.

I do not want to go into details of other weak features of the book, such as a huge number of unneeded definitions, which can only overload a student’s memory; the monotony of many absolutely similar exercises, where exactly the same formula is used and only numerical values and item names differ; and the lack in most sections of even minimally challenging problems, which would require students to do a little bit of reasoning of their own.

No wonder that with such textbooks and under growing pressure from the university administration to reduce the percentage of failing grades, many of our graduates prove to be less prepared in mathematics than their counterparts in, for example, Europe, Japan, China, and Israel.

—Alexander Yushkevich
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(Received September 2, 2003)

Towards More Varied and Better Calculus Texts
The letter by Ostrovskii in the September 2003 issue of the Notices addresses an important issue for all mathematicians. Quality teaching is a major part of our profession. How we teach is not just supported, but strongly influenced by the textbooks we use. His suggestions are interesting. While I do not necessarily agree with all of them, I would like to add a few remarks on distributed authorship and on dissemination/improvement mechanisms that may encourage those of us who have similar concerns and hopes for novel approaches to calculus.

Distributed authorship can turn into a logistical nightmare. However, it might be realizable by modularizing the text. As long as each module has clearly stated prerequisites and learning objectives, there is no reason why modules on differential equations and on differentiation formulas could not be written by different people. This approach will not lead to compartmentalization if the authors communicate with each other and appropriate cross-references are implemented.

Rapid improvement of a text can come from multiple authors who proofread each other’s work, but also (and maybe more rapidly) through fast reactions to user comments. Some people say that textbooks get really good only after the second or third edition. These editions take about ten years to materialize because of the way books are currently disseminated. On-demand publishing may become a new avenue that allows more rapid product improvement while lowering the overall prices.

With present-day typesetting tools, a book with (near) professional quality layout, fonts, graphics, etc., can be produced by the author in pdf form. Rather than printing the book off the pdf, then storing the hard copies and eventually shipping them across the country to be sold, why not sell the right to print the pdf to the adopting campuses? This will reduce the cost of texts, because the only overhead encountered is the electronic transmission of a file (essentially zero cost) or the mailing of a disk (negligible cost). The price will be the cost to print the text locally (which is low for high-quality grayscale production), plus an author’s royalty, plus the bookstore markup, plus (if so desired) a markup that goes to the adopting school’s mathematics department for scholarships or similar purposes. Even with all these markups, a high-quality 600-700-page text should cost the student less than $40. Moreover, because the texts exist primarily in electronic form, errors can be removed and new exercises and projects can be incorporated immediately. A new pdf can be posted every semester. That means that after ten years such a text could be (at least) in the twentieth “edition” and it should have benefited from multiple user input. The early thresholds (second, third edition) will be passed before the end of the first two years, though the time scale may need to be adjusted slightly.

The creation and dissemination process described above sounds terribly easy. It will not be that trivial once the rubber hits the road. Yet I know that soon there will be truly high-quality alternatives to the current textbooks. If they are good alternatives, they will thrive. If not, we have lost nothing by trying.

—Bernd Schroeder
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(Received September 15, 2003)
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The circle is arguably the most studied object in mathematics, yet I am here to tell the tale of circle packing, a topic which is likely to be new to most readers. These packings are configurations of circles satisfying preassigned patterns of tangency, and we will be concerned here with their creation, manipulation, and interpretation. Lest we get off on the wrong foot, I should caution that this is NOT two-dimensional “sphere” packing: rather than being fixed in size, our circles must adjust their radii in tightly choreographed ways if they hope to fit together in a specified pattern.

In posing this as a mathematical tale, I am asking the reader for some latitude. From a tale you expect truth without all the details; you know that the storyteller will be playing with the plot and timing; you let pictures carry part of the story. We all hope for deep insights, but perhaps sometimes a simple story with a few new twists is enough—may you enjoy this tale in that spirit. Readers who wish to dig into the details can consult the “Reader’s Guide” at the end.

Once Upon a Time...

From wagon wheel to mythical symbol, predating history, perfect form to ancient geometers, companion to π, the circle is perhaps the most celebrated object in mathematics.

Kenneth Stephenson is professor of mathematics at the University of Tennessee, Knoxville. His email address is kens@math.utk.edu.

The author gratefully acknowledges support of the National Science Foundation, DMS-0101324.

There is indeed a long tradition behind our story. Who can date the most familiar of circle packings, the “penny-packing” seen in the background of Figure 1? Even the “apollonian gasket” (a) has a history stretching across more than two millennia, from the time of Apollonius of Perga to the latest research on limit sets. And circles were never far from the classical solids, as suggested by the sphere caged by a dodecahedron in (b). Equally ancient is the ἄρβηλος or “shoemaker’s knife” in (c), and it is amazing that the Greeks had already proved that the nth circle \( C_n \) has its center \( n \) diameters from the base. This same result can be found, beautifully illustrated, in sangaku, wooden temple carvings from seventeenth-century Japan. In comparatively recent times, Descartes established his Circle Theorem for “quads” like that in (d), showing that the bends \( b_j \) (reciprocal radii) of four mutually tangent circles are related by

\[
(b_1 + b_2 + b_3 + b_4)^2 = 2(b_1^2 + b_2^2 + b_3^2 + b_4^2). 
\]

Nobel laureate F. Soddy was so taken by this result that he rendered it in verse: The Kiss Precise (1936). With such a long and illustrious history, is it surprising or is it inevitable that a new idea about circles should come along?

Birth of an Idea

One can debate whether we see many truly new ideas in mathematics these days. With such a rich history, everything has antecedents—who is to say, for example, what was in the lost books of Apollonius and others? Nonetheless, some topics have fairly well-defined starting points.
Our story traces its origin to William Thurston's famous Notes. In constructing 3-manifolds, Thurston proves that associated with any triangulation of a sphere is a "circle packing", that is, a configuration of circles which are tangent with one another in the pattern of the triangulation. Moreover, this packing is unique up to Möbius transformations and inversions of the sphere. This is a remarkable fact, for the pattern of tangencies—which can be arbitrarily intricate—is purely abstract, yet the circle packing superimposes on that pattern a rigid geometry. This is a main theme running through our story, that circle packing provides a bridge between the combinatoric on the one hand and the geometric on the other.

Although known in the topological community through the Notes, circle packings reached a surprising new audience when Thurston spoke at the 1985 Purdue conference celebrating de Branges's proof of the Bieberbach Conjecture. Thurston had recognized in the rigidity of circle packings something like the rigidity shown by analytic functions, and in a talk entitled "A finite Riemann mapping theorem" he illustrated with a scheme for constructing conformal maps based on circle packings. He made an explicit conjecture, in fact, that his "finite" maps would converge, under refinement, to a classical conformal map, the type his Purdue audience knew well. As if that weren't enough, Thurston even threw in an iterative numerical scheme for computing these finite Riemann mappings in practice, with pictures to back it all up.

So this was the situation for your storyteller as he listened to Thurston's Purdue talk: a most surprising theorem and beautiful pictures about patterns of circles, an algorithm for actually computing them, and a conjectured connection to a favorite topic, analytic function theory. This storyteller was hooked!

As for antecedents, Thurston found that his theorem on packings of the sphere followed from prior work by E. Andreev on reflection groups, and some years later Reiner Kuhnau pointed out a 1936 proof by P. Koebe, so I refer to it here as the K-A-T (Koebe-Andreev-Thurston) Theorem. Nonetheless, for our purposes the new idea was born at Purdue in 1985, and our tale can begin.

Internal Development
Once a topic is launched and begins to attract a community, it also begins to develop an internal ecology: special language, key examples and theorems, central themes, and—with luck—a few gems to amaze the uninitiated.

The main players in our story, circles, are well known to us all, and we work in familiar geometric spaces: the sphere $\mathbb{P}$, the euclidean plane $\mathbb{C}$, and the hyperbolic plane represented by the unit disc $\mathbb{D}$. Working with configurations of circles, however, will require a modest bit of bookkeeping, so bear

\begin{itemize}
  \item **Complex:** The tangency patterns for circle packings are encoded as abstract simplicial 2-complexes $K$; we assume $K$ is (i.e., triangulates) an oriented topological surface.
  
  \item **Packing:** A circle packing $P$ for $K$ is a configuration of circles such that for each vertex $v \in K$ there is a corresponding circle $c_v$, for each edge $(v, u) \in K$ the circles $c_v$ and $c_u$ are (externally) tangent, and for each positively oriented face $(v, u, w) \in K$ the mutually tangent triple of circles $(c_v, c_u, c_w)$ is positively oriented.
  
  \item **Label:** A label $R$ for $K$ is a collection of putative radii, with $R(v)$ denoting the label for vertex $v$.
\end{itemize}

Look to Figure 2 for a very simple first example. Here $K$ is a closed topological disc and $P$ is a euclidean circle packing for $K$. I show the carrier of the packing in dashed lines to aid in matching circles to their vertices in $K$; there are 9 interior and 8 boundary circles. Of course the question is how to find such packings, and the key is the label $R$ of radii—knowing $K$, the tangencies, and $R$, the sizes, it is a fairly simple matter to lay out the circles themselves. In particular, circle centers play a secondary role. The computational effort in

---

**Figure 1. A long tradition.**

with me while I introduce the essentials needed to follow the story.
circle packing lies mainly in computing labels. It is in these computations that circle packing directly confronts geometry and the local-to-global theme plays out. Here, very briefly, is what is involved.

- **Flower**: A circle $c_v$ and the circles tangent to it are called a flower. The ordered chain $c_{v_1}, \ldots, c_{v_k}$ of tangent circles, the petals, is closed when $v$ is an interior vertex of $K$.

- **Angle Sum**: The angle sum $\theta_R(v)$ for vertex $v$, given label $R$, is the sum of the angles at $c_v$ in the triangles formed by the triples $(c_v, c_{v_1}, c_{v_1 + 1})$ in its flower. Angle sums are computed via the appropriate law of cosines; in the euclidean case, for example,

$$
\theta_R(v) = \sum_{(v, u, w)} \arccos \left( \frac{(R(v) + R(u))^2 + (R(v) + R(w))^2 - (R(u) + R(w))^2}{2(R(v) + R(u))(R(v) + R(w))} \right),
$$

where the sum is over all faces containing $v$.

- **Packing Condition** The flower of an interior vertex $v$ can be realized as an actual geometric flower of circles with radii from $R$ if and only if $\theta_R(v) = 2\pi n$ for some integer $n \geq 1$.

It is clear that circles trying to form a packing for $K$ must tightly choreograph their radii. The packing condition at interior vertices is necessary, so a label $R$ is called a packing label if $\theta_R(v)$ is a multiple of $2\pi$ for every interior $v \in K$. When $K$ is simply connected, this and a monodromy argument yield a corresponding packing $P$, and the labels are, in fact, radii. When $K$ is multiply connected, however, the local packing condition alone is not enough, and global obstructions become the focus. Here are a last few pieces of the ecology.

- **Miscellany**: A packing is univalent if its circles have mutually disjoint interiors. A branch circle $c_v$ in a packing $P$ is an interior circle whose angle sum is $2\pi n$ for integer $n \geq 2$; that is, its petals wrap $n$ times around it. A packing $P$ is branched if it has one or more branch circles; otherwise it is locally univalent. (Caution: Global univalence is assumed for all circle packings in some parts of the literature, but not here.) Möbius transformations map packings to packings; a packing is said to be essentially unique with some property if it is unique up to such transformations. In the disc, a horocycle is a circle internally tangent to the unit circle and may be treated as a circle of infinite hyperbolic radius.

You are now ready for the internal art of circle packing. Someone hands you a complex $K$. Do there exist any circle packings for $K$? How many? In which geometry? Can they be computed in practice? What are their properties? What do they look like?

Let's begin by explicating certain extremal packings shown in Figure 3. The spherical packing in (a) illustrates the K-A-T Theorem using the combinatorics of the soccer ball. However, our development really starts in the hyperbolic plane; Figure 3(b) illustrates the key theorem (the outer circle represents the boundary of $\mathbb{D}$).

**Key Theorem.** Let $K$ be a closed disc. There exists an essentially unique circle packing $P_K$ for $K$ in $\mathbb{D}$ that is univalent and whose boundary circles are horocycles.

The proof involves induction on the number of vertices in $K$ and simple geometric monotonicities, culminating in a result which deserves its own statement. Here $R_K$ is the hyperbolic packing label.
for the packing $P_K$, so this result justifies the adjective “maximal” that I will attach to these extremal packings.

**Discrete Schwarz Lemma** [DSL]. Let $K$ be a closed disc and $R$ any hyperbolic packing label for $K$. Then $R(v) \leq R_K(v)$ for every vertex $v$ of $K$; equality for any interior vertex $v$ implies $R \equiv R_K$.

Our Key Theorem is easily equivalent to the K-A-T Theorem, but its formulation and proof set the tone for the whole topic. The next step, for example, is to extend the Key Theorem to open discs $K$ by exhausting with closed discs $K_j \uparrow K$. When we apply the monotonicity of the DSL to the maximal labels $R_j$ for these nested complexes, a fundamental *dichotomy* emerges:

$$
\text{as } j \to \infty \quad \begin{cases} 
\text{either} & R_j(v) \downarrow r(v) > 0 \quad \forall v \in K \\
\text{or} & R_j(v) \not\downarrow 0 \quad \forall v \in K.
\end{cases}
$$

In the former case, a geometric diagonalization argument produces a univalent hyperbolic packing $P_K$ for $K$, its label being maximal among hyperbolic labels as in the DSL. In the latter case, the maximal packings of the $K_j$ may be treated as euclidean and rescaled, after which geometric diagonalization produces a euclidean univalent circle packing $P_K$ for $K$. Archetypes for the dichotomy are the maximal packings for the constant 6- and 7-degree complexes, the well-known penny-packing, and the heptagonal packing of Figure 3(c), respectively. We can now summarize the simply connected examples.

**Discrete Riemann Mapping Theorem** [DRMT]. If $K$ is a simply connected surface, then there exists an essentially unique, locally finite, univalent circle packing $P_K$ for $K$ in one and only one of the geometries $\mathbb{P}$, $\mathbb{C}$, or $\mathbb{D}$. The complex $K$ is termed spherical, parabolic, or hyperbolic, respectively, and $P_K$ is called its maximal packing.

For complexes $K$ which are not simply connected, topological arguments provide an infinite universal covering complex $\tilde{K}$. By the DRMT, $\tilde{K}$ is parabolic or hyperbolic (the sphere covers only itself) and has a maximal packing $\tilde{P}$ in $\mathbb{P}$ (i.e., $\mathbb{C}$ or $\mathbb{D}$, respectively). Essential uniqueness of $\tilde{P}$ implies existence of a discrete group $\Lambda$ of conformal automorphisms of $\mathbb{P}$ under which $\tilde{P}$ is invariant. $G/\Lambda$ defines a Riemann surface $S$, and the projection $\pi : G \twoheadrightarrow S$ carries the metric of $G$ to the *intrinsic* metric of constant curvature on $S$, euclidean or hyperbolic, as the case may be. Some quiet reflection and arrow-chasing shows that $\pi(\tilde{P})$ defines a univalent circle packing $P_K$ for $K$ in the intrinsic metric on $S$. In other words, we have found our maximal circle packing $P_K$ for $K$.

**Discrete Uniformization Theorem** [DUT]. Let $K$ be a triangulation of an oriented surface $S$. Then there exists a conformal structure on $S$ such that the resulting Riemann surface supports a circle packing $P_K$ for $K$ in its intrinsic metric, with $P_K$ univalent and locally finite. The Riemann surface $S$ is unique up to conformal equivalence, and $P_K$ is unique up to conformal automorphisms of $S$.

The DUT is illustrated in Figure 3(d) for a torus having just 10 vertices. I have marked a fundamental domain and its images under the covering group. The 10 darkened circles form the torus when you use the dashed circles for side-pairings.

This theorem completes the existence/uniqueness picture for extremal univalent circle packings. It is quite remarkable that every complex has circle packings. From the pure combinatorics of $K$ one gets not only the circle packing but even the *geometry* in which it must live! This highlights central internal themes of the topic:

- *combinatorics* -- *geometry*
- *local packing condition* -- *global structure*

You can see that the DUT opens a wealth of questions. It is known that the “packable” Riemann surfaces, those supporting some circle packing, are dense in Teichmüller space, but they have yet to be characterized, and the connections between $K$ and the differential geometry of $S$ remain largely unknown.

Extremal packings only scratch the surface; in general a complex $K$ will have a huge variety of additional circle packings if we are allowed to manipulate boundary values and/or branching. When $K$ possesses a boundary, it has been proved that given any hyperbolic (respectively euclidean) labels for the boundary vertices of $K$, there exists a unique locally univalent hyperbolic (respectively euclidean) circle packing $P_K$ for $K$.
euclidean) packing $P$ having those labels as its boundary radii. In a similar vein, necessary and sufficient conditions for finite sets of branch circles have been established in many cases. The most I can do here is illustrate a variety of packings for a single complex. I've done this in Figure 4, using a $K$ with good visual cues. The maximal packing is at the top; then below it, left to right, are a univalent but nonmaximal hyperbolic packing, euclidean and spherical packings with prescribed boundary angle sums, and... the last one? At the heart of this last owl is a single branch circle, one whose petal circles wrap twice around it. We will refer back to these images later.

Pretty as the pictures are, the real gems in this topic are the elementary geometric and monotonicity arguments. Challenge yourself with some of these:

- Distinct circles can intersect in at most two points! Amazingly, Z-X. He and Oded Schramm proved that this is the key to the uniqueness for parabolic maximal packings.
- In hyperbolic geometry the central circle in a flower with $n$ petals has hyperbolic radius no larger than $-\log(\sin(\pi/n))$.
- The important Rodin/Sullivan Ring Lemma: for $n \geq 3$ there exists a constant $\epsilon_n > 0$ such that in any closed univalent flower of circles having $n$ petals, no petal can have radius smaller than $\epsilon_n$ times that of the center. By Descartes's Circle Theorem, the best constants are all reciprocal integers, beginning with $\epsilon_3 = 1, \epsilon_4 = 1/4, \epsilon_5 = 1/12$. I'll let the reader compute $\epsilon_6$.
- Figures 5(a) and (b) show hexagonal spirals. The first, created by Coxeter from the "quad" shown in Figure 1(d), is linked to the golden ratio. The second, along with a whole 2-parameter family of others, results from an observation of Peter Doyle: for any parameters $a, b > 0$, a chain of six circles with successive radii $\{a, b, b/a, 1/a, 1/b, a/b\}$ will close up precisely around a circle of radius 1 to form a 6-flower.
- The spherical packing of Figure 5(c), which has the same complex as the packing in Figure 3(a), was generated using $(2, 3, 5)$ "Schwarz" triangles; if you look closely at one of the twelve shaded circles, you will see that its five neighbors wrap twice around it.
- And what of Figure 5(d), the snowflake? Sometimes a pretty picture is just a pretty picture.

The internals of the topic that I have outlined here are wonderfully pure, clean, and accessible, and those who prefer their geometry unadulterated should know that pictures and computers are not necessary for the theory. On the other hand, the pictures certainly add to the topic, and the fact that these packings are essentially computable begs the question of numerical algorithms, which are another source of packing pleasure. There are many, many open questions; let me wrap up with one of my favorites: He and Schramm proved that if $K$ is an open disc which packs $\mathbb{D}$, i.e., is hyperbolic, then it can in fact pack ANY simply connected proper subdomain $\Omega \subset C$. Consider the combinatorics behind the packing of Figure 3(c) on page 1379, for example. Can you imagine your favorite horribly pathological domain $\Omega$ filled—every nook and cranny—with a univalent packing in which every circle has seven neighbors? How does one compute such packings?
Dust Off the Theory

Whatever internal richness a new topic develops, the drive of mathematics is towards the broader view. Where does it fit in the grand scheme? What are the analogies, links, organizing principles, applications? What does this topic need and what can it offer?

The tools we have used so far—basic geometry and trigonometry, surface topology, covering theory—are hardly surprising in the context, but perhaps you wondered about references to the Schwarz Lemma, Riemann Mapping Theorem, and Uniformization. The claim is, quite frankly, that one can look to the classical counterpart, it plays a central role on analytic function theory as a model for organizing circle packings.

wondered about references to the Schwarz Lemma, many others: discrete disc algebra functions; discrete versions of sine and cosine; a full family of discrete polynomials; and, when \( K \) is compact, discrete meromorphic functions, though these are quite challenging and the theory is just in its infancy.

The whole panoply of function-theory machinery also opens to us. In particular, the names attached to the theorems in the last section make perfect sense. One comes to recognize the DSL as the hyperbolic contraction principle; analytic self-maps of the hyperbolic plane are hyperbolic contractions. Like its classical counterpart, it plays a central role on the way to DRMT and DUT. The hyperbolic/parabolic dichotomy for infinite complexes is just the classical "type" problem and yields, for example, the

\[
\text{Definition.} \quad \text{A discrete analytic function is a map } f : Q \to P \text{ between circle packings which preserves tangency and orientation.}
\]

The study of circle packings \( P \) for \( K \) may now be posed as the study of the discrete analytic functions \( f : P_K \to P \); namely, for each vertex \( v \) of \( K \) define \( f(C_v) = C_v \), where \( C_v \) and \( C_v \) are the circles for \( v \) in \( P_k \) and \( P \), respectively. For first examples look to Figure 4, where the maximal packing is the common domain for four discrete analytic functions, \( f_a \), \( f_b \), \( f_c \), \( f_d \), mapping to the packings (a), (b), (c), (d), respectively.

With this definition we immediately inherit a wonderful nomenclature: \( f_a \) from Figure 4 is a discrete analytic self-map of \( D \), and \( f_b \) is a discrete conformal (Riemann) mapping, the discrete analytic function from the packing of Figure 3(a) to that of Figure 5(c) is a discrete rational function with twelve simple branch points. A map from the penny-packing to the Doyle spiral of Figure 5(a) or (b) is a discrete entire function, in fact, a discrete exponential map. Among my favorite examples are the discrete proper analytic self-mappings of \( D \), the discrete finite Blaschke products. And there are many others: discrete disc algebra functions; discrete versions of sine and cosine; a full family of discrete polynomials; and, when \( K \) is compact, discrete meromorphic functions, though these are quite challenging and the theory is just in its infancy.

This is where Thurston's startling conjecture enters our tale, for he saw in the rigidity of circle packings a direct link to conformality. According to Thurston, if one cookie-cuts a region \( \Omega \), as in Figure 6, using increasingly fine hexagonal packings, one obtains discrete mappings which converge to the classical Riemann mapping \( F : D \to \Omega \). The conjecture was soon proved by Burt Rodin and Dennis Sullivan in the seminal paper of this topic. Their result has now been extended to more general (i.e., nonhexagonal) and multiply connected complexes, to all three classical geometries, and to nonunivalent and branched packings. The Thurston model holds: given a class of functions, formulate the discrete (i.e., circle packing) analogues, create instances with increasingly fine combinatorics, appropriately normalized, then watch as the discrete versions converge to their classical models.

Of course there are details, for example, geometric finiteness conditions on valence and branching, but putting these aside we have this

- **Metatheorem:** Discrete analytic functions converge under refinement to their classical analytic counterparts.

Thus discrete Blaschke products converge to Blaschke products, discrete polynomials to polynomials, discrete rational functions to rational functions, and so forth. I cannot show these in static pictures, but we can nonetheless capture the intuition quite succinctly: A classical analytic function is said to "map infinitesimal circles to
This is a toy problem in discrete conformal geometry; your materials are shown above. $S$ is a piecewise affine (p.w.a.) surface in 3-space constructed out of ten equilateral triangles; the cartoon $K$ shows how these are pasted together and designates four boundary vertices as "corners". $S$ is not "flat"; it has two interior cone points with cone angles $\pi$ and $3\pi$. The p.w.a. structure on $S$ brings with it a canonical conformal structure, so $S$ is in fact a simply connected Riemann surface. By the Riemann Mapping Theorem there exists an essentially unique conformal map $F : S \to \mathbb{A}$, where $\mathbb{A}$ is a plane rectangle and $F$ maps the corner vertices of $S$ to the corners of $\mathbb{A}$. Question: What are the shapes of the ten faces when they are mapped to $\mathbb{A}$?

Here is the parallel discrete construction. Mark each equilateral face of $S$ with arcs of circles as in the triangle labelled "$n = 0$". These arcs piece together in $S$ to define an in situ packing $Q_0$. By using prescribed boundary angle sums, $Q_0$ can be computationally flattened to the packing $P_0$ shown below, which has rectangular carrier and the designated vertices as corners. In our terminology, $f_0 : Q_0 \to P_0$ is a discrete conformal mapping, and it carries the ten faces of $S$ to ten triangles in the plane.

Clearly, this "coarse" packing cannot capture the conformal subtleties of $S$. Therefore, we use a simple "hex-refine" process which respects the p.w.a. structure of $S$: namely, break each equilateral face into four equilateral faces half its size. Applying $n$ such refinement steps gives an in situ circle packing $Q_n$ in $S$, and flattening $Q_n$ to get a rectangular packing $P_n$ yields a refined discrete conformal mapping $f_n : Q_n \to P_n$. With four stages of refinement, for example, each face of $S$ looks like the triangle labelled "$n = 4$". Its rectangular flat packing $P_4$ is shown below with the ten faces outlined.

As with Thurston's conjecture for plane regions, it can be proven that the discrete mappings $\{f_n\}$ converge on $S$ to the classical mapping $F$. In other words, as you watch successive image packings $P_n$, you are seeing the ten faces converge to their true conformal shapes.

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\[ \text{infinitesimal circles";} \text{a discrete analytic function does the same, but with real circles.} \]

Fortunately for our pictorial tale we can bring this same intuition to bear in a more directly geometric way. A Riemann surface is one having a conformal structure, which is, loosely speaking, a consistent way to measure angles. A conformal map between Riemann surfaces is one which preserves this measurement (magnitude and orientation). (When things are appropriately formulated, conformal maps are just analytic maps and vice versa.) The discussion in the box above illustrates construction and refinement of discrete conformal maps from a Riemann surface to plane rectangles. A formal statement of the limit behavior is somewhat involved, but we have

- Metatheorem: Discrete conformal mappings converge under refinement to their classical counterparts.

Any lingering doubts the reader may have about connections with analyticity should be put to rest by the fact that the K-A-T Theorem actually implies the Riemann Mapping Theorem for plane domains. The last critical piece involves elementary (though by no means easy) geometric arguments of He and Schramm which replace the original quasiconformal methods in Rodin/Sullivan.
That Special Something

Every topic exhibits, at least to its adherents, some special character that sets it apart, even as it finds its place in the larger scheme. Will it make a lasting imprint on mathematics? Does it represent a paradigm shift? The true believer always holds out hope.

The synergy among mathematics, computation, and visualization that began with Thurston's 1985 talk infuses circle packing with an experimental character that I believe is unique in mathematics. Let me speak in the context of CirclePack, a graphically based software package for creating, manipulating, storing, and displaying packings interactively on the computer screen. CirclePack handles arbitrary triangulated surfaces, simply or multiply connected, with or without boundary, in any of the three geometries. Packings range from 4 to 1,600,000 circles (the current record in one of Bill Floyd's tilings); those up to roughly 10,000 circles now qualify as "routine", since packing times of a few seconds give an interactive feel. Multiply connected packings are manipulated in their intrinsic metrics and are displayed in the standard geometric spaces as fundamental regions with associated side-pairings, as with the torus of Figure 3(d). Nearly all the images in this paper come directly from CirclePack and are typical of what one views on-screen during live experiments.

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- Mathematics: This is discrete complex analysis, so it touches not only function theory but also potential theory and brownian motion, Möbius and conformal geometry, number theory, Fuchsian and Kleinian groups, Riemann surfaces and Teichmüller theory, not to mention applications. This is core mathematics, and the key geometric tools are here: topology, boundary conditions, group actions, branching, and, of course, conformality, in the form of the packing condition. And these tools are not tied to preconceived roles. You want to double a complex across a boundary? slit two surfaces and paste them together? mix boundary conditions? try some fractional branching? puncture a torus or carry out a Dehn twist? Go ahead! You may miss familiar tools—no complex arithmetic, no power series, no functional composition—but much of complex analysis is fundamentally geometric, and you can see it in action.

- Computation: Space prevents me from giving the numerics of circle packing its due. Thurston's algorithm works directly on the geometry, manipulating the distribution of curvature among the circles. In the computations of the ten-triangle pattern in the box on page 1382, for example, there is a remarkably stationary flow in the computations: comparing Figure 7 to the packing $P_4$ there, you can almost see the curvature streaming from points of excess to points of shortage. There is also a markov model of Thurston's algorithm, plus there are alternative algorithms by Colin de Verdière and by Bobenko and Springborn. Every improvement in algorithms seems to be associated with new geometric insights; curvature flow, for example, has a classical interpretation and may aid in parallelizing packing computations. Perhaps the main open question concerns a provable algorithm that works directly in spherical geometry; at this time spherical
Bobenko and his collaborators have extended these ideas into the study of discrete minimal surfaces and related topics; one of their gorgeous images is shown in (c).

- Circle packing powers the visualization of millions of knot and link projections in Thistlethwaite and Hoste's KnotScape program; here the (3, 7) torus knot is shown (with the circles that give it shape). Circle packing has been used to find graph separators, to generate grids, and to study Whitehead moves, hence the motto of Figure 8.

I would argue that CirclePack is to a geometer what a moderately well-equipped laboratory is to an organic chemist (only safer). The potential for open-ended experiments is unique, and yet the machinery is accessible to people at all levels; who knows, a few experiments and you or your students might be hooked!

New Kid on the Block

The new topic has linked itself to a rich classical vein which it has exploited shamelessly: definitions, theorems, examples, philosophy. But former colleagues are beginning to feel used: time for the new kid to step up and contribute.

Much as I would love to tour various applications in discrete function theory, it is probably better to settle on a single, more directly geometric example. 2D tiling is well known for its mixture of combinatorics and geometry, and there is a new theme which grew directly out of circle packing experiments called "conformal" tiling. One reverses tradition by starting with the combinatorics and asking, With what tile shapes and in which geometry can these combinatorics be realized? Let me recount the story of the "twisted pentagonal" tiling. This will necessarily be very brief, but Notices readers are known to enjoy a challenge.

The twisted pentagonal subdivision is one of many conceived by Cannon, Floyd, and Parry in ongoing work on Thurston's Geometrization Conjecture; my thanks to Bill Floyd for the combinatorial data.

We begin with the cartoon in Figure 9, which shows a rule for breaking one pentagon into five by adding edges and vertices. Your task, starting with one pentagon, is to repeatedly apply this subdivision rule: at the first stage you get 5 pentagons, then these are subdivided into 25, and these into 125, etc. The combinatorics quickly get out of hand, and circle packing is brought in initially just to get useful embeddings: at each stage, a barycenter added to each pentagon gives a triangulation which can then be circle-packed, giving shape to the pentagons. The first three stages are shown in Figure 9 with their circles.
The pictures are an immediate help, for after a few additional stages you come to realize that the "subdivision" rule can be replaced by a corresponding "expansion" rule. There is, in fact, an essentially unique infinite combinatorial tiling $T$ which is subdivision-invariant: i.e., if you simultaneously subdivide all the pentagons, the result is again combinatorially equivalent to $T$. This $T$ is suggested by Figure 10.

If you caught the spirit of our ten-triangle example in the box on page 1382, you might try the same treatment here. Pasting regular euclidean pentagons together in the pattern of $T$ yields a simply connected p.w.a. Riemann surface $\mathcal{S}$. Riemann himself would have known that there is a conformal homeomorphism $f$ from $\mathcal{S}$ to one of $\mathbb{C}$ or $\mathbb{D}$. The images of the faces under $f$ form a so-called conformal tiling $\mathcal{C}$ with the combinatorics of $T$. Is this tiling parabolic or hyperbolic? (i.e., does it lie in $\mathbb{C}$ or in $\mathbb{D}$?) What are the shapes of its tiles? Does the pattern have internal structure? Before circle packing, there was no way to approach such questions, so they weren't asked!

Now we have a method. As you might have suspected, Figure 10 was created using circle packing; it is a rough approximation of $T$ by "coarse" circle packings like those of Figure 9. Your first instinct might be to improve conformal fidelity via refinement, as we did in the box on page 1382. The key experiments, however, turn out to be of quite a different nature. Stare at $\mathcal{C}$ for a moment—perhaps let your eyes defocus. The longer you look, the more certain you become of some large-scale pattern. Let me help you pull it out. As $T$ is invariant under subdivision, so must it be invariant under aggregation (unsubdividing). On the left in Figure 11 are the outlines of the first four stages of aggregation; that is, each of the outlined aggregates is combinatorially equivalent to a subdivision of its predecessor.

Do you see a hint of a pattern now? A little work in PostScript to dilate, rotate, and overlay the outlines leads to the picture on the right in Figure 11. The scale factor turns out to be roughly the same from one stage to the next, suggesting that the tiling is parabolic. More surprising, you find that the corners of the outline from one stage seem to line up with corners of the next: each edge at one stage is replaced by a zig-zag of three edges at the next. Motivated by these very images, Cannon, Floyd, Parry, and Rick Kenyon have confirmed all these observations. In fact, a wealth of mathematics converges in these images: This tiling turns out to be associated with one of Grothendieck's dessins d'enfants on the sphere. Hence there exists a rational function with algebraic coefficients whose iterates encode the subdivision rule. That iteration gives an associated Königsfunction $k$, an entity right out of nineteenth-century function theory, and $\mathcal{C}$ is just the cell decomposition of $\mathbb{C}$ defined by $k^{-1}([0,1])$. And with the scaling confirmed, renormalization (as started on the right in Figure 11) suggests a limit tiling in the pattern of $T$ which would have perfect scaling, fractal pentagonal tiles, and a

![Figure 11. Outline, scale, rotate, and overlay the aggregates.](image)

![Figure 12. Circle packing for conformal structure.](image)
Then one can search for, perhaps even prove, parallel classical results. In summarizing the intuition, it seems only fair to let the discrete side take the lead: A discrete conformal structure on a surface is determined by a triangulation; a classical conformal structure is determined in the same way, but with “infinitesimal” triangles.

I cannot leave this section without mentioning a point of closure in the theory provided by results of He and Schramm. They have made a major advance on a classical conjecture concerned with the conformal mapping of infinitely connected regions, the so-called Kreisnormierungsproblem, by applying methods which they developed in circle packing. And exactly whose conjecture was this? None other than P. Koebe himself: he proved the finitely connected case and then applied his classical methods to establish the K-A-T Theorem!

Reaching Out

It is an article of mathematical faith that every topic will find connections to the wider world—eventually. For some, that isn’t enough. For some it is real-time exchange between the mathematics and the applications that is the measure of a topic.

The important roles complex analysis traditionally played in the physical sciences—electrostats, fluid flow, airfoil design, residue computations—are largely gone, replaced by numerical partial differential equations or symbolic packages. But the core of complex analysis is too fundamental to go missing for long. Surfaces embedded in threespace are becoming pervasive in new areas of science, image analysis, and computer visualization, and conformal geometry is all about such surfaces. With new tools to (faithfully) access conformality, perhaps complex analysis has new roles to play.

I would like to illustrate briefly with brain-flattening work that has garnered recent exposure outside of mathematics. The work is being carried on by an NSF-sponsored Focused Research Group: Chuck Collins and the author (Tennessee); Phil Bowers, Monica Hurdal, and De Witt Sumners (Florida State); and neuroscientist David Rottenberg (Minnesota).

The first image in Figure 13 shows the type of 3D data which is becoming routinely available through noninvasive techniques such as MRI (magnetic resonance imaging), in this case, one hemisphere of a human cerebrum. Our mental processing occurs largely in the cortex, the thin layer of neurons (grey matter) on the brain surface. Neuroscientists wishing to apply surface-based techniques need to map the cortex to a flat domain—hence the topic of “brain-flattening”. As you can see, the cortex is an extremely convoluted surface (the shading here reflects the mean curvature), and it is well known that there can exist no flat map which preserves its areas or surface

Figure 13. A 3D cortical hemisphere and three flat maps.
distances. However, by the 150-year-old Riemann Mapping Theorem there does exist a conformal flat map. Using standard techniques, one can produce a triangulation which approximates the cortical surface from the volumetric data. Figure 13 illustrates three discrete conformal flat maps based on such a triangulation (180,000 vertices): clockwise from upper right are spherical, hyperbolic, and euclidean flat maps.

It is not our goal to discuss the potential scientific value in these maps (though I will mention that our neuroscience colleagues have a surprising affinity for the hyperbolic maps; perhaps these are reminiscent of the view in a microscope). However, there are some points that do bear on our story.

• First, one does not have to believe that conformality per se has any relevance to an application to exploit its amazing richness—existence and uniqueness first, then companion notions such as extremal length and harmonic measure.

• Second, approximation of true conformality may be superfluous if its companion structures appear faithfully at coarse stages, as seems often to be the case with circle packing.

• Finally, the structures take precedence over technique; circle-packing experiments can contribute to a topic even if other methods replace it in practice. What would be nice to hear at the end of a neuro consult is, “You know, we need to hire another conformal geometer.”

Conclusion
Of course, a mathematical topic itself never concludes: the tradition is “definition-theorem-proof-publication” as new contributions add to the line. A mathematical tale, on the other hand, must have closure, and the storyteller is allowed to put some personal spin on the story (if not a moral).

I have related this tale in the belief that it has some touch of universality to it. We are drawn to mathematics for a variety of reasons: the clarity of elementary geometry, the discipline of computation, the challenge of richly layered theory and deep questions, the beauty of images, or the pleasures of teaching and applying the results. I feel that I have seen all these in circle packing, and perhaps you have glimpsed parallels with your own favorite topic.

Personally, it has been a pleasure to watch an old friend, complex function theory, emerge in a form with so much appeal: new theory, new applications, stunning visuals, an exciting experimental slant. For me circle packing is quantum complex analysis, classical in the limit. The discrete results and their proofs are pure mathematics, the pictures and software being not only unnecessary, but for some, unwanted. Yet the experimentation and visualization, the very programming itself, are at the research frontier here. In this regard, circle packing illustrates the growing challenge mathematics faces to incorporate new modes of research into its practices and literature.

Of course circle packing, like any mathematical topic, has many potential storylines. In that spirit, let me end our mathematical tale in a very traditional way, namely, in the hope that it nourishes others who can pass along their own stories in their own words.

Reader's Guide

Once: [12], [26], [28], [1], [30]. Birth: [25], [2], [35], [36], [13]. Internal: [27], [5], [4], [9], [21], [3], [22], [10]. Dust: [19], [18], [34] (survey), [31]. Special: [32], [20] (survey), [15], [7], [17], [29], [6], [23]. New Kid: [33] (survey), [21], [19], [11], [8], [37], [14], [16]. Reach Out: [24]. (You can download a more complete bibliography and CirclePack from my website: http://www.math.utk.edu/~kens.)

References


About the Cover

Conformal maps by packing circles

This month's cover illustrates how one of the simplest possible conformal maps can be approximated by the technique of circle packing explained in Kenneth Stephenson's article. In constructing it, the very detailed recipe to be found in "A circle packing algorithm" by Charles Collins and Stephenson (Computational Geometry 25 (2003)) was followed.

Both circle configurations are associated to the same triangulation, which is also shown—vertices correspond to circles, and edges correspond to circles that touch. The corners are left out for technical reasons.

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In its original setting, the Riemann-Hilbert problem is the question of surjectivity of the monodromy map in the theory of Fuchsian systems.

An $N \times N$ linear system of differential equations

$$\frac{d\Psi(\lambda)}{d\lambda} = A(\lambda)\Psi(\lambda)$$

is called Fuchsian if the $N \times N$ coefficient matrix $A(\lambda)$ is a rational function of $\lambda$ whose singularities are simple poles. Each Fuchsian system generates, via analytic continuation of its fundamental solution $\Psi(\lambda)$ along closed curves, a representation of the fundamental group of the punctured Riemann sphere (punctured at the poles of $A(\lambda)$) in the group of $N \times N$ invertible matrices. This representation (or rather its conjugacy class) is called the monodromy group of equation (1), and it is the principal object of the theory of Fuchsian systems. The question of whether there always exists a Fuchsian system with given poles and a given monodromy group was included by Hilbert in his famous list as problem number twenty-one. The problem got the name “Riemann-Hilbert” for its obvious relation to the general idea of Riemann that an analytic (vector-valued) function could be completely defined by its singularities and monodromy properties.

Subsequent developments put the Riemann-Hilbert problem into the context of analytic factorization of matrix-valued functions and brought to the area the methods of singular integral equations (Plemelj, 1908) and holomorphic vector bundles (Röhrl, 1957). This resulted eventually in a negative (!) solution, due to Bolibruch (1989), of the Riemann-Hilbert problem in its original setting and to a number of deep results (Bolibruch, Kostov) concerning a thorough analysis of relevant solvability conditions. We refer the reader to the book of Anosov and Bolibruch [2] for more on Hilbert’s twenty-first problem and the fascinating history of its solution (and for more details on the genesis of the name “Riemann-Hilbert”).

Simultaneously, and to a great extent independently of the solution of the Riemann-Hilbert problem itself, a powerful analytic apparatus—the Riemann-Hilbert method—was developed for solving a vast variety of problems in pure and applied mathematics. The Riemann-Hilbert method reduces a particular problem to the reconstruction of an analytic function from jump conditions or, equivalently, to the analytic factorization of a given matrix- or scalar-valued function defined on a curve. Following a tradition that developed in mathematical physics, it is these problems, and not just the original Fuchsian one, that we will call Riemann-Hilbert problems. In other words, we are adopting a point of view according to which the Riemann-Hilbert (monodromy) problem is formally treated as a special case (although an extremely important one) of a Riemann-Hilbert (factorization) problem. The latter is viewed as an analytic tool, but one whose implementation is not at all algorithmic and which might use quite sophisticated and

1 It should be mentioned that in the theory of boundary values of analytic functions the problem of reconstructing a function from its jumps across a curve is sometimes called the "Hilbert boundary-value problem". This adds even more subtlety to the origin of the name "Riemann-Hilbert problem".
"custom-made" analytic ideas (depending on the particular setting of the factorization problem).

A classical example of the use of analytic factorization techniques is the Wiener-Hopf method in linear elasticity, hydrodynamics, and diffraction.

The goal of this article is to present some new developments in the Riemann-Hilbert formalism which go far beyond the classical Wiener-Hopf schemes and, at the same time, have many important similarities with the analysis of the original Fuchsian Riemann-Hilbert problem. These developments come from the theory of integrable systems.

The modern theory of integrable systems has its origin in the seminal works of Gardner, Green, Kruskal, and Miura (1967), Lax (1968), Faddeev and Zakharov (1971), and Shabat and Zakharov (1971), where what is now widely known as the Inverse Scattering Transform (IST) method in soliton theory originated (we will recall the essence of the IST method later on; we point out the monograph [16] as the principal reference). Integrable systems is currently an expanding area that includes the analysis of exactly solvable quantum field and statistical physics models; the theory of integrable nonlinear partial differential equations (PDEs) and ordinary differential equations (ODEs)—equations of KdV and Painlevé types; and quantum and classical dynamical systems that are integrable in the sense of Liouville. During the last thirty years, the theory of integrable systems has developed into an important part of mathematical physics and analysis, and it has become one of the principal sources of new analytic and algebraic ideas for many branches of contemporary mathematics and theoretical physics. 2 The most recent "beneficiaries" are orthogonal polynomials, combinatorics, and random matrices.

We call a system of (nonlinear) differential equations an integrable system if it can be represented as a compatibility condition of an auxiliary overdetermined linear system of differential equations. Following the tradition in soliton theory, we call this auxiliary linear system a Lax pair. 3 of the given (nonlinear) system, even though it actually might involve more than two equations. We also require that the Lax pair depend rationally on an auxiliary complex parameter, which is called a spectral parameter. This requirement is crucial: 4 it makes an integrable system completely integrable in the sense of Liouville and, even more importantly, makes possible an effective evaluation of the commuting integrals of motion, the invariant submanifolds, and the corresponding angle variables (that is, an effective realization of the Liouville-Arnold integration algorithm). Indeed, the presence of the spectral parameter in the Lax pair brings the tools of complex analysis into the problem, and this ultimately transforms the original problem of solving a system of differential equations into the question of reconstructing an analytic function from the known structure of its singularities. In turn, this question (almost) always can be reformulated as a Riemann-Hilbert problem of finding an analytic function (generally matrix-valued) from a prescribed jump condition across a curve. The Riemann-Hilbert problem, especially in the matrix case, might itself be a transcendental one. But even then it describes the solution of the differential system in terms independent of the theory of differential equations. In this sense, the original differential system is "solved". In fact, the solution might even be explicit: namely, given in terms of elementary or elliptic or abelian functions and a finite number of contour integrals of such functions. In general, the Riemann-Hilbert formalism provides a representation in terms of the solutions of certain linear singular integral equations, which in turn can be related to the theory of infinite-dimensional Grassmannians and holomorphic vector bundles.

This notion of integrable systems and the Riemann-Hilbert method of solving them was essentially worked out in the 1970s and 1980s in the theory of nonlinear PDEs of KdV type, that is, in the soliton theory. Since then, the Riemann-Hilbert approach has gradually become a quite universal analytic tool for studying problems from many areas of modern mathematics not previously considered as "integrable systems". Moreover, some of these problems in their initial setting are not necessarily differential systems at all.

In this article we will describe the application of the Riemann-Hilbert formalism to integrable systems, emphasizing the analytic aspects. We shall start by explaining in more detail what Riemann-Hilbert (factorization) problems are and what the advantage is of reducing a problem to Riemann-Hilbert type. Then we will consider the

2 Perhaps the most celebrated example of such influence is quantum groups, which emerged out of the works of Faddeev, Sklyanin, Takhtajan, and other members of the Leningrad group on the quantum version of the IST. A more recent example is the quite remarkable appearance, in the Seiberg-Witten N = 2 supersymmetric gauge theory, of the so-called algebraically integrable systems (the Liouville tori are Jacobi varieties), which have their roots in the theory of periodic solutions of integrable PDEs developed in the 1970s (see the review paper [9] and the monographs [16] and [4] for the history and the main references concerning the periodic version of the IST).

3 Strictly speaking, the compatibility-condition generalization of the original Lax-equation formalism came after Lax's paper; it first appeared in 1974, in the work of Novikov (periodic problem for KdV) and of Ablowitz, Kaup, Newell, and Segur (sine-Gordon equation).

4 In fact, the more general settings due to Hitchin (1987) and Krichever (2001) allow the spectral parameter to vary in an algebraic curve. Also, one can consider difference or differential-difference Lax pairs as well.
appearance and use of Riemann-Hilbert problems in the theory of special functions of Painlevé type. Simultaneously, we will see that this area indeed falls into the category of integrable systems.

Choosing Painlevé functions (all the necessary definitions and historical references will be given later) as a principal example enables us to introduce the Riemann-Hilbert scheme in a rather elementary, although sufficiently general, manner. Also, this will put us in the context of the Fuchsian monodromy theory where both the “original” Riemann-Hilbert problem and the Painlevé equations belong. The drawback of the approach is that we will not have room for many other exciting applications, which range from integrable PDEs of KdV type to exactly solvable quantum field and statistical mechanics models and (most recently) to the theory of orthogonal polynomials, matrix models, and random permutations. It is, however, worth mentioning that in all these areas the Painlevé functions play an important role as the relevant “nonlinear special functions”.

Here are some key references where the interested reader can find material concerning the topics mentioned above and which we are unable to cover in this article. The Riemann-Hilbert method for integrable PDEs originated in the works of Manakov, Shabat, and Zakharov done in 1975-1979, and since then it has been widely used in soliton theory. We refer the reader to the monographs [16], [10], [1], and [3] for a detailed presentation of the different aspects of the method. The Riemann-Hilbert approach to quantum exactly solvable models was initiated in the beginning of the 1980s by Jimbo, Miwa, Môri, and Sato, and it was further developed in the late 1980s and in the 1990s in the series of works of Izergin, Korepin, Slavnov, Deift, Zhou, and this author. The method is presented in the monograph [14] (see also the more recent survey [5]). The Riemann-Hilbert approach to orthogonal polynomials and matrix models was suggested in 1991 by Fokas, Kitaev, and this author, and recently it helped in solving some of the long-standing problems in the asymptotics of orthogonal polynomials related to universalities in random matrices (the works of Bleher, Deift, Kricherbauer, McLaughlin, Venakides, Zhou, and this author, done in the late 1990s) and random permutations (the 1999 work of Baik, Deift, and Johansson followed by an explosion of activity in the area). We refer the reader to the monograph [6] and the survey [7] for a detailed presentation of the approach and for more on its history.

Riemann-Hilbert Problems

An analytic function is uniquely determined by its singularities, in virtue of Liouville’s theorem. In a way, this is the most general example of “integrability”: the local properties of an object yield complete information about its global behavior.

Therefore, one can suggest the most general, and hence quite tautological, “definition” of an integrable system as a problem whose solution can be reduced to reconstructing an analytic function from the known structure of its singularities. In turn, as indicated in the introduction, this question (almost) always can be formulated as a Riemann-Hilbert problem.

Roughly speaking, as already indicated, a Riemann-Hilbert problem is the problem of finding an analytic function in the complex plane having a prescribed jump across a curve. More precisely, suppose \( \Gamma \) is an oriented contour in the complex \( \lambda \) plane. The contour \( \Gamma \) might have points of self-intersection, and it might have more than one connected component. Figure 1 depicts typical contours appearing in applications. The orientation defines the + and the – sides of \( \Gamma \) in the usual way. Suppose in addition that we are given a map \( G \) from \( \Gamma \) into the set of \( N \times N \) invertible matrices. The Riemann-Hilbert problem determined by the pair \( (\Gamma, G) \) consists in finding an \( N \times N \) matrix-valued function \( Y(\lambda) \) with the following properties:

- \( Y(\lambda) \) is analytic for \( \lambda \) in \( \mathbb{C} \setminus \Gamma \).
- \( Y(\lambda) \) is analytic for \( \lambda \) in \( \mathbb{C} \setminus \Gamma \).
- The limit \( Y_+(\lambda) \) of \( Y \) from the minus side of \( \Gamma \) and the limit \( Y_-(\lambda) \) from the plus side of \( \Gamma \) are related for \( \lambda \in \Gamma \) by the equation

\[
Y_+(\lambda) = Y_-(\lambda)G(\lambda).
\]

5 The more general settings are the so-called nonlocal Riemann-Hilbert problem and the \( \delta \)-problem which were brought to the theory of integrable systems in the 1980s in the works of Ablowitz, Bar-Yaacov, Fokas, Manakov, and Zakharov devoted to the 2+1 integrable PDEs.

6 It is an instructive exercise to reformulate as a Riemann-Hilbert problem the standard question of reconstructing a rational function from its poles and the principal parts at the poles.
• \( Y(\lambda) \) tends to the identity matrix \( I \) as \( \lambda \to \infty \).

The precise sense in which the limit at \( \infty \) and the limits from the two sides of \( \Gamma \) exist are technical matters that should be specified for each given pair \((\Gamma, G)\). The highly nontrivial questions concerning the minimal restrictions on the contour \( \Gamma \) and the allowable functional classes for the map \( G \) are issues of the general theory of analytic matrix factorization. For a detailed exposition of this extremely interesting and deep area of modern complex analysis we refer the reader to the 1981 monograph of Clancey and Golberg and to the 1987 monograph of Litvinchuk and Spitkovskii (see also [3], the works of Zhou on the Riemann-Hilbert approach to inverse scattering, and the most recent works of Deift and Zhou on the \( L_2 \)-Riemann-Hilbert theory). The general facts established in this area, especially the ones concerning the properties of the Cauchy operators defined on contours with self-intersections, are extremely important; they provide the Riemann-Hilbert formalism with the necessary mathematical rigor.

Why should it help if a problem can be reduced to a Riemann-Hilbert problem? The advantage is immediate in the scalar case, \( N = 1 \). Indeed, in this case the original multiplicative jump condition can be rewritten in the additive form

\[
\log Y_+(\lambda) = \log Y_-(\lambda) + \log G(\lambda).
\]

An additive jump relation of the form \( y_+(\lambda) = y_-(\lambda) + g(\lambda) \) can always be resolved by means of the contour integral

\[
y(\lambda) = \frac{1}{2\pi i} \int_{\Gamma} \frac{g(\mu)}{\mu - \lambda} \, d\mu
\]

(the Cauchy-Plemelj-Sokhotskii formula). In the scalar case, therefore, or more generally in the abelian case when

\[
[G(\lambda_1), G(\lambda_2)] = G(\lambda_1)G(\lambda_2) - G(\lambda_2)G(\lambda_1) = 0
\]

for all \( \lambda_1 \) and \( \lambda_2 \) in \( \Gamma \), the solution of the Riemann-Hilbert problem admits an explicit integral representation

\[
Y(\lambda) = \exp \left\{ \frac{1}{2\pi i} \int_{\Gamma} \frac{\log G(\mu)}{\mu - \lambda} \, d\mu \right\}.
\]

There is a subtle matter of how to treat this equation if the problem has a nonzero index, that is, if \( \partial \Gamma = 0 \) and \( \Delta \log G|_{\Gamma} \neq 0 \). Still, formula (2), after a suitable modification in the case of nonzero index (see, e.g., Gakhov's monograph *Boundary Problems*), yields a contour-integral representation for the solution of the original problem. Moreover, in typical concrete situations one can evaluate the integral in (2) in closed form or, equivalently, one can find an explicit formula involving known elementary or special functions directly by examining the jump function \( G(\lambda) \).

In the general nonabelian matrix case, formula (2) does not work. A generic matrix Riemann-Hilbert problem cannot be solved explicitly (this is a common belief, not a theorem!) in terms of contour integrals. It can, however, always be reduced to the analysis of a linear singular-integral equation. Therefore replacing the original problem by a Riemann-Hilbert problem is still advantageous. Indeed, nonabelian Riemann-Hilbert problems usually arise when the original problem is nonlinear, so a Riemann-Hilbert reformulation effectively linearizes an originally nonlinear system.

The main benefit of reducing originally nonlinear problems to the analytic factorization of given matrix functions arises in asymptotic analysis. In typical applications, the jump matrices \( G(\lambda) \) are characterized by oscillatory dependence on external large parameters, say space \( x \) and time \( t \). The asymptotic evaluation of the solution \( \{Y(\lambda, x, t)\} \) of the Riemann-Hilbert problem as \( x, t \to \infty \) turns out to be in some (not all!) ways quite similar to the asymptotic evaluation of oscillatory contour integrals via the classical method of steepest descent. Indeed, after about twenty years of significant efforts by several authors, starting from the 1973 works of Shabat, Manakov, and Ablowitz and Newell (see [8] for a detailed historical review), the development of the relevant scheme of asymptotic analysis of integrable systems finally culminated in the nonlinear steepest descent method for oscillatory Riemann-Hilbert problems, which was introduced in 1992 by Deift and Zhou. In complete analogy to the classical method, it examines the analytic structure of \( G(\lambda) \) in order to deform the contour \( \Gamma \) to contours where the oscillatory factors involved become exponentially small as \( x, t \to \infty \), and hence the original Riemann-Hilbert problem reduces to a collection of local Riemann-Hilbert problems associated with the relevant saddle points. The noncommutativity of the matrix setting requires, however, developing several totally new and rather sophisticated technical ideas, which, in particular, enable an explicit solution of the local Riemann-Hilbert problems.\(^8\) For more details we refer the reader to the original papers of Deift and Zhou, and also to the review article [8]. Remarkably, the final result of the analysis is as efficient as the asymptotic evaluation of the oscillatory integrals.

\(^7\) The possibility of an explicit factorization might actually occur in (very) special matrix cases as well: in fact, certain problems in diffraction are solved by using such factorizations.

\(^8\) It is worth mentioning that as a by-product a new collection of matrix functions admitting an explicit analytic factorization has been obtained.
Later we will illustrate this statement by an example from the modern theory of integrable ODEs.

In summary, our major point is that to have a solution to a (nonlinear) problem represented in terms of the function $Y(\lambda)$ defined via the factorization of a given matrix function is just as good as to have the solution written in terms of contour integrals. In other words, the Riemann-Hilbert representation extends the notion of "integral representation" to the nonlinear, noncommutative case.

We conclude this section with a few additional general remarks concerning Riemann-Hilbert problems.

(i) The following simple observation strengthens the idea of viewing the Riemann-Hilbert formalism as a noncommutative analog of contour integral representation. Let

$$L = \int_{\Gamma} g(\lambda) d\lambda$$

be a contour integral, and define the matrix function

$$Y(\lambda) = \begin{pmatrix} 1 & \int_{\Gamma} \frac{g(\mu)}{\mu - \lambda} d\mu \\ 0 & 1 \end{pmatrix}.$$  

Assuming that all the integrals and limits make sense (e.g., $g(\lambda)$ and $\Gamma$ are continuous, and $\Gamma$ is bounded), we can write

$$L = \lim_{\lambda \to \infty} \text{res}_{\lambda \to \infty} Y_{12}(\lambda).$$

On the other hand, the matrix function $Y(\lambda)$ can alternatively be defined (again by the Cauchy-Plemelj-Sokhotskii formula) as the unique solution of the Riemann-Hilbert problem determined by the pair $(\Gamma, G)$, where

$$G(\lambda) = \begin{pmatrix} 1 & 2\pi i g(\lambda) \\ 0 & 1 \end{pmatrix}.$$  

Hence the evaluation of the contour integral (3) is equivalent to the analytic factorization of the matrix function (6).\(^9\) Since the matrices $G(\lambda)$ for different values of $\lambda$ commute with each other, the equation (4) is just the integral representation (2) in the triangular case.

(ii) Let $\Gamma$ be a closed Jordan curve that divides the $\lambda$-plane into two open connected sets: the interior domain $\Omega$, and the exterior domain $\Omega^\prime$. Let $G$ be a constant map, say $G(\lambda) = G_0$. Then the Riemann-Hilbert problem can be solved immediately: namely,

$$Y(\lambda) = \begin{cases} I & \text{for } \lambda \in \Omega, \\ G_0^{-1} & \text{for } \lambda \in \Omega^\prime. \end{cases}$$

\(^9\) The reader might find it amusing to try to evaluate, via the factorization of the relevant triangular matrices, standard integrals of the form $\int_{-\infty}^{\infty} R(x) dx$ and $\int_{-\infty}^{\infty} R(x)e^{ix} dx$, where $R(x)$ is a rational function.

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\[ \text{Figure 2. Fuchsian Riemann-Hilbert problem.} \]

The easiest way to make the problem nontrivial is to let the constant map $G$ (the jump matrix) become piecewise constant. The Riemann-Hilbert problem that arises in this way is exactly the kind of factorization problem that appeared in the classical work of Plemelj devoted to solving Hilbert's twenty-first problem. Figure 2 depicts the Fuchsian (i.e., piecewise-constant) Riemann-Hilbert problem in more detail. There, the contour $\Gamma$ is a polygonal path, $\Gamma = [a_1, a_2] \cup [a_2, a_3] \cup \ldots \cup [a_{n-1}, a_n] \cup [a_n, a_1]$, and the jump matrix $G(\lambda)$ is defined by

$$G(\lambda) = M_1M_2 \cdots M_k, \quad \lambda \in (a_k, a_{k+1}),$$

where $\{M_1, M_2, \ldots, M_n\}$ is a given set of nonsingular constant matrices. For generic $M_k$ satisfying the cyclic relation $M_1M_2 \cdots M_n = I$, the unique solution $Y(\lambda)$ of this Riemann-Hilbert problem exists (Plemelj). Moreover, it satisfies a Fuchsian differential equation whose poles are $a_k$ and whose monodromy group is generated (see Figure 2) by the matrices $M_1, \ldots, M_n$; that is,

$$\tau_k(Y)(\lambda) = Y(\lambda)M_k,$$

where $\tau_k$ denotes the operator of analytic continuation along the loop $\gamma$. This relates the Riemann-Hilbert problems with piecewise-constant jump matrices to the theory of Fuchsian systems. Plemelj used this relation in his near solution of Hilbert's twenty-first problem. A principal difficulty arises when we drop the word "generic" in the description of the given matrices $M_k$. In the general case, as was shown by Kohn and by Arnold and Il'yanshenko, Plemelj's proof has gaps. The very surprising fact that these gaps cannot be closed was shown by Bolibruch by a counterexample (see [2] for further details).

(iii) As already indicated in the introduction, the modern theory of integrable systems began with the discovery of the Inverse Scattering Transform method. The essence of the method is a linearization of a nonlinear (integrable) PDE via a direct scattering transform generated by the spatial part.
of the corresponding Lax pair. This reduces the solution of an integrable nonlinear PDE to the solution of the inverse scattering problem for a relevant linear differential operator. It was apparently first realized by Shabat in 1979 (although some of the basic ideas can be found in old works of Krein) that the inverse scattering problem can be reformulated as a Riemann-Hilbert problem of analytic factorization of the scattering matrix. This was how the Riemann-Hilbert approach in integrable PDEs started. It is significant to notice that the “first” Riemann-Hilbert problem, i.e., the Fuchsian one, and the inverse scattering Riemann-Hilbert problem represent the two opposite ends of the whole spectrum of possible Riemann-Hilbert problems: the Fuchsian problem is the first nontrivial problem, while the inverse scattering problem is the most general one, as its jump matrix $G(\lambda)$ allows a virtually arbitrary dependence on $\lambda$.

(iv) The use of the Riemann-Hilbert problem as an analytic apparatus goes back to the beginning of the twentieth century. The main examples are the Wiener-Hopf method in linear diffraction and the theory of Toeplitz operators. The principal player in these fields is a scalar, that is, an abelian Riemann-Hilbert factorization, and the principal objects are linear PDEs. The basic reference for the classical aspects of the theory and applications of the Riemann-Hilbert problem is the 1968 monograph of Muskhelishvili. There is a very interesting revival of the “linear theme” in the recent works of Fokas, where a unified approach is suggested, based on the Riemann-Hilbert method, for solving initial-boundary-value problems for linear PDEs with constant coefficients and integrable nonlinear PDEs.

(v) Although this article deals with only the analytic aspects of the Riemann-Hilbert method, the method has two other very important and intertwining components. One is geometric: the relation to holomorphic vector bundles. Another is algebraic: the relation to loop groups. For these, see the survey [17] and the monographs [2] and [10].

**“From Gauss to Painlevé”**

This is the main section of the article. The title, but not the content, is borrowed from the 1991 book on special functions of Iwasaki, Kimura, Shimomura, and Yoshida.

Using the Airy equation and its natural nonlinear analog—the second Painlevé equation—as the basic examples of linear (Gauss) and nonlinear (Painlevé) special functions, we will describe the principal analytic ideas and the kind of results that can be obtained via the Riemann-Hilbert method in the theory of integrable systems. At the same time, we will explain why the special functions make integrable systems.

The Airy functions are defined as solutions of the linear ordinary differential equation

$$u_{xx} = xu.$$ 

As mentioned above, the Airy functions belong to the family of classical special functions. Before we proceed with the derivation of the Riemann-Hilbert formalism for the Airy function, we address the following basic issue: What is so “special” about the special functions in general and the Airy function in particular? One way to answer this question is the following.

Equation (7) is a particular case of a linear differential equation of the form

$$u_{xx} = p(x)u,$$

where $p(x)$ is a polynomial. Unless $p(x)$ is of a very special type, this equation cannot be solved in terms of elementary functions. However, one can always find the elementary asymptotic solutions, $u_\pm(x|a_\pm)$, to the equation as $x \to \pm \infty$. Here the $a_\pm$ indicate sets of asymptotic parameters. The principal question is this: Suppose that $u_\pm(x|a_\pm)$ and $u_\mp(x|a_\mp)$ represent the asymptotics of the same solution. Can one describe the map $a_\pm \to a_\mp$ in terms of elementary functions or finitely many contour integrals of elementary functions (i.e., avoiding the necessity of solving an integral equation)? In other words, does equation (8) admit explicit connection formulae? For a generic polynomial $p(x)$ the answer is “no,” but for the Airy equation the answer is “yes”. From the analytic point of view, this fact justifies the title “special” for the Airy function. Similarly, the other classical special functions of hypergeometric type, such as the Bessel functions and the Whittaker functions, all are defined as solutions of second-order linear differential equations possessing this extremely special property—each of them admits explicit asymptotic connection formulae.\(^\dagger\)

The analytic mechanism that yields explicit connection formulae for Airy (as well as for Bessel, Whittaker, etc.) functions is the contour integral representations which are available for all the special functions of hypergeometric type. Therefore, according to our idea of viewing contour integrals as abelian Riemann-Hilbert problems, there should be a Riemann-Hilbert representation for the Airy functions as well. In order to obtain it, we have to recall the Airy integral formulae.

Consider the collection of six rays

\(\dagger\) Strictly speaking, this is again the general belief, not a theorem.

\(\dagger\) It is worth noticing that asymptotic connection formulae are exactly what is most frequently needed from the special functions in applications.
The classical integral representation of the general solution of the Airy equation (7) can be written as

\[ u(x) = \frac{i}{\pi} \left( s_2 \int_{\Gamma_2} + s_4 \int_{\Gamma_4} + s_6 \int_{\Gamma_6} \right) e^{\frac{2i}{3} \lambda^3 - 2ix\lambda} d\lambda, \]

where the complex parameters \( s_2, s_4, \) and \( s_6 \) satisfy a single restriction, the cyclic relation \( 12 \)

\[ s_2 + s_4 + s_6 = 0. \]

In view of equations (3)–(6), the integral representation (10) implies that

\[ u(x) = 2 \lim_{\lambda \to \infty} [\lambda Y_{12}(\lambda)], \]

where the matrix function \( Y(\lambda) = Y(\lambda, x) \) is the solution of the (abelian) \( 2 \times 2 \) matrix Riemann-Hilbert problem for the contour \( \Gamma \). The corresponding jump matrix \( G(\lambda) \) is the upper-triangular oscillatory matrix function defined by

\[ G(\lambda) = G(\lambda, x) = \begin{pmatrix} 1 & s_k e^{\frac{2i}{3} \lambda^3 - 2ix\lambda} \\ 0 & 1 \end{pmatrix}, \]

\[ \lambda \in \Gamma_k, \quad k = 2, 4, 6. \]

The oscillatory factor in (12) and the choice of the contour \( \Gamma \) are consistent with the normalization condition at \( \lambda = \infty \). Indeed, the matrix function \( G(\lambda) \) rapidly approaches the identity matrix as \( \lambda \to \infty \) along the contour \( \Gamma \). This makes the Airy Riemann-Hilbert problem well posed.

Similar considerations, based on the relevant contour integrals, easily produce Riemann-Hilbert representations for all the other classical special functions, including even those which are not of the hypergeometric type, e.g., the Euler Gamma-function (Kitaev, 2002) and the Riemann zeta-function (see the end of this article).

Although the Riemann-Hilbert treatment of the classical special functions does not seem to have a big technical advantage over integral representations, it does lead, via a natural nonabelianization procedure, to the next, more exotic, analytic objects, the Painlevé transcendents.

A simple way to obtain a nonabelian generalization of the Airy Riemann-Hilbert problem is to augment the contour \( \Gamma \) by the three complementary rays \( \Gamma_5 \), \( \Gamma_6 \), and \( \Gamma_3 \) (shown in Figure 3 by dashed lines), simultaneously complementing equations (12) by three more equations defining the jump matrix on the new rays (note the change of the triangularity and of the sign of the exponent):

\[ G(\lambda) = G(\lambda, x) = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \]

\[ \lambda \in \Gamma_k, \quad k = 1, 3, 5. \]

Along the augmented contour \( \Gamma \), we still have the asymptotic consistency condition that \( G(\lambda) \) tends to the identity matrix as \( \lambda \to \infty \). The nonabelian extension leads to the following nonlinearization of the Airy cyclic relation (11):

\[ s_{k+3} = -s_k, \quad k = 1, 2, 3, \quad s_1 - s_2 + s_3 + s_1 s_2 s_3 = 0. \]

We will see shortly that, just as in the case of their linear counterpart, these relations are needed to eliminate the possible singularity of the function \( Y(\lambda) \) at \( \lambda = 0 \).

Let \( Y(\lambda, x) \) be the solution of this nonabelian Riemann-Hilbert problem, and define the function \( u(x) \) again by the same limit formula as in the linear case; i.e., put

\[ u(x) = 2 \lim_{\lambda \to \infty} [\lambda Y_{12}(\lambda)]. \]

Then, in place of the linear Airy equation (7), the following nonlinear second-order differential equation arises:

\[ u_{xx} = xu + 2u^3. \]

Unlike in the linear case, the proof of (15) is not straightforward. Indeed, we no longer have an explicit formula for \( Y(\lambda) \) or for \( u(x) \), so the very existence of the solution \( Y(\lambda) \) of the Riemann-Hilbert problem and its “good” analytic properties with respect to the parameter \( x \) are now quite nontrivial analytic facts. They can be established by using

\[ u_{xx} = xu + 2u^3. \]
techniques based on the Fredholm analysis of the associated singular integral equation or by applying methods of holomorphic vector bundles based on the generalized Birkhoff-Grothendieck theorem with parameters. A precise statement concerning the solution \( Y(\lambda) = Y(\lambda, x) \) reads as follows.\footnote{Theorem 1 as stated was proved recently by Bolibruch, Kapaev, and this author. It may also be properly viewed as a refinement of earlier work of Fokas and Zhou and of Novokshenov and this author, and apparently it also can be extracted from more general results of Malgrange, Palmer, and Mason and Woodhouse.}

**Theorem 1.** Suppose the set \( s = (s_1, \ldots, s_n) \) satisfies the cyclic relation (13). Then there exists a countable subset \( X_k \) of the complex \( \lambda \)-plane, having the point at \( \infty \) as its only accumulation point, and a matrix function \( Y(\lambda, x) \) solving the non-abelian Airy Riemann-Hilbert problem for all \( x \not\in X_k \). Moreover, if \( \Omega_k \) denotes the sector in the complex \( \lambda \)-plane bounded by the rays \( \Gamma_{k,1} \) and \( -\Gamma_k \), then each restriction \( Y_k(\lambda, x) \equiv (Y|_{\Omega_k})(\lambda, x) \) is holomorphic in \( \Omega_k \times (\mathbb{C} \setminus X_k) \) and meromorphic along \( \Omega_k \times X_k \). The normalizing condition at \( \lambda = \infty \) extends to the full asymptotic series

\[
Y(\lambda, x) \sim I + \sum_{j=1}^{\infty} \frac{m_j(x)}{\lambda^j}, \quad \lambda \to \infty,
\]

which is differentiable with respect to \( \lambda \) and \( x \). The coefficient functions \( m_j(x) \) are meromorphic in \( \lambda \) and have the set \( X_k \) as the set of their poles.

The \( x \)-meromorphy is a new analytic feature of the function \( Y(\lambda, x) \) in the nonabelian case (in the linear—abelian—case, the function \( Y(\lambda, x) \) is entire with respect to \( x \)). In fact, the solutions of all Riemann-Hilbert problems arising in the theory of special functions are meromorphic with respect to the relevant parameters.

Theorem 1 allows us to differentiate the functions \( Y(\lambda, x) \) and \( u(x) \), and the proof of the differential equation (15) becomes relatively easy. Nevertheless, it involves ingredients which are central to the whole modern theory of integrable systems: the **Lax pair formalism** and the **Isomonodromy deformation**. Here is a sketch of the proof.

Let \( \theta(\lambda) = \frac{1}{2} \lambda^3 + \lambda t \), let \( \sigma_j \) denote the Pauli matrix \((\sigma_j = (1, 0, 0))\), and put \( \Psi(\lambda) = Y(\lambda)e^{-i\theta(\lambda)\sigma_3} \). The diagonal matrix \( e^{-i\theta(\lambda)\sigma_3} \) conjugates the jump matrix \( G(\lambda) \) into constant matrices:

\[
G(\lambda) = e^{-i\theta(\lambda)\sigma_3} S_k e^{i\theta(\lambda)\sigma_3}, \quad \lambda \in \Gamma_k,
\]

where \( S_k \) is upper (lower) triangular if \( k \) is even (odd), has unit diagonal, and has \( s_k \) as its nontrivial off-diagonal entry. In terms of the function \( \Psi \), the jump relation becomes

\[
\Psi^+(\lambda) = \Psi^-(\lambda) S_k, \quad \lambda \in \Gamma_k,
\]

while the normalization condition at \( \lambda = \infty \) transforms into the asymptotic condition

\[
\Psi(\lambda) = (I + O\left(\frac{1}{\lambda}\right)) e^{-i\theta(\lambda)\sigma_3}.
\]

The main point is that the \( \lambda \)- and \( x \)-independence of the matrices \( S_k \) implies that the "logarithmic derivatives"

\[
A(\lambda) := \Psi^*(\lambda)^{-1} \quad \text{and} \quad U(\lambda) := \Psi^*(\lambda)^{-1}
\]

have no jumps across the rays \( \Gamma_k \). In addition, the cyclic relation (13), which can be rewritten as the matrix equation

\[
S_1 S_2 \cdots S_6 = I,
\]

implies that the logarithmic derivatives \( \Psi^*(\lambda)^{-1} \) and \( \Psi^*(\lambda)^{-1} \) have no singularities at \( \lambda = 0 \). Hence the matrix functions \( A(\lambda) \) and \( U(\lambda) \) are, in fact, polynomials of the second and the first degree, respectively:

\[
A(\lambda) = -4i\lambda^2 \sigma_3 + \lambda A_1 + A_0
\]

and

\[
U(\lambda) = -i\lambda \sigma_3 + U_0.
\]

The matrix coefficients \( A_1, A_0, \) and \( U_0 \) can be easily evaluated in terms of the matrix coefficients \( m_j \) of the asymptotic series (16). After elementary algebra and a few more technical tricks, the matrix coefficients \( A_1, A_0, \) and \( U_0 \) can be expressed in terms of a single functional parameter \( u \equiv u(x) \) defined according to (14) (note that \( u = 2(m_{11}) \)). In fact, the following equations result:

\[
A(\lambda) = -4i\lambda^2 \sigma_3 - 4u_2 \sigma_2 - 2u_3 \sigma_1 - (ix + 2iu^2) \sigma_3
\]

and

\[
U(\lambda) = -i\lambda \sigma_3 - u \sigma_2,
\]

where \( \sigma_1 \) and \( \sigma_2 \) denote the Pauli matrices \((\sigma_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix})\) and \((\sigma_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix})\), respectively.

After establishing the polynomial structure of \( A(\lambda) \) and \( U(\lambda) \), we can reinterpret (20) as saying that the matrix function \( \Psi(\lambda, x) \equiv \Psi(\lambda, x) \) is a solution of the **linear overdetermined system**

\[
\begin{cases}
\Psi = A(\lambda) \Psi, \\
\Psi = U(\lambda) \Psi.
\end{cases}
\]

The compatibility condition \( \Psi \chi = \Psi \chi \) yields the following relation on the coefficient matrices:

\[
U(\lambda) - A_x(\lambda) = [A(\lambda), U(\lambda)], \quad \text{identically in} \ \lambda.
\]
A straightforward calculation shows, in view of (22) and (23), that this matrix identity is equivalent to the scalar differential equation (15) for the functional parameter \( u(x) \).

According to the terminology of integrable systems, the linear system (24) and the nonlinear equation (25) are the Lax pair and the zero-curvature (or Lax) representation of the nonlinear ordinary differential equation (15).

The Lax pair (24) puts the nonabelian Airy Riemann-Hilbert problem into the context of the theory of linear ODEs with rational coefficients. Notice, however, that the \( \lambda \)-equation of the system (24) is not Fuchsian. Its only singular point is the irregular singular point at \( \lambda = \infty \). This means that the fundamental solutions of the equation behave exponentially as \( \lambda \to \infty \). In fact, this is exactly the behavior which is indicated by equation (19).

Simultaneously, equation (18) manifests the relevant Stokes phenomenon, that is, different fundamental solutions with the same asymptotics. In this context, the matrices \( S_k \) are the Stokes multipliers, and the set \( \{ S \} \) represents a set of generalized monodromy data of the first equation in (24). This implies that, similar to the Fuchsian case, the Riemann-Hilbert problem itself can be interpreted as an example of the inverse monodromy problem. In fact, this is the first nontrivial case interpreted as an example of the inverse monodromy problem for linear systems allowing irregular singularities.

The \( x \)-independence of the matrices \( S_k \), which is responsible for the \( x \)-equation in (24), indicates that the zero-curvature equation (25) describes the isomonodromy deformations of the \( \lambda \)-equation. Indeed, as was shown in 1980 by Flaschka and Newell, one can derive directly from the zero-curvature equation (25) that the Stokes matrices \( S_k = S_k(x, u, u_x) \) of the \( \lambda \)-equation in (24) are the first integrals of motion of the differential equation (15). This and the uniqueness property of Riemann-Hilbert problems (an easy fact) yield the following strengthening of the statement concerning the representation (14) for solutions of differential equation (15).

**Proposition 1.** The map defined by equation (14) is a bijection of the algebraic manifold

\[ \{ s = (s_1, s_2, s_3) \in \mathbb{C}^3 : s_1 - s_2 + s_3 + s_1 s_2 s_3 = 0 \} \]

into the set of solutions of the differential equation (15). In particular, the notation \( u(x) = u(x; s) \) for solutions of (15) is justified.

An important corollary of Theorem 1 and Proposition 1 is the following global analytic property of the solutions of equation (15).

**Proposition 2.** Every solution of the differential equation (15) is a meromorphic function of the complex variable \( x \). If \( s \) is the corresponding monodromy data, then the set of poles of the solution coincides with the set \( X_s \) of points where the nonabelian Airy Riemann-Hilbert problem fails to be solvable.

It is now time to reveal the name of the differential equation (15). It is (a particular case) of the second equation from the Painlevé-Gambier list of ordinary differential equations having the so-called Painlevé property. A second-order differential equation of the form \( u_{xx} = F(x, u, u_x) \), where \( F \) is meromorphic in \( x \) and rational in \( u \) and \( u_x \), is said to have the Painlevé property if every solution has a meromorphic continuation to the universal covering of a punctured \( x \)-Riemann sphere which is determined by the equation only. This is a statement concerning the global behavior of a general solution, and as such it is often taken as a definition of the very concept of integrability.

At the turn of the last century, Painlevé and Gambier showed that there exist, up to proper transformations of the dependent and independent variables, only fifty equations satisfying the Painlevé property. Moreover, each of these equations can be either integrated by quadrature or reduced to a linear equation or reduced to one of a list of six nonlinear equations (for more details see [11]). These six equations, which are called the Painlevé equations, are not integrable in terms of the classical "linear" special functions and classical "nonlinear" special functions (elliptic functions). The solutions of Painlevé equations are called Painlevé functions or Painlevé transcendents. As already indicated, equation (15) is the second equation of Painlevé's list.

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14 Assuming in (17) the abelian reduction, i.e., \( s_k = 0 \) for \( k = 1, 3, 5 \), and repeating the same arguments based on the analysis of the logarithmic derivatives \( \mathcal{Y}_1 \mathcal{Y}^{-1} \) and \( \mathcal{Y}_2 \mathcal{Y}^{-1} \), we arrive again at the Lax pair (24), but this time with the upper triangular coefficient matrices \( A(\lambda) \) and \( U(\lambda) \). The zero-curvature equation (25) in this case is equivalent to the Airy equation. This Lax pair for Airy functions was suggested by Kapaev, Kitaev, and this author in 1988 in a paper where (it seems) the Lax-pair point of view was applied to the classical special functions for the first time. The method of this paper (slightly different from the one presented here) has been further extended by Kitaev in his 2000 paper (Acta Appl. Math. 64) where the development of a unified "isomonodromic" approach to both linear and nonlinear special functions has been essentially completed.

15 Although, as the example of a general linear second-order equation indicates, the Painlevé property does not necessarily yield explicit connection formulas.

16 Strictly speaking, this fact was proved completely rigorously only recently in the works of Umemura and his collaborators in the framework of differential Galois theory.
It is becoming increasingly evident that Painlevé transcendents should be considered as new nonlinear special functions. It is amazing in how many apparently different applications they appear. Here we cannot go further into the modern theory of Painlevé transcendents, so we refer the reader to the monographs [1], [13], [15], and the review paper [12].

Analogously to our discussion of the second Painlevé equation (15), a Riemann-Hilbert formalism can be developed for each of the six Painlevé transcendents, and for all but the first one it can be developed starting from the relevant linear counterpart. In particular, each Painlevé transcendent admits a Riemann-Hilbert representation and an isomonodromy deformation interpretation. These can be used to provide a monodromy data parametrization of the solution manifolds of the Painlevé equations and to prove the analog of Proposition 2 (the Painlevé property) for each of the Painlevé functions. In fact, one can do more.

According to our view of Riemann-Hilbert representations as a nonabelian version of contour integration, one might wonder about the possibility of carrying out a comprehensive global asymptotic analysis of the Painlevé functions, including explicit connection formulae, as \( x \) approaches relevant critical points (the "Painlevé-punctures" of the \( x \)-Riemann sphere) along different directions in the complex plane. That this can indeed be done was apparently unknown to Painlevé and his contemporaries. To give the reader the flavor of these modern developments, which in our view make the strongest case for the Riemann-Hilbert approach in integrable systems, we present a complete description of the asymptotic behavior of the second Painlevé transcendent \( u(x; s) \) as \( x \to \pm \infty \) in the case \( s_2 = -s_1 \). This restriction on the monodromy data corresponds to selecting second Painlevé functions that are purely imaginary for real \( x \) and hence (by an easy calculation) have no poles on the real line.

**Theorem 2.** An arbitrary purely imaginary solution \( u(x) \) of the second Painlevé equation (15) has the following oscillatory asymptotic behavior as \( x \to -\infty \):

\[
(26) \quad u(x) = t(x)^{-1/4} \alpha \\
\times \sin \left\{ \frac{\pi}{3} (x)^{3/2} + \frac{3}{4} \alpha^2 \log(-x) + \varphi \right\} \\
+ o((-x)^{-1/4}).
\]

Here the constants \( \alpha > 0 \) and \( \varphi \in \mathbb{R} \ (\text{mod } 2\pi) \) can be any real numbers; they determine the solution \( u(x) \) uniquely and hence form a set \( \mathfrak{a} \equiv (\alpha, \varphi) \) of asymptotic parameters at \(-\infty\).

Let

\[
\Delta(\alpha, \varphi) = \frac{3}{2} \alpha^2 \log 2 - \frac{\pi}{4} - \arg \Gamma \left( \frac{3}{2} \right) - \varphi,
\]

where \( \Gamma(z) \) denotes Euler's gamma function. The behavior of \( u(x) \equiv u(x; \alpha, \varphi) \) as \( x \to +\infty \) depends on the value of \( \Delta(\alpha, \varphi) \). If \( \text{(generic case)} \)

\[
(27) \quad \Delta(\alpha, \varphi) \neq 0 \quad (\text{mod } \pi),
\]

then the solution \( u(x) \) oscillates and tends to \( \pm t' \sqrt{2/3} \) as \( x \to +\infty \); more precisely, one has

\[
(28) \quad u(x) = \sigma t' \sqrt{\frac{x}{2}} \\
+ \sigma t'(2x)^{-1/4} \rho \cos \left\{ \frac{\pi}{3} x^{3/2} - \frac{3}{4} \rho^2 \log x + \theta \right\} \\
+ o(x^{-1/4}) \quad \text{as } x \to +\infty,
\]

where \( \sigma = \pm, \rho > 0, \) and \( \theta \in \mathbb{R} \ (\text{mod } 2\pi) \). If instead

\[
\Delta(\alpha, \varphi) = 0 \quad (\text{mod } \pi),
\]

then the solution \( u(x) \) decreases exponentially as \( x \to +\infty \); indeed in this case the asymptotics are the same as for the Airy function \( Ai(x) \); i.e.,

\[
(29) \quad u(x) = \sigma t \sqrt{\frac{3}{2}} x^{-1/4} e^{-0.5x^{3/2}} (1 + o(1))
\]

as \( x \to +\infty \), where \( \sigma = \pm \) and \( \rho > 0 \). The set \( \mathfrak{a} \) of asymptotic parameters at \( +\infty \) is the triple \( (\rho, \theta, \sigma) \) in the generic situation and the pair \( (\rho, \sigma) \) in the special case.

The following explicit connection formulae give the map \( \mathfrak{a} \to \mathfrak{a}' \).

\[17\] Painlevé equations have extremely deep relations, due to Clarkson, Dubrovin, Hitchin, Manin, Okamoto, Umemura, and their collaborators, with group theory and algebraic geometry. We do not touch upon these at all, nor upon issues of the explicit particular solutions of Painlevé equations (Gromak, Lukashchewich, Tsegel'nik) and the Hamiltonian formalism (Boalch, Flaschka, Harnad, Krichever, Newell, Okamoto). In fact, all these subjects can be also treated in the framework of the Riemann-Hilbert approach, although not all the connections (e.g., with Okamoto's parametrization of the space of initial data) are completely clear at the moment.

\[18\] It also should be mentioned that the isomonodromy interpretation of all six Painlevé equations was first obtained in the classical works of Fuchs, Garnier, and Schlesinger. It was rediscovered and put in the context of the modern theory of integrable systems by Flaschka and Newell, and by Miwa, Jimbo, and Ueno in the early 1980s. The Lax pair (22)–(24) was first obtained by Flaschka and Newell as a result of a self-similar reduction of the Lax pair for the mKdV equation.

\[19\] These results were first obtained in 1986 by Kapaev and this author; some technical gaps that were present in the original proof were filled in by the papers of Deift and Zhou (1995) and Fokas, Kapaev, and this author (1994).
(30) \[ \rho^2 = \alpha^2 - \frac{1}{\pi} \log \left( 2(e^{\pi \alpha^2} - 1)^{1/2} \sin \Delta(\alpha, \varphi) \right), \]
\[ \theta = -\frac{3\pi}{4} - \frac{7}{4} \rho^2 \log 2 + \arg(i\rho^2) \]
\[ + \arg \left( 1 + (e^{\pi \alpha^2} - 1)e^{2i\Delta(\alpha, \varphi)} \right), \]
\[ \sigma = -\text{sign} \left( \sin \Delta(\alpha, \varphi) \right), \]
\[ \text{if } \Delta(\alpha, \varphi) \not\equiv 0 \pmod{\pi}, \text{ and} \]
(31) \[ \rho = (e^{\pi \alpha^2} - 1)^{1/2}, \quad \sigma = (-1)^n, \]
\[ \text{if } \Delta(\alpha, \varphi) \equiv n\pi. \]

Here are some remarks about Theorem 2.
(a) Some parts of the theorem can be obtained without using the Riemann-Hilbert formalism. This is true for the existence, for a given pair \((\alpha, \varphi)\), of a solution \(u(x)\) with the asymptotics (26) (the works of Abdullaev, 1985) or the asymptotics (28) and (29). Since these are local statements, they do not reflect the integrability of the second Painlevé equation. The global fact that formulae (26) and (28)-(29) describe all the possible types of asymptotic behavior of the purely imaginary solutions of the second Painlevé equation (15) as \(x \to \pm \infty\) can also be proved, in principle, without appealing to the Riemann-Hilbert representation—this was done in the 1988 and 1992 works of Joshi and Kruskal, but already one has to make use of the integrability of equation (15); indeed, Joshi-Kruskal's constructions essentially exploit the Painlevé property. Without using the Riemann-Hilbert formalism, it does not seem feasible to obtain the parts of the theorem concerning the bifurcation condition (27) and the connection formulae (30)-(31).

(b) The derivation of the connection formulae (30)-(31) is based on the prior evaluation, via the asymptotic analysis of the second Painlevé Riemann-Hilbert problem, of the asymptotic parameters \(a_k\) in terms of the monodromy data \(s_1\). The connection formulae (30)-(31) follow by eliminating the common parameter \(s_1\) from the equations \(a_k = a_k(s_1)\).

(c) There are two major approaches to the asymptotic analysis of the oscillatory Riemann-Hilbert problems appearing in the theory of integrable systems and, in particular, in the theory of Painlevé equations. The first scheme, the isomonodromy method developed in the 1980s and 1990s in the works of Andreev, Kapaev, Kitaev, Novokshenov, Suleimanov, and this author, is based on the asymptotic solution of the direct monodromy problem for the corresponding \(\lambda\)-equation and on the interpretation of the monodromy data as first integrals of motion of the Painlevé equations. This approach was inspired by the pioneering paper of Zakharov and Manakov (1976) on the asymptotic analysis of integrable PDEs, and its implementation required a nontrivial development (see, e.g., the works of Kapaev on the first and second Painlevé equations and the 1998 work of Bassom, Clarkson, Law, and McLeod on the second Painlevé equation) of the classical WKB method in the complex domain (see the monograph [13] and the review article [12] for more details; see also the recent works of Bleher and this author on the asymptotics of orthogonal polynomials). The second approach, the nonlinear steepest descent method, was developed, as already mentioned, in the beginning of the 1990s by Deift and Zhou. The Deift-Zhou approach suggests an extremely elegant direct asymptotic analysis of the relevant Riemann-Hilbert problems, so that no prior information about the asymptotic behavior of the solutions is needed. The essence of the nonlinear steepest descent method was briefly outlined in the first section of this survey.

(d) The first connection formulae for specific families of Painlevé transcendents were obtained in 1977 by Ablowitz and Segur (the one-parameter family (29) of the solutions of (15)) and by McCoy, Tracy, and Wu (a one-parameter family of solutions of the third Painlevé equation arising in the 2D Ising model). Ablowitz and Segur used the Zakharov-Manakov formulae and the fact that the second Painlevé equation is a self-similar reduction of the KdV equation. The Ablowitz-Segur connection formulae were rigorously justified in the later work of Clarkson and McLeod and of Suleimanov. The work of McCoy, Tracy, and Wu was actually the first rigorous work on the Painlevé connection formulae. Remarkably, it was done before the discovery of the Riemann-Hilbert formalism for Painlevé equations. There is, however, an important technical point specific to the one-parameter family considered in the McCoy-Tracy-Wu work: it admits a certain Fredholm determinant representation, which, in a sense, is a “shadow” of the Riemann-Hilbert formalism. The “Fredholm determinant branch” of the Riemann-Hilbert approach has been further developed in the recent works of Tracy and Widom devoted to some important special classes of solutions of an integrable higher-order generalization of the third Painlevé equation.

(e) A large number of results concerning the asymptotic descriptions in the full complex domain, including the connection formulae and an explicit evaluation of the distributions of poles near the relevant critical points, have been already obtained for the first five Painlevé equations, mostly in the works of Kapaev, Kitaev, and Novokshenov. The asymptotics and connection formulae for a generic case of the Painlevé VI equation were evaluated via
the Riemann-Hilbert approach in 1982 by Jimbo. Important special cases, not covered by Jimbo's results, were worked out in the recent works of Doyon, Dubrovin, Guzzetti, and Mazzocco.

A Riemann-Hilbert Problem for the Riemann Zeta-function

We think it is relevant to conclude this article with the following simple observation, which brings in the name of Riemann in one more fundamental way and which the reader might find intriguing.

Starting with the Riemann integral representation for the Riemann zeta-function \( \zeta(s) \) (see, e.g., the book of Titchmarsh), we should, according to (3)-(6), arrive at a representation of type (5) for \( \zeta(s) \) in terms of the solution \( Y(\lambda; s) \) of the Riemann-Hilbert problem posed, with the proper regularization, on the positive real line \( \lambda > 0 \) with the jump matrix defined by the equation

\[
G(\lambda; s) = \begin{pmatrix}
\pi i \lambda^{s-1} \theta_3(0; i \lambda) & 1 \\
0 & 1
\end{pmatrix},
\]

where \( \theta_3(z; \tau) = \sum e^{\pi i m^2 + 2\pi i n z} \) is the Jacobi theta-function.\(^{21}\) Put \( Y(\lambda) = Y(\lambda) \left( \lambda^{s-1} \right)^{1/3} \) and consider the "logarithmic derivatives"

\[
\sigma_3 Y \left( \frac{1}{\lambda}; 5 - s \right) \sigma_3 Y^{-1}(\lambda; s)
\]

and

\[
Y(\lambda; s + 2) Y^{-1}(\lambda; s).
\]

Due to the well-known symmetry properties of the theta-constant, the \( Y \) jump matrix is invariant with respect to the transformations \( (\lambda, s) \to (1/\lambda, 5 - s) \) and \( s \to s + 2 \). Analogously to the derivation of the differential Lax pair (24), these properties would lead to the "discrete-discrete" Lax pair

\[
\begin{align*}
\sigma_3 Y \left( \frac{1}{\lambda}; 5 - s \right) \sigma_3 &= A(s) Y(\lambda; s), \\
Y(\lambda; s + 2) &= U(\lambda; s) Y(\lambda; s),
\end{align*}
\]

whose compatibility condition has the form of the cyclic equation

\[
\sigma_3 U \left( \frac{1}{\lambda}; 3 - s \right) \sigma_3 A(s + 2) U(\lambda; s) A^{-1}(s) = I,
\]

and it yields, surely, the classical functional equation for \( \zeta(s) \). One can now proceed with the process of nonabelianization of the Riemann-Hilbert problem (32) and arrive at a notion of a "nonlinear" Riemann zeta-function.

We are not taking this construction too seriously. At least not yet!

\(^{21}\) The regularization mentioned consists in the replacement of \( \theta_3(0; i \lambda) \) by \( \theta_3(0; i \lambda) - 1 \) for \( \lambda > 1 \) and by \( \theta_3(0; i \lambda) - \lambda^{-1/2} \) for \( 0 < \lambda < 1 \).

References

Max Shiffman was Richard Courant's most brilliant student in America, Ph.D. 1938. For about fifteen years in the middle of the last century he was a leader in the calculus of variation applied to partial differential equations. He gave an invited address at Princeton University's 200th anniversary conference in 1946 and at the International Congress of Mathematicians in Cambridge in 1950. He gave a one-hour address at a meeting of the American Mathematical Society.

Shiffman's mother died when Max was two years old, and he was brought up by an older sister, Molly. Her daughter Vivian recalls that already as a child Max's thoughts revolved around mathematics, and he often wrote out his mathematical ideas on the wall over his bed. He received his undergraduate education at CCNY (City College of New York), which in the thirties was a hotbed of brilliant young students who were too poor or too Jewish to go to Harvard.

He was an instructor at CCNY in 1939-42. In 1942 he joined a research project of the OSRD (Office of Scientific Research and Development) at New York University (NYU), and from 1945 to 1948 he was associate professor at NYU. Here he was a major influence on a whole generation of graduate students, including Avron Douglis, Clifford Gardner, Joe Keller, Martin Kruskal, Cathleen Morawetz, Louis Nirenberg, and the author.

In 1948 Gábor Szegő hired him as a full professor at Stanford. There Shiffman modernized the curriculum in analysis, teaching for the first time there a course on functional analysis. His brilliant career came to a tragic halt in 1951, due to a schizophrenic breakdown. He recovered and continued his research and teaching until a second breakdown in 1956. With the support of his friends and a generous trustee of Stanford University, he was admitted to Chestnut Lodge, a prestigious psychiatric institute. After nine years of therapy he was transferred to Agnew State Hospital in California, where Max took advantage of a state law and sued in court to be released; he convinced a jury that he was mentally competent.

From 1965 to 1967 he was appointed to a research position at Stanford, mainly through the efforts of his friend and admirer, Don Spencer. In 1967 he obtained an appointment as a professor at California State University at Hayward. There he taught calculus, vector analysis, ordinary and partial differential equations, number theory, set theory, and measure theory to undergraduates, and special topics courses on the graduate level. He was willing to deal, kindly and patiently, with angle trisectors, circle squarers, and Fermat provers. According to Edward Keller, most of Max's colleagues regarded him as the greatest mathematician ever to serve on the faculty at Cal State at Hayward. He retired in 1981.

Much of Shiffman's work dealt with Plateau's problem. He showed that if a boundary curve spans two minimal surfaces that are relative minima, then it also spans one which is not a relative minimum. In one of his last publications he showed that a doubly connected minimal surface whose boundary consists of two circles on parallel planes intersects any other parallel plane in a circle. Shiffman also worked on problems of conformal mapping, and the differentiability and analyticity of solutions of double integral variational problems. Most of these papers appeared in the Proceedings of the National Academy of Sciences and the Annals of Mathematics.

Shiffman used variational methods to study the flow of fluids, incompressible and compressible. He proved a basic theorem about compressible flows around bodies with prescribed subsonic speed at infinity; he showed that such flows are smooth until the flow becomes sonic. The technical tool he used, altering the equation of state, is called "shiffmanization" by cognoscenti.

In the summer of 1950, spent at the Rand Corporation, Shiffman became interested in game theory and obtained a far-reaching generalization of von Neumann's minimax theorem.

He is survived by his sons, Bernard, a professor of mathematics at Johns Hopkins; and David, who owns an investment company; and five grandchildren.
Energized by the success of wavelets, the last two decades saw the rapid development of a new field, computational harmonic analysis, which aims to develop new systems for effectively representing phenomena of scientific interest. The curvelet transform is a recent addition to the family of mathematical tools this community enthusiastically builds up. In short, this is a new multiscale transform with strong directional character in which elements are highly anisotropic at fine scales, with effective support shaped according to the parabolic scaling principle length $\sim$ width.

To fix ideas (although this is a distortion of reality) it is useful to think about curvelets as obtained by applying parabolic dilations, rotations, and translations to a specifically shaped function $\psi$; they are indexed by a scale parameter $a$ $(0 < a < 1)$, a location $b$, and an orientation $\theta$ and are nearly of the form

$$
\psi_{a,b,\theta}(x) = a^{-3/4} \psi(D_a R_\theta(x - b)) = a^{-3/4} \psi\left(\begin{pmatrix} 1/a & 0 \\ 0 & 1/\sqrt{a} \end{pmatrix} x - b\right),
$$

where $D_a$ is a parabolic scaling matrix, $R_\theta$ is a rotation by $\theta$ radians, and for $(x_1, x_2) \in \mathbb{R}^2$, $\psi(x_1, x_2)$ is some sort of admissible profile (analogous exist in higher dimensions). The geometry of a curvelet is now apparent: if the function $\psi$ is supported near the unit square, we see that the envelope of $\psi_{a,b,\theta}$ is supported near an $a$ by $\sqrt{a}$ rectangle with minor axis pointing in the direction $\theta$. An important property is that curvelets obey the principle of harmonic analysis stating that it is possible to analyze and reconstruct an arbitrary function $f(x_1, x_2)$ as a superposition of such templates. One can, indeed, easily expand an arbitrary function $f(x_1, x_2)$ as a series of curvelets, much like an expansion in an orthonormal basis. (The question of whether there exist orthonormal bases of curvelets is open.) Continuing at an informal level of exposition, there is a discretization of scale/location/angle which roughly goes like $a_j = 2^{-j}$, $j = 0, 1, 2, \ldots$, $\theta_{j,\ell} = 2\pi \ell \cdot 2^{-[j/2]}$, $\ell = 0, 1, \ldots, 2^{[j/2]} - 1$, and $b_{k,j,\ell} = R_{\theta_{j,\ell}}(k_1 2^{-j}, k_2 2^{-j/2})$, $k_1, k_2 \in \mathbb{Z}$, so that with $\psi_{j,\ell,k} = \psi_{a_j b_{k,j,\ell}}$ the collection $(\psi_{j,\ell,k})$ obeys

$$
f = \sum_{j,\ell,k} \langle f, \psi_{j,\ell,k} \rangle \psi_{j,\ell,k},
$$

$$
\|f\|_2^2 = \sum_{j,\ell,k} |\langle f, \psi_{j,\ell,k} \rangle|^2.
$$

All right. So curvelets comprise an interesting new multiscale architecture which gives very concrete representations. There are many others. Why should we care?

**Curvelets for What?**

It is well known that discontinuities destroy the sparsity of a Fourier series. This is the Gibbs phenomenon; we need many, many terms to reconstruct a discontinuity to within good accuracy. Wavelets, because they are localized and multiscale, do much better in one dimension, but because of their poor orientation selectivity, they do not represent higher-dimensional singularities effectively. What makes curvelets interesting and actually motivated their development is that they provide a mathematical architecture that is ideally adapted for representing objects which display *curve-punctuated smoothness*—smoothness except for discontinuity along a general curve with bounded curvature—such as images with edges, for example. The curvelet transform is organized in such a way that most of the energy of the object is...
localized in just a few coefficients. This can be quantified. Simply put, there is no basis in which coefficients of an object with an arbitrary singularity curve would decay faster than in a curvelet frame. This rate of decay is much faster than that of any other known system, including wavelets. Improved coefficient decay gives optimally sparse representations that are interesting in image-processing applications, where sparsity allows for better image reconstructions or coding algorithms.

**Beyond Scale-Space?**

A beautiful thing about mathematical transforms is that they may be applied to a wide variety of problems as long as they have a useful architecture. The Fourier transform, for example, is much more than a convenient tool for studying the heat equation (which motivated its development) and, by extension, constant-coefficient partial differential equations. The Fourier transform indeed suggests a fundamentally new way of organizing information as a superposition of frequency contributions, a concept which is now part of our standard repertoire. In a different direction, we mentioned before that wavelets have flourished because of their ability to describe transient features more accurately than classical expansions. Underlying this phenomenon is a significant mathematical architecture that proposes to decompose an object into a sum of contributions at different scales and locations. This organization principle, sometimes referred to as scale-space, has proved to be very fruitful—at least as measured by the profound influence it bears on contemporary science.

Curvelets also exhibit an interesting architecture that sets them apart from classical multiscale representations. Curvelets partition the frequency plane into dyadic coronae and (unlike wavelets) subpartition those into angular wedges which again display the parabolic aspect ratio. Hence, the curvelet transform refines the scale-space viewpoint by adding an extra element, orientation, and operates by measuring information about an object at specified scales and locations but only along specified orientations. The specialist will recognize the connection with ideas from microlocal analysis. The joint localization in both space and frequency allows us to think about curvelets as living inside "Heisenberg boxes" in phase-space, while the scale/location/orientation discretization suggests an associated tiling (or sampling) of phase-space with those boxes. Because of this organization, curvelets can do things that other systems cannot do. For example, they accurately model the geometry of wave propagation and, more generally, the action of large classes of differential equations: on the one hand they have frequency localization so that they approximate wave behavior, but on the other hand they have enough spatial localization so that the flow will essentially preserve their shape.

Research in computational harmonic analysis involves the development of (1) innovative and fundamental mathematical tools, (2) fast computational algorithms, and (3) their deployment in various scientific applications. This article essentially focused on the mathematical aspects of the curvelet transform. Equally important is the significance of these ideas for practical applications.

**Multiscale Geometric Analysis?**

Curvelets are new multiscale ideas for data representation, analysis, and synthesis which, from a broader viewpoint, suggest a new form of multiscale analysis combining ideas of geometry and multiscale analysis. Of course, curvelets are by no means the only instances of this vision which perceives those promising links between geometry and multiscale thinking. There is an emerging community of mathematicians and scientists committed to the development of this field. In January 2003, for example, the Institute for Pure and Applied Mathematics at UCLA, newly funded by the National Science Foundation, held the first international workshop on this topic. The title of this conference: Multiscale Geometric Analysis.

**References**


James Gleick is a remarkable individual. An English major at Harvard University, his first adventure after college was an attempt to start up a newspaper. That failed, and he eventually moved into news reporting. He was a staffer for the New York Times for several years, and his rotation among various jobs at the Times led to his exposure to a good deal of interesting scientific activity. And then Gleick did a noteworthy thing: he synthesized everything that he had been seeing and hearing—the disparate works of Yorke and Feigenbaum and Hubbard and Mandelbrot and others. Gleick realized that the melange he had described was “chaos” (a word that had already been used in the literature), and he wrote a bestselling book GLE1 on the subject.

Whatever you may think of chaos as a subject (and I happen to think it is little more than a random sequence of ejaculations), it is difficult to gainsay the fact that Gleick’s book has accomplished quite a lot, garnered a good bit of attention for a notable slice of modern scientific activity, and virtually spawned a literary genre (i.e., the current spate of popular scientific writing). Gleick’s success with that first book is well deserved. It allowed him to retire to a big house in Brooklyn and to become a full-time writer.

Gleick’s second book GLE2, almost as important as the first, was a biography (the first ever) of the noted physicist Richard Feynman. Gleick had a tricky path to walk because Feynman had already told his story himself (in a pair of charming books [FEY1], [FEY2]). Of course Gleick did not want simply to repeat all the bons mots that Feynman himself had already shared with us. But he could not very well omit them all either, since they were some of the highlights of Feynman’s life and career. Gleick carried off the job with élan and grace, and this second book was also a considerable success.

I might note that I have spent time with James Gleick and talked to him at length about chaos and other scientific issues. It is safe to say that Gleick does not know much, nor does he profess to know much, about science. But he is an excellent listener and a talented reporter. The proof is, after all, in the pudding. Gleick gave a public lecture about chaos at my university a few years ago.

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It was an astonishing performance—enlightening, entertaining, and insightful.

Now Gleick has turned his hand to a biography of Isaac Newton. I must say that I was a bit surprised. After all, Newton has been dead for 275 years. He was, by all estimations, our greatest scientist. His life has been chewed over extensively, and there are plenty of biographies. Why do we need another? Why doesn’t Gleick write a biography of Stephen Wolfram (of whom there is no biography and who has led a fascinating life) or William Shockley (same comment)? But we mustn’t sell Gleick short. He is a keen observer and a good storyteller. He always has a fresh take on things. And Isaac Newton does not disappoint.

It is well-documented and oft-told that Isaac Newton was an irascible, unsociable, solitary man who had neither parents (in the sense that he lived with neither of them) nor friends nor spouses nor lovers. He died a virgin. One of the most famous Isaac Newton quotations is “I do not know what I may appear to the world but, to myself, I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.” Yet James Gleick points out that Isaac Newton almost certainly never saw the seashore.

Newton rarely published his results and never did so in a timely manner. He conducted savage feuds with other scientists who he felt had wronged him. There seems to be little doubt that the long-running rift between the Leibniz partisans on the continent and the Newton partisans in England over the primacy to the calculus was due in no small part to Newton’s secretiveness. But Gleick concentrates on a different feature of the life of Newton. The scientist’s youth, and the incipient thought processes that made for a great historic analytical genius, seem to have been less thoroughly studied over time. Newton’s state of mind while he was writing the Principia has not been heretofore carefully documented. It is these aspects of Newton’s life that Gleick chooses to develop in detail.

Gleick tells of how, when he was young, Newton had very little paper. And, even while at Cambridge, his access to books was extremely restricted. We are told that, when the young man finally did get a notebook, he filled its pages with minute recordings of recipes for ink, with speculations about nature, with calculations, and with philosophical musings. Newton took great pleasure, even as an adult, in copying classical texts word for word—just as did the ancient Greeks. Isaac Newton’s father died before the scientific genius was born, and his mother had to abandon the child in order to marry another man. Thus, even though his mother had considerable means, Newton had to attend Cambridge as a subsizar—basically a servant to the other students. He studied with Isaac Barrow, who was the first professor of mathematics that Cambridge ever had. When Newton inherited a 1,000-page bound vellum notebook from his stepfather, it changed his life. For now he could really write!

Of course the plague epidemic was the best thing that ever happened to Newton. Schooling at Cambridge was disbanded in order to limit contagion, and the young genius was forced to repair to the country for twenty months (in 1664 and 1665 by our modern calendar)—a period during which young Isaac had limitless stretches of uninterrupted time for concentration and reflection. He labored away at the 1,000-page notebook that he had inherited and which he called his “Waste Book”. It was in this single notebook that Newton carried out the calculations that became calculus, the theory of infinite series, mechanics, optics, and myriad other key ideas of modern science.

It is difficult, from our modern Olympian perspective, to understand the mindset of Newton’s day. Even the concept of “velocity” was relatively new at that time. While Newton was inventing mechanics, he was also inventing the very language in which it is expressed. And Newton’s great nemesis, in all his ruminations, was the concept of infinitesimal. He constantly had to confront Zeno’s paradox, and the many apparent contradictions arising therefrom, in all his considerations of fluxions and fluents and quadrature and acceleration. Some representative passages taken from Newton’s grappling with the notion of infinitesimal give a flavor of his struggles:

Thus \( \frac{2}{3} \) is double to \( \frac{1}{6} \) & \( \frac{0}{1} \) is double to \( \frac{0}{1} \),
for multiply the 2 first & divide the \( 2^{\text{ds}} \) by 0, & there results \( \frac{2}{3} : \frac{1}{6} & \frac{1}{1} \) : \( \frac{1}{2} \) ...

(that is undetermined)

Tis indefinite \( \wedge \) how great a sphere may be made how greate a number may be reckoned, how far matter is divisible, how much time or extension wee can fansy but all the Extension that is, Eternity, \( \frac{d}{d} \) are infinite.

It is safe to say that Isaac Newton never fully came to grips with the notion of infinitesimal, but he made peace with it well enough to develop the science that he wanted to develop.

It has frequently been argued—and it is easy to do so—that a good historian of science should have considerable knowledge of history and also considerable knowledge of the sciences. I am fairly sure that James Gleick is no master of Isaac Newton’s science. And his pedigree is also not as a historian. But he is a gifted writer, he is a quick
study, and he is very careful. His book is painstakingly researched and copiously footnoted. His list of references is more than impressive. And he says himself that his driving force in writing this book was to work from the primary texts. The result is a beautiful work and a delightful read.

It is clear, as one works one's way through the text, that when Gleick describes calculus, he is delicately dancing around things that he does not thoroughly understand. But he is scholarly and exact. As he indicates in his acknowledgments, he had many good people checking his accuracy and his credence. One is tempted to compare this book (very favorably!) with Sylvia Nasar's biography of John Nash [NAS]. Many of the statements that Nasar makes about mathematics (such as her formulation of the fundamental theorem of algebra) are incorrect. And it would have been so easy for her or her publisher to hire a proofreader. Gleick is a bit more careful, and the mathematical reader is considerably more comfortable with his result.

In all, I am very happy indeed that James Gleick wrote this book. Unlike some of the other modern treatments of Newton's life (see, for instance, [WES]), Gleick's life of Newton is neither ponderous nor prolix. It moves along rapidly but carefully and gives one a great and glorious sense of the age of enlightenment and of Isaac Newton's role in it.

Gleick pulls no punches in recounting Newton's fisticuffs with Robert Hooke, with Gottfried Wilhelm von Leibniz, and with other scientific luminaries of the day. He treats Newton's periodic descents into near madness with delicacy but precision. He in no sense paints Isaac Newton as a saint, but rather as a very gifted man with very human frailties.

Since Gleick does not come from the culture of mathematics and holds perhaps different values from the typical Notices reader, he makes some choices that we may find surprising. He mentions Newton's famous solution of the brachistochrone problem only in passing. In fact the word "brachistochrone" is never used, and the problem is never described; Gleick refers to it only as an "esoteric geometry problem." Hah! Stories like this are part of our hagiography. We do not want to see them lost in the shuffle. On the other hand, Gleick does pay suitable homage to the legend of Newton's derivation of Kepler's laws from the universal law of gravitation—that Newton solved it and forgot about it until Edmond Halley pried it out of him in a much later conversation.

One could fault Gleick, if one were wont to do so, for shortchanging certain very interesting aspects of Newton's story. For example, Newton willed a huge chest, containing all his scientific papers, to Catherine Barton (a niece who kept house for him). The tale of what became of those papers, how—at the hands of a fascist heir—they became scattered to the winds at an ill-conceived auction held to raise money for the Führer's cause, and how (due to the efforts of John Maynard Keynes and others) they were mostly reassembled is a fascinating tale that Gleick does not attempt to treat.1 However, Gleick had to make certain shrewd decisions to keep his tale to 191 brisk pages. I think that he did well and has left us with an enlightening and inspiring saga that will educate student and scholar and layman alike. One can only look forward to James Gleick's next scholarly enterprise.

References


1But see Freeman Dyson's review of this same book in [DYS].
The English mathematician G. H. Hardy is one of the most famous collaborators in the history of our subject. He is best known for his joint work with J. E. Littlewood, which began in 1911, and for his intense collaboration with Srinivasa Ramanujan, which Hardy termed "the one romantic incident of my life" [2, p. 2]. The relationship between Hardy and Ramanujan, which figures prominently in Robert Kanigel's "The Man Who Knew Infinity" [3], is the subject of an intriguing new play—Ira Hauptman's "Partition".

Although the term partition takes on a number of meanings in the context of the play, the most important partition is the divide between Hardy and Ramanujan. Because Hardy was fearful of being touched by others, both literally and figuratively, there was a great awkwardness between Hardy and Ramanujan when they first met. At the same time the two mathematicians were separated by a great intellectual gulf, which stemmed from Ramanujan's isolation from contemporary European mathematics [2, p. 1]. Throughout "Partition" we see Ramanujan struggling to master the concept of rigorous proof, which Hardy believes to be essential to mathematics but which is foreign to Ramanujan's way of thinking. Ramanujan finds fault with himself because of the difficulty of this struggle. He senses that he has failed Hardy by leaving unresolved some of Hardy's mathematical questions.

"Partition" has five major characters: Hardy and Ramanujan are complemented by a fictional Trinity College classicist named Billington; the mathematician Pierre de Fermat; and the goddess Namagiri, who was the personal deity of the real-life Ramanujan in India. In the play, Namagiri is seen often interacting with Ramanujan—she follows him to England, prepares his meals, tries to cover him with blankets in his chilly college rooms, and supplies his mathematical inspirations. Somewhat jarringly, we see Namagiri literally writing equations on Ramanujan's tongue with her finger. On the rare occasion when Namagiri's considerable divine mathematical abilities fail her, she scours heaven and earth in search of the keys to combinatorial and Diophantine mysteries.

The presence of Monsieur Fermat in a play about mathematics in Cambridge in the early years of the last century is something of a surprise. He was most welcome in "Fermat's Last Tango", but what is he doing here? The short answer is that he is entertaining us while having a good time for himself. A longer answer is that the Hardy of "Partition" sets out Fermat's Last Theorem (FLT) as a challenge to Ramanujan's mathematical skills. To deal with this challenge, Ramanujan enlists the help of Namagiri, who in turn consults Fermat directly. While this consultation occurs only in the second half of the play, Fermat has been with us since the earliest scenes. We first see Fermat in his study as he is writing his famous marginal note and then periodically after his death as he gloats over the failure of his successors to tame $a^n + b^n = c^n$. Hauptman's Fermat is a witty, engaging, and sardonic fellow who speaks directly to the audience whenever he surfaces to gloat over the failure of Euler, Lamé, and others to...
prove his "last theorem".

During his discussion with Namagiri, Fermat confesses that he no longer remembers his seventeenth-century technique for proving FLT. Fermat's confession forces Namagiri to do a literature search that leads to an over­looked 1908 Ukrainian article on FLT and Poincaré. When Hardy visits Ramanujan in a sanitarium (where Ramanujan has been wrestling with equations instead of resting up to conserve his strength), Ramanujan tells Hardy that Poincaré and modular forms are the key to Fermat's Last Theorem. To those who are familiar with the recent history of Fermat's Last Theorem, this remark by Ramanujan is a strong suggestion that the mathematician on stage can make their peace with a historical distortion that allows the audience to hook up with a familiar and famous problem. Once I was able to separate the real Hardy and Ramanujan from their counterparts on stage, I found only good things to say about "Partition". I thought that the acting and production were superb; I especially liked the performance of David Arrow, who played G. H. Hardy. The Aurora Theatre space is very small and intimate: the audience surrounds the stage on three sides and sits a mere four rows deep. Because of the design of the theater, there was a direct connection between the players and the audience. My friends in Berkeley, both mathematicians and non­mathematicians, were very pleased with the production.

The Aurora Theatre's website http://www.auroratheatre.org/ contains information of interest to readers of this review, including a history of the company and a photograph of the production. Halfway through the play's run in Berkeley and at the end of a week-long workshop on the history of algebra in the nineteenth and twentieth centuries, the Mathematical Sciences Research Institute organized a panel discussion on the Berkeley campus titled "Partition: Hardy and Ramanujan in Berkeley". The discussion included Barbara Oliver, the artistic director of the Aurora Theatre and the director of the "Partition" production; mathematical historian Jeremy Gray; MSRI Associate Director David Hoffman; and actors David Arrow (Hardy) and Rahul Gupta (Ramanujan), who read scenes from the play. The panel discussion was summarized in a story ("Partition: Plays with History to Create Drama") in the Berkeley Daily Planet [1]. I hope very much that the play will be performed elsewhere and become better known.

References
The Value of Mathematical Archives

Steve Batterson
with Charles Curtis, Albert Lewis, and Karen Parshall

Archives are indispensable resources to scholars in many disciplines. It is at such repositories that the papers of Thomas Jefferson and William Faulkner are stored. Unpublished materials, including correspondence and manuscript drafts, may reveal important insights that are not apparent in published works. Thus it is understandable that colleagues in the social sciences and humanities rely on archival study to advance their research. The case for mathematical archives may seem less compelling, especially since few mathematicians have ever ventured into an archive. Yet the papers of John von Neumann, G. D. Birkhoff, and other leading mathematicians are readily available.

The purpose of this article is to promote the donation and use of archival material by mathematicians. Below are three accounts, by Karen Parshall, Charles Curtis, and myself, of how unpublished records have contributed to studies in the history of mathematics.

Karen Parshall on James Joseph Sylvester
In 1870 one of the two most renowned mathematicians in England, the fifty-five-year-old James Joseph Sylvester, found himself out of a job; the regulations governing the Royal Military Academy, Woolwich, where he had held the professorship of mathematics since 1855 had just been changed to prohibit any civilian over the age of fifty-five from holding a teaching position at the school. Sylvester spent the next five years unemployed and living off of his pension in London, but he was restless and eager for another position in mathematics. In the winter of 1875 the London newspapers carried news both of the death of the professor of mathematics at the University of Melbourne and of the search for his replacement. Writing to his friend, Arthur Cayley, England’s other most renowned mathematician, Sylvester confessed to being “more than half inclined to go out to the Antipodes rather than remain unemployed ... in England” [4, page 144]. It would have been a very bold move for the sixty-year-old Englishman, but he had a clear sense of life not yet fulfilled.

By the summer of 1875 news of more job openings, this time in America at the newly forming Johns Hopkins University in Baltimore, reached England. Sylvester’s friends both at home and in the United States wrote to the University’s president-designate, Daniel Coit Gilman, with their unanimous recommendation for the professorship of mathematics. Joseph Henry, the first Secretary of the Smithsonian Institution and a friend since Sylvester’s first sojourn in the United States in the 1840s, described Sylvester to Gilman as “one of the
very first living mathematicians", one whose "appointment would give a celebrity to the institution which would at once direct to it the attention of the whole scientific world" [5, page 72]. Like Henry, Benjamin Peirce, the Perkins Professor of Astronomy and Mathematics at Harvard and another longtime friend of Sylvester's, knew that Gilman was in search of proven researchers who would train future researchers and in so doing make a name internationally for the new university. Peirce minced no words in telling Gilman that Sylvester was the mathematician for the job, at the same time that he was not the teacher for the undergraduate classroom. "[A]s the barn yard fowl cannot understand the flight of the eagle," he explained to Gilman, "so it is the eaglet only who will be nourished by his instruction.... Among your pupils, sooner or later, there must be one, who has a genius for geometry. He will be Sylvester's special pupil—the one pupil who will derive from the master, knowledge and enthusiasm—and that one pupil will give more reputation to your institution than the ten thousand, who will complain of the obscurity of Sylvester, and for whom you will provide another class of teachers" [5, pages 73–74].

After personal interviews in London, Gilman had settled on Sylvester as his choice for the professorship of mathematics by the late fall of 1875, but the mathematician played hardball. Writing on 17 December 1875 in response to an official letter from the Hopkins Board of Trustees, Sylvester accepted the University's offer only "if the $5,000 salary therein named be understood to mean gold and if a house and the club fees be attached to [his] appointment" [4, page 150]. Sylvester had been burned financially by the Royal Military Academy, and he was not about to take a financial risk in addition to the risk he would already be taking in making a transatlantic move. After numerous telegrams and letters back and forth across the Atlantic in January and February and after at least one withdrawal of his acceptance of the post, Sylvester and the Hopkins authorities agreed on Sylvester's terms, and the Englishman made a move not to the Antipodes but to Baltimore in the spring of 1876. He was once again gainfully employed, and this time he had the chance, for the first time in his career, to train students at the graduate level.

Sylvester's seven-and-a-half years at Hopkins were a marked success. Nine of the "eaglets" Peirce envisioned completed their doctorates under Sylvester's influence; the American Journal of Mathematics began in 1878 under Sylvester's leadership; Sylvester put Hopkins on the international mathematical map. These successes did not come without their prices, however.

Sylvester could be difficult. In February of 1881, he blew up at his teaching associate and the associate editor of the American Journal, William Story, and in taking the matter to Gilman, blew up in the president's office, too. That fit brought a stern, written rebuke from Gilman. "I have always intended to treat you with the respect due to an honored colleague," Gilman stated, "but I must refuse to be again exposed to such a scene as occurred in my office on Thursday for no business can be transacted wisely when either party is excited" [4, page 199]. Eighteen months later Sylvester was once again displeased, but this time with Gilman's handling of an invitation to Lord Kelvin. In a letter dated 10 August 1882, Sylvester carped about the invitation before dropping a bombshell on the unsuspecting president. "I am wearied and dispirited and feel no longer equal to the discharge of what I consider to be the duties of my office in a manner satisfactory to myself or conducive to the best interests of the University," Sylvester stated. "I write therefore (after much anxious deliberation) to request that you will take the first opportunity to lay my resignation before the Board of Trustees to take effect as soon after the 1st of October next as may be found not too inconvenient" [4, pages 209–210]. Sylvester, debilitated by the heat and humidity and depressed by the fact that he had remained in the United States for the first summer since he had taken the job at Hopkins, had clearly overreacted. Several carefully penned letters from Gilman, who had become Sylvester's personal friend in the years of their professional association, calmed and heartened the mathematician. The crisis was averted.

Not even this brief sketch of Sylvester's association with Hopkins would have been possible without archives. Sylvester, never very organized, made no provisions for his papers at the time of his death. The relatively large collection of his letters that exists at his alma mater, St. John's College, Cambridge, is there only because Cayley was organized, because Susan Cayley, his wife, preserved them after Cayley's death in 1895, and because after her death they fell to the mathematician W. W. Rouse Ball, who saw to their deposition. Without these letters, we would have no hint of the lengths Sylvester considered going to—literally the other side of the globe—in securing another job in academia. If the letters Cayley saved were all that remained, moreover, we would know little of Sylvester's stay in Baltimore beyond the mathematics he worked on while there. Gilman's presidential papers, held at the Johns Hopkins University, contain everything from letters of recommendation like those from Henry and Peirce.
to correspondence to and from individual faculty members like Sylvester to letters of application from potential students and annual reports from graduate students on their progress in their programs. The Sylvester letters there represent a major cache that allow us to flesh out not only Sylvester the professor of mathematics but also to glimpse, in ways not possible through published mathematical papers, Sylvester the man. The picture that emerges is one of a living, breathing individual with strong motivations and feelings, not merely a name attached to four volumes of published mathematical papers and to which amusing anecdotes have been associated. We could not hope to know Sylvester without archives, and, in not knowing him, we would be deprived of one of the most fascinating characters in the history of mathematics.

**Charles Curtis on Representation Theory**

My interest in the history of mathematics was awakened during my collaboration with Irving Reiner when writing our book [2]. While the book was intended to give an introduction to the work of Richard Brauer on modular representation theory of finite groups, we soon discovered that Brauer presupposed familiarity with the work done around the turn of the twentieth century by Ferdinand Georg Frobenius, William Burnside, and Issai Schur. Collected works of these authors were not yet available, and we were forced to explore the archives of libraries to find the volumes of the *Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin* containing Frobenius's great papers of 1896 and 1897 in which he created the theory of characters and representation of finite groups, and subsequent papers by Frobenius and by Schur, along with Burnside's publications in the journals of the London Mathematical Society, which were the starting points of Brauer's work.

In 1990 I was invited to give a joint AMS-MAA lecture at the annual meeting in Louisville, and chose as a topic "Representation Theory of Finite Groups: from Frobenius to Brauer". Following the lecture I was encouraged to write a book on the sub­ject, and the result was [3].

My aim in writing the book was to give an account of the early work on representation theory with enough of the mathematics to enable an interested graduate student or professional mathematician to follow the development and read the proofs of some of the main results in detail. An account of the early history of representation theory had already been published in the *Archive for History of Exact Sciences* by Thomas Hawkins. I realized that I needed to give impressions of Frobenius, Burnside, Schur, and Brauer as persons and how their mathematics fitted into their lives. For this I needed to consult archives containing their personal records, correspondence, etc.

The first item of correspondence available to me that hinted at what might be found in the archives was a letter about Burnside from W. L. Edge at Cambridge to Louis Solomon, which Solomon received in 1979 and kindly made available to me. In it Edge stated that after Burnside was admitted to Cambridge University with an entrance scholarship to St. John's College, he migrated to Pembroke College after a year when he found that the standard of rowing at St. John's was so high that he could not be in the crew of eight who rowed in the first boat. Edge also mentioned some correspondence between Burnside and H. F. Baker that was acquired by the library at St. John's College after Baker's death in 1956.

In the fall of 1992 I visited the Institute for Experimental Mathematics at the University of Essen, and I began my historical research with a visit to archives in Berlin where I hoped to find information about Schur and Frobenius, who had both been professors at the University of Berlin (now Humboldt University) and members of the Academy of Science. Christine Bessenrodt, a member of the Institute, helped arrange a meeting with Hannalore Bernhardt, a historian at Humboldt University, Berlin. She in turn set up appointments for me at the archives of Humboldt University and the archives of the Berlin-Brandenburg Academy of Science (all done at a rather hectic pace, as it turned out that she was leaving the next day to run in the New York Marathon).

At the university archives the personnel records of Frobenius and Schur were available along with a few letters on the non-Aryan Schur reporting to the Reichsminister für Wissenschaft, Erziehung und Volksbildung [minister of science and education] in the Nazi government. For example, one letter stated that Schur had been diagnosed with arterial sclerosis in 1936, while in another, Ludwig Bieberbach, who was then the dean of faculty, reported on Schur's visit to Zürich in February 1936 to give a course on group representations. At the archives of the Academy of Science, I was able to copy handwritten letters of recommendation for Frobenius's admission to the Academy by Weierstrass and Fuchs, and by Fuchs and Helmholtz. These were

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William Burnside

A short time later, with the help of Jan Saxl at Cambridge University, I visited the archives at Pembroke College and St. John’s College, Cambridge, where I had access to correspondence and other documents associated with William Burnside. The correspondence between Burnside and Henry Frederick Baker (1866–1956), who was at the time the correspondence began around 1903 a Fellow at St. John’s College, was particularly interesting as it showed the breadth of Burnside’s mathematical interests. Burnside was professor of mathematics at the Royal Naval College, Greenwich, from 1885 until his retirement. The letters to Baker showed that he was a regular participant in Baker’s geometry seminar, or “tea party”, held at his home every Saturday during term. According to W. V. D. Hodge it “was the prototype of the numerous seminars that are held nowadays, but was for a long time the only one of its kind” in England. Burnside continued until his death in 1927 to correspond with Baker, and the letters, along with occasional telegrams, covered a wide range of topics, from algebraic geometry related to Baker’s seminar to Galois theory and the theory of invariants of finite groups, to which Burnside devoted a chapter of the second edition of his book.

The archives at Pembroke College contained other letters from the Burnside–Baker correspondence, an inventory of Burnside’s collection of mathematics books, some reprints of his papers, and items related to rowing events in which Burnside participated. These showed that Burnside was known for more than his mathematical teaching and research. For example there was a clipping of an obituary of Burnside, from the “Sports Gossip” page of “The Evening News” (London), August 31, 1927, which began, “Rowing men will regret to hear of the death of W. Burnside, one of the best known athletes of his day.” The obituary mentions Burnside’s teaching career at the Royal Naval College, but omits any reference to his mathematical research.

One of the main topics in my book was the historical development of Richard Brauer’s research, beginning with his research on central simple algebras and his collaboration with Emmy Noether and Helmut Hasse. While I was working on this part, I learned from Bhama Srinivasan that a collection of letters and postcards from Emmy Noether to Richard Brauer had been placed in the archives of the Bryn Mawr College Library. I obtained copies of them, and found that although I knew they contained important information about the mathematics I was writing about, I was unable to read the handwriting. Walter Ledermann translated some of the crucial letters containing information about how the collaboration of Brauer, Hasse, and Noether began, and the letters appear in Chapter VI of my book. The letters from Noether to Brauer, and another set of letters from Brauer to Hasse and from Noether to Hasse from the Hasse papers in the Handschriftenabteilung of the Staats- und Universitätsbibliothek Göttingen, are in the process of being transcribed and put on the internet with commentaries by Peter Roquette and Franz Lemmermeyer.

**Steve Batterson on Stephen Smale**

Early in 1956 a University of Michigan graduate student was completing his thesis research and looking for jobs. He approached one of his professors, Raymond Wilder, for a letter of recommendation. Wilder was a good choice. As the current president of the American Mathematical Society, his judgment carried considerable weight. Wilder knew the student well, recognizing him as an underachiever who had recently seemed to catch fire. Wilder composed the following letter for the future Fields Medalist:

Stephen Smale, one of our graduate students, asked me to drop you a note regarding his mathematical promise.

I believe he shows lots of promise. I did not think so, however, until this year. Maybe his getting married was the turning point; for he has been developing very rapidly this year. He has been participating in my seminar, and shows himself very quick to pick up suggestions for investigation, as well as quick to bring in results. Possibly you heard his paper at the recent meeting in New York; this was a result of the seminar, and embodied a homotopy analogue of the Vietoris mapping theorem. He formulated the conditions himself (as well as the proof, of course).

I haven’t the slightest idea of Bott’s opinion of him; as you probably know, he is writing his dissertation under Bott and Bott is at the Institute this year. I assume you will get his independent opinion of Smale. Perhaps Bott does not know Smale’s wife; she is a very charming and capable lady—a professional librarian. She is working in Dearborn—commutes every day—to help out with family expenses. [1, pages 37-38].

Smale immediately exceeded these modest expectations. By the end of the year he obtained his famous result on evertting the sphere. In 1960 Smale established the higher dimensional Poincaré Conjecture and the following summer the
h-Cobordism Theorem. These remarkable papers are available in the Transactions of the American Mathematical Society, the Annals of Mathematics, and the American Journal of Mathematics, respectively. Wilder also published his mathematical results in such traditional outlets. However, it is because Wilder archived his papers that we gain insight into the suddenness of Smale's rise to mathematical prominence. Much of Wilder's correspondence and work are stored among his papers in the Archives of American Mathematics at The Center for American History in Austin.

Wilder's incongruous remarks about Clara Smale are a reminder that his letter must be viewed in the cultural context of a different time. This raises a question as to whether Wilder's assessment has been devalued by years of inflation. Further calibration of Wilder's norms comes from comparing a letter that he wrote at the same time for one of his own students. Wilder enthusiastically predicts a brilliant future and makes a comparison to Norman Steenrod. Even with allowances for possible favoritism toward his progeny, it is clear that Wilder had no clue as to Smale's true talent. Wilder was not the only one who underestimated Smale. Recollections of other department members are more or less consistent with the appraisal in the letter above. However, contemporaneous writings, when available, provide a stark authenticity.

Other perspectives of Smale's college days are found in the University of Michigan archives located in the Bentley Historical Library on the Ann Arbor campus. Smale was among a handful of students who were prominent in left-wing political groups. During these McCarthy-era years, University administrators closely scrutinized gatherings of such bodies, fearful that their beliefs might become popular with impressionable students. When Smale attended a dinner with an unauthorized, controversial speaker, he and the other participants were charged with disciplinary violations. The Michigan archives contain transcripts of Smale's interrogation at the ensuing hearings. His uncooperative testimony reveals a young man who could not be intimidated to betray his principles.

In another document the dean of women offers her analysis of six leading campus radicals. Dean Bacon reviews personal and intellectual characteristics of the students and then speculates on the threat each poses to subverting peers. There was no concern about Smale. In this case it was Smale's leadership potential that was being sold short. One decade later he would collaborate with Jerry Rubin to launch a historic campaign of civil disobedience against the Vietnam War.

These testimonies demonstrate the role of archives in lending perspective on the development of mathematics and of mathematicians. The success of this process depends on three factors. Individuals and institutions must make a long-term investment by supplying the materials they control, repositories require support to maintain these records, and scholars must avail themselves of the opportunities that are afforded.

It is impossible to foresee what current materials will have importance one hundred years from now. Regrettably, it will then be too late to resurrect items that are being discarded today. Please consider whether you or your department have papers that should be available in perpetuity. Pointers on how to proceed can be found at http://www.ams.org/mathweb/history/donors.html. Moreover, the nature of materials and storage is changing as electronic means become prevalent. The sidebar by Albert Lewis on the next page offers an update on these issues.

A list of archival collections, ordered by mathematician, is maintained by the AMS-MAA Joint Archives Committee and is available on the Web at http://www.ams.org/mathweb/history/collections.html. The committee encourages use of these resources. Since mathematicians are unlikely to be familiar with the workings of the library subculture associated with archives, the guide on page 1415 is designed to enhance the experience.

References
Preserving the Electronic Record

The archives committee has sometimes been asked, How do you propose to encourage the preservation of the historical record in the face of the rapidly increasing use of electronic communication? A similar question probably arose for archivists and historians when use of the telephone became widespread, at least for business use, in the 1920s. In some ways the telephone presented more of a challenge, since at the time there was no widely available means of recording those conversations that the participants may have wished to preserve. Today it is possible, at least in principle, to automatically record all electronic, digitized communications. However, just as with an electro-magnetic recording that might have been made in the 1920s, this does not ensure the long-term preservation of the record. For one thing, the physical medium deteriorates; the lifespan of present-day optical media, such as CDs, can range from 15 to 200 years, for example. This can be overcome by a program of transferring to new media. An even more significant factor working against preservation is the obsolescence of the encoding protocol and of the software and hardware used to create and make use of the original documents, images, databases, and so forth. The computer landscape of the past forty years is heavily littered with machines, programming languages, software, and their output that have been rendered unusable in the wake of advancement. Solutions to this problem are being investigated, including the feasibility of preserving, in effect, the software and hardware itself through emulation.

As the reliance on centralized electronic resources increases, new problems arise that go beyond the traditional preservation issues. The very advantages of accessibility and modifiability that the electronic age has brought to the realm of documents also opens up the possibility of changing what we normally think of as the historical past. The recent case of the publisher Elsevier removing, without notice, entire journal articles from their electronic database of published journals is an example. The protest over this particular incident led to changes in Elsevier’s policy (“Elsevier Announces New Procedures for Retracting Online Articles”, The Chronicle of Higher Education: Information Technology, February 28, 2003, Volume 49, Issue 25, Page A35), but, as libraries move away from paper and subscribe only to such electronic repositories for their journals, this raises the larger question of what constitutes the historical record which publication in multiple paper copies traditionally provided. Again, we understand that means are being investigated of ensuring the long-term integrity of these types of community records.

Closer to home, the AMS has had a records management policy in place for some years that provides guidelines for its administrative offices with respect to record retention and archival transfer. It is mainly directed at paper records and may need to be updated with respect to new media, but it has proven to be an effective program. Much if not most of the Society’s official records (agendas and minutes of committees, for example) still appears to be in paper form, even if often in parallel with electronic propagation. The AMS as a whole, however, continues to computerize more of its operations, especially within its publications division and particularly in the production of journals—from article submissions and refereeing, to publication. Special policies are in place for the archiving of AMS electronic products, and there are procedures for maintaining their historical integrity. Evidently a movement is beginning that could eventually see the digitizing of the whole of the mathematical literature, past and future. (John Ewing, “Twenty Centuries of Mathematics: Digitizing and Disseminating the Past Mathematical Literature”, Notices 49 (2002), 771–777.)

In the face of such changes and unsolved problems, the best advice the committee feels it can give to individuals and institutions at this point is threelfold:

1) Retain electronic copies of at least those documents (including emails) that would be retained were the documents in paper form only, including significant drafts. The fact that electronic copies take up less room may invite saving more documents than otherwise might be saved, and this certainly does not hurt.

2) Develop a personal or institutional records management plan, however modest. For example, try to have more than one archival copy stored separately from ongoing work, and move it to new media as new storage devices are acquired.

3) For the most important documents, consider keeping a paper copy as well—still the most reliable form of document preservation.

This leaves much to be done by repositories which may eventually receive this material. Even without the special task of maintaining electronic records, it is no small undertaking for a research library to acquire, process, and store traditional paper archives and to make them available to users. The whole of the mathematical community will benefit as new ways are found to meet the new needs.

—Albert Lewis
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A User's Guide for a First Visit to an Archive

Collections are normally organized into acid-free folders that are placed in numbered boxes. The most important terminology is finding aid, the index to a collection. The detail in finding aids varies substantially. In seeking a particular item, say a letter to a known correspondent, consulting the finding aid should narrow the search to a specified box, or boxes. It is always desirable to view the finding aid prior to the actual visit. Some finding aids are easily obtained on the Web. For example, the finding aid URL for John von Neumann's papers at the Library of Congress is http://lcweb2.loc.gov/cgi-bin/query/r?faid/field(DOCID+ms996003). If the finding aid is available only at the site or a more detailed version is in existence there, the reference staff may be willing to mail a copy upon request.

Much can be gained with an advance phone call. For example, some materials may be stored at a different site. Making a request for retrieval prior to the visit can avoid a frustrating delay. Even if an online finding aid states that papers are available onsite, it is a good idea to confirm that the information is current. Some collections may restrict access or require advance permission.

Upon arrival at the archive, the first step is to register and to receive indoctrination on the local rules. There are likely to be restrictions on what possessions are permitted in the study area. Writing implements other than pencils are normally forbidden. When these preliminaries are completed, requested materials become available for viewing. Expect surprises, both interesting and mundane.

Duplication procedures and costs should be explored early in the visit. If self-copying is permitted, it may be necessary to obtain a card elsewhere. Check out the machines and assess their availability. Sometimes the facilities are inadequate and competition leads to lines. Under such circumstances it is a good idea to formulate a strategy on when to copy. Many archives require that the duplication be performed by members of their staff. These policies are motivated by security concerns. Costs for these services vary, but are often on the order of 25 cents per page. If the number of copies is small and the job is requested well before closing time, it may be completed on the same day. Typically it is mailed a week or so later. Each archive has its own procedures for researchers to indicate which records are to be duplicated.

Publishing a quotation from an archival record is likely to require additional permission. This issue should be discussed with the reference staff, and the appropriate citation should be ascertained. It is advisable to identify a knowledgeable staff member with whom to maintain communication. Archives tend to attract long-term personnel who are dedicated to connecting scholars with the material they are seeking. Sometimes researchers assume items do not exist when actually they are stored under an unfamiliar heading or in a different collection. An experienced staff member can be a valuable resource in suggesting additional stones to overturn. Finally, it is possible to return from a visit and realize that one or two additional records are needed. Obtaining help electronically or over the phone goes more smoothly if a relationship has already been established.

—Steve Batterson
Andy Magid Appointed 
Notices Editor

Andy Magid of the University of Oklahoma will begin a three-year term as editor of the Notices, starting with the January 2004 issue. He succeeds Harold P. Boas of Texas A&M University, who has been editor since January 2001.

Magid did his undergraduate work at the University of California, Berkeley, and received his Ph.D. from Northwestern University in 1969 under the direction of Daniel Zelinsky. After a three-year term as a Ritt Instructor at Columbia University, he went in 1972 to the University of Oklahoma, where he has remained ever since.

Magid has a broad spectrum of research interests. The areas he has worked in include the Galois theory of commutative rings, differential Galois theory, algebraic and proalgebraic groups, and representation theory of discrete groups. The representation varieties and character varieties of discrete groups play an important role in geometry and topology. He is an author of five books: three research books reflecting his areas of interest, a textbook in linear algebra with a special emphasis on computer applications, and a book on mathematics education. In addition, he edited four volumes of conference proceedings.

Magid has had a long association with the AMS, beginning with his election in 1988 as associate secretary for the Central Section. He served in that capacity for eight years and built a strong tradition for Central Section meetings. He also helped to organize four AMS Annual Meetings. In 1997, he was elected as a member of the AMS Board of Trustees and served a five-year term.

In 1995, when the Notices was redesigned and Hugo Rossi of the University of Utah was appointed editor, Magid became a member of the Editorial Board and has remained on the board ever since. He and Susan Friedlander of the University of Illinois at Chicago are the two longest-serving board members. In addition, Magid served as acting editor of the Notices for a period in 1997, between the time when Rossi stepped down and the next editor, Anthony W. Knapp of the State University of New York at Stony Brook, took over. Magid's editing experience includes a two-year stint as book reviews editor for the Bulletin and service on the editorial board for the book series Contemporary Mathematics.

Much of Magid's work on AMS meetings and publications has dealt with making exposition about mathematics available to a wide audience. “The AMS makes mathematics accessible to mathematicians, wherever they happen to be based, and whatever their background is,” Magid remarked. He intends to continue the tradition of publishing high-quality mathematics exposition in the Notices. “One thing that is needed are expository articles that can be consumed in a short period of time, so you can learn something about what's going on in...
an area in an hour's worth of reading," he said. "Those articles are the hardest, of course, to write." He also plans to seek articles that describe interesting applications of mathematics—applications to other disciplines, or applications of one area of mathematics to another. Such articles "are fun to read and useful," he noted.

Magid pointed out that there are various occasions on which a Notices mathematics article might be written. "If you hear or give a good colloquium talk, write it up for the Notices, or ask the speaker to write it up," he suggested. "It should be shared." Magid also encourages those who have just finished writing a book to consider writing an expository article for the Notices on the topic of the book. "Many intellectual magazines publish such articles on topics of upcoming books," he said. "It's perfectly appropriate for mathematics to do this as well."

Magid envisions having in the Notices an occasional series of reminiscences by mathematicians about aspects of the mathematical life. This might be a brief description about how an important result came into being, how a well-known paper came to be written, or anecdotes about colleagues. Noting that his service on the Board of Trustees made him aware of many developments within the AMS that affect mathematics and mathematicians, Magid said he hopes to increase coverage of such developments "so that the broad spectrum of Society members is aware of the issues being brought to the leadership."

One of the distinctive features of Notices articles is the amount of editing and polishing they receive, which goes quite a bit beyond what one finds in an average mathematics journal. In this regard, Magid credits the work of the Notices Editorial Board. "The contributions of the board members in reading articles and making suggestions for changes improves the articles greatly," he said. "The Editorial Board also makes a big contribution in recruiting authors to write."

Magid said that he does not plan to introduce any major changes in the Notices. "It will be an evolution," he said. "I think the Society did the right thing in enhancing the Notices, and my predecessors have all made heroic efforts to make it a success. I want to follow in their footsteps to maintain the readability, quality, and usefulness of the Notices. At the same time, I hope to institutionalize some things in order to demonstrate that you don't have to be a hero to be the Notices editor."

—Allyn Jackson

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### The Honors Class: Hilbert's Problems and Their Solvers

Ben Yandell

2003; 496 pp.;

ISBN 1-56881-216-7

Paperback; $19.95

-- Allyn Jackson

### DECEMBER 2003 NOTICES OF THE AMS
Each year, the American Astronomical Society (AAS), the AMS, and the American Physical Society (APS) present Public Service Awards to individuals who have performed outstanding public service in support of science.

The 2003 recipients are Congressmen Sherwood L. Boehlert, Congressman Alan B. Mollohan, and Senator Pete V. Domenici.

Boehlert (R-NY) is chairman of the House Science Committee. Mollohan (D-WV) is ranking member of the House Appropriations Subcommittee on Veterans' Affairs, Housing and Urban Development, and Independent Agencies; this subcommittee oversees appropriations for the National Science Foundation. Domenici (R-NM) is chairman of the Senate Energy and Natural Resources Committee and of the Senate Appropriations Subcommittee on Energy and Water. All have been consistent supporters of science and advocates for strong federal funding for research.

Boehlert and Mollohan attended the July 23, 2003, reception on Capitol Hill during which the awards were given. AMS past-president Arthur Jaffe of Harvard University presented the awards.

Previous recipients of the AAS-AMS-APS Public Service Award are Harold Varmus, Senator Bill Frist, and Senator Joseph Lieberman (2000); Neal F. Lane and Congressman Vernon J. Ehlers (2001); Congressman James Walsh and Senator Barbara Mikulski (2002).
Ball Awarded Crighton Medal

JOHN BALL, Sedleian Professor of Natural Philosophy at the University of Oxford, is the first recipient of the David Crighton Medal, awarded jointly by the Institute of Mathematics and its Applications (IMA) in Essex, United Kingdom, and the London Mathematical Society (LMS). Ball's research focuses on the calculus of variations and its applications to solid mechanics using the knowledge and techniques of mathematical analysis and algebra. He is currently president of the International Mathematical Union.

The Crighton Medal was instituted in 2002 in memory of David George Crighton. The award will be given every three years to a mathematician who has shown outstanding service both to mathematics and to the mathematical community.

—From an LMS announcement

National Science Award of Singapore

HARALD NIEDERREITER, LING SAN, and XING CHAOPING have received one of two National Science Awards of Singapore. The award recognizes research scientists and engineers in Singapore who have made outstanding contributions in basic research leading to the discovery of new knowledge or the pioneering development of scientific or engineering techniques and methods. Award recipients receive a crystal trophy, a citation, and a prize of 15,000 Singapore dollars (approximately US$8,700). The awards were presented in September 2003.

Niederreiter, San, and Chaoping are in the Department of Mathematics at the National University of Singapore. They were cited for “their outstanding contribution to the application of algebra, algebraic curves and number theory in coding, cryptography, nets and low-discrepancy sequences.”

The other award went to two researchers at the National University of Singapore who are investigating chemical reaction dynamics.

The award is given by A*STAR, the Agency for Science, Technology, and Research. The Science and Engineering Research Council, which oversees public sector research and development activities in Singapore, is part of A*STAR.

—Allyn Jackson

National Defense Science and Engineering Graduate Fellowships Awarded

Nine young mathematicians have been awarded National Defense Science and Engineering Graduate (NDSEG) Fellowships by the Department of Defense (DoD). As a means of increasing the number of U.S. citizens trained in disciplines of military importance in science and engineering, DoD awards fellowships to individuals who have demonstrated ability and special aptitude for advanced training in science and engineering. The fellowships are awarded for a period of three years for study and research leading to doctoral degrees in mathematical, physical, biological, ocean, and engineering sciences. The fellowships are sponsored by the United States Army, Navy, and Air Force.

Following are the names of the fellows in mathematics and the offices that awarded the fellowships. SAMUEL EHRLICHMAN, Army Research Office (ARO); NATHAN GEORGE, Air Force Office of Scientific Research (AFOSR); KATHLEEN GRUHER, AFOSR; BRUCE JOHNSON, AFOSR; SHILPA KHATRI, AFOSR; CHENG LY, ARO; JEREMY ROUSE, Office of Naval Research (ONR); NITIN SAKSENA, ARO; and CAMILLA SMITH, ONR.

—From an NDSEG announcement
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Mathematics Opportunities

NSF Integrative Graduate Education and Research Training

The Integrative Graduate Education and Research Training (IGERT) program was initiated by the National Science Foundation (NSF) to meet the challenges of educating Ph.D. scientists and engineers with the interdisciplinary backgrounds and the technical, professional, and personal skills needed for the career demands of the future. The program is intended to catalyze a cultural change in graduate education for students, faculty, and universities by establishing innovative models for graduate education in a fertile environment for collaborative research that transcends traditional disciplinary boundaries. It is also intended to facilitate greater diversity in student participation and to contribute to the development of a diverse, globally aware science and engineering workforce. Supported projects must be based on a multidisciplinary research theme and administered by a diverse group of investigators from U.S. Ph.D.-granting institutions with appropriate research and teaching interests and expertise.

The preproposal deadline for the next IGERT competition is anticipated to be in January 2004. Further information may be found at the website http://www.nsf.gov/home/crssprgm/igert/start.htm.

—From an NSF announcement

NRC Research Associateship Programs

The Policy and Global Affairs Division of the National Research Council (NRC) is sponsoring the 2004 Postdoctoral and Senior Research Associateship Programs. The programs are meant to provide opportunities for Ph.D., Sc.D., or M.D. scientists and engineers of unusual promise and ability to perform research at one of more than 100 research laboratories throughout the United States and overseas.

Full-time associateships will be awarded for research in the fields of mathematics, chemistry, earth and atmospheric sciences, engineering, applied sciences and computer science, life and medical sciences, space and planetary sciences, and physics. Most of the laboratories are open to both U.S. and non-U.S. nationals and to both recent doctoral recipients and senior investigators.

Awards are made for one or two years, renewable for a maximum of three years. Annual stipends for recent Ph.D. recipients range from $30,000 to $50,000, depending on the sponsoring laboratory; the awards for senior recipients will be higher. Support is also provided for allowable relocation expenses and for limited professional travel during the period of the award.

Awards will be made three times during the year, and applications will be accepted on a continuous basis. The deadlines for application materials to be postmarked, or for electronic submissions, are February 1, May 1, and August 1, 2004. For further information and application materials, see the NRC website at http://www4.nationalacademies.org/pga/rap.nsf, or contact Research Associateship Programs, Keck Center of the National Academies, 500 Fifth Street, NW, GR322A, Washington, DC 20001; telephone 202-334-2760; fax 202-334-2759; email: rap@nas.edu.

—From an NRC announcement

National Defense Science and Engineering Graduate Fellowships

As a means of increasing the number of U.S. citizens trained in disciplines of military importance in science and engineering, the Department of Defense (DoD) awards
National Defense Science and Engineering Graduate (NDSEG) Fellowships each year to individuals who have demonstrated ability and special aptitude for advanced training in science and engineering. The fellowships are awarded for a period of three years for study and research leading to doctoral degrees in mathematical, physical, biological, ocean, and engineering sciences. The number of fellowships awarded depends on available funding.

The NDSEG Fellowship Program is open only to applicants who are citizens or nationals of the United States. NDSEG Fellowships are intended for students at or near the beginning of their graduate studies in science or engineering. Applicants must have received or be on track to receive their bachelor's degrees by fall of 2004. Applications are encouraged from women, persons with disabilities, and minorities, including members of ethnic minority groups such as African American, American Indian and Alaska Native, Asian, Native Hawaiian and other Pacific Islander, Hispanic, or Latino.

The deadline for submitting a complete application is January 9, 2004. Application materials are available from, and completed applications should be returned to, the American Society for Engineering Education (ASEE) at NDSEG Fellowship Program, c/o American Society for Engineering Education, 1818 N Street, N.W. #600, Washington, DC 20036; telephone 202-331-3516; fax 202-265-8504; email: ndseg@asee.org. For further information, see the website http://www.asee.org/ndseg/preface.cfm.

—From an NDSEG announcement

NRC-Ford Foundation Fellowships for Minorities

The National Research Council (NRC) administers the Ford Foundation Fellowships for Minorities program. This program offers predoctoral fellowships, dissertation fellowships, and postdoctoral fellowships. Eligible applicants must be U.S. citizens or nationals who are members of one of the following groups: Black/African American, Alaskan Native (Eskimo or Aleut), Mexican American/Chicano, Native American, Native Pacific Islander (Polynesian, Micronesian), or Puerto Rican.

The Predoctoral Fellowship Program offers support for three years in research-based programs in social and behavioral sciences, humanities, physical and biological sciences, engineering, and mathematics, or for interdisciplinary programs comprising two or more eligible disciplines leading to the Ph.D. or Sc.D. The annual stipend is $17,000, and there is an additional cost-of-education allowance of $6,000. The deadline to apply is November 19, 2003.

The Dissertation Fellowship is intended for the final year of dissertation writing. The stipend is $21,000. The application deadline is December 3, 2003.

The Postdoctoral Fellowship offers one year of postdoctoral support for individuals who have received their Ph.D.'s no earlier than January 1996 and no later than January 17, 2004. The stipend is $40,000, with an employing institution allowance of $1,500. The application deadline is December 17, 2003.

Applicants are encouraged to apply online at http://www7.nationalacademies.org/fellowships/applyonline.html. The postal address is: Fellowship Office, GR 346A, National Research Council of the National Academies, 550 Fifth Street, NW, Washington, DC 20001. The telephone number is 202-334-2872. The email address is infofell@nas.edu.

—From an NRC announcement

EDGE Summer Program

Funded by the National Science Foundation and the Andrew W. Mellon Foundation, the Enhancing Diversity in Graduate Education (EDGE) Program, a postbaccalaureate summer enrichment program, is designed to strengthen the ability of women and minority students to successfully complete graduate programs in the mathematical sciences.

The summer program consists of two core courses in analysis and algebra/linear algebra. There will also be minicourses in vital areas of mathematical research in pure and applied mathematics, short-term visitors from academia and industry, guest lectures, graduate student mentors, and problem sessions. In addition, a follow-up mentoring program and support network will be established with the participants' respective graduate programs.

Applicants to the program should be women who are (1) graduating seniors who have applied to graduate programs in the mathematical sciences, (2) recent recipients of undergraduate degrees who are now entering graduate programs, or (3) first-year graduate students. All applicants should have completed standard junior-senior level undergraduate courses in analysis and abstract algebra and have a desire to earn the doctorate degree. Women from minority groups who fit one of the above three categories are especially encouraged to apply. Final acceptance to the program is contingent on acceptance to a graduate program in the mathematical sciences.

In 2004, the program will be held at Spelman College in Atlanta, Georgia. The dates for the summer program are June 7–July 2, 2004. It will be codirected by Sylvia Bozeman (Spelman College), Rhonda Hughes (Bryn Mawr College), and local coordinator Yewande Olubummo (Spelman College). A stipend of $2,000 plus room and board will be awarded to participants. Names of applicants chosen to participate in the program will be announced by April 15, 2004.

The application deadline is March 4, 2004. Applications should be sent to: EDGE Program, Department of Mathematics, Bryn Mawr College, 101 North Merion Avenue, Bryn Mawr, PA 19010. For more information, visit the program's website at http://www.edgeforwomen.org/index.html.

—EDGE Program announcement
Call for Nominations for Waterman Award

Congress established the Alan T. Waterman Award in August 1975 to mark the twenty-fifth anniversary of the National Science Foundation (NSF) and to honor its first director. The annual award recognizes an outstanding young researcher in any field of science or engineering supported by the NSF. In addition to a medal, the awardee receives a grant of $500,000 over a three-year period for scientific research or advanced study in the mathematical, physical, medical, biological, engineering, social, or other sciences at the institution of the recipient's choice.

Candidates must be U.S. citizens or permanent residents and must be thirty-five years of age or younger or not more than seven years beyond receipt of the Ph.D. degree by December 31 of the year in which they are nominated. Candidates should have demonstrated exceptional individual achievements in scientific or engineering research of sufficient quality to place them at the forefront of their peers. Criteria include originality, innovation, and significant impact on the field. Nominations for the award and supporting references must be postmarked by December 31, 2003. For more detailed information concerning the nomination procedures, see the NSF website: http://www.fastlane.nsf.gov/fastlane.jsp.

—From an NSF announcement

News from the Fields Institute

The Fields Institute for Research in the Mathematical Sciences thematic program for 2003–2004 is on the topic of partial differential equations and focuses principally on problems that stem from questions in applied mathematics and in mathematical physics. The subject matter is chosen from active topics of research that are of particular current interest.

The winter 2004 semester will focus on Hamiltonian partial differential equations, in particular hyperbolic equations and nonlinear dispersive evolution equations that arise in mathematical physics and in continuum mechanics, and on the equations of kinetic theory that arise in the study of statistical mechanics and of wave turbulence. A list of activities and dates for the winter and spring programs follows.


June 1–11, 2004: Workshop on Semiclassical Analysis (joint with the CRM).


For more information, including funding opportunities from the Fields Institute and the National Science Foundation, see the website http://www.fields.utoronto.ca/programs/scientific/03-04/pde/.

The Fields Institute invites applications for postdoctoral fellowship positions at the institute for the 2004–2005 academic year, during the Thematic Program on the Geometry of String Theory. These fellowships provide an opportunity to spend at least one year engaged in research and participating in the research activities of the institute. Applications for the Program on String Theory should be received by January 2, 2004. Applicants seeking postdoctoral fellowships funded by other agencies (such as NSERC and international fellowships) should request the Fields Institute as their proposed location of tenure and should apply to the Fields Institute for a letter of invitation. For further information, see http://www.fields.utoronto.ca/programs/scientific/04-05/string-theory/.

—From a Fields Institute announcement

News from the Institut Mittag-Leffler

The Institut Mittag-Leffler, Djursholm, Sweden, has announced its program for the academic year 2004–2005. The fall term will be devoted to queuing theory and teletraffic theory. The organizing committee consists of S. Asmussen, Aarhus; I. Kaj (Chair), Uppsala; G. Karlsson, Stockholm; and J. Virtamo, Helsinki. The spring term will be devoted to algebraic combinatorics. The organizing committee consists of A. Björner (Chair), Stockholm, and R. Stanley, MIT.

The application deadline for postdoctoral fellowships is January 31, 2004. Applications should be sent to
Mathematics Opportunities

Marie-Louise Koskull, Institut Mittag-Leffler, Auravägen 17, SE-182 60 Djursholm, Sweden; email: koskull@rnl.kva.se. For further information see the institute’s website, http://www.m1.kva.se.

—Institut Mittag-Leffler announcement

News from the IMA

The theme of the current academic year at the Institute for Mathematics and its Applications (IMA), in Minneapolis, Minnesota, is “Probability and Statistics in Complex Systems” (http://www.ima.umn.edu/complex/). The program addresses systems with a very large number of interacting parts in which the interactions are nonlinear in the sense that the behavior of the system cannot be predicted simply by understanding the behavior of the component parts. The mathematical and statistical foundations of this program include stochastic modeling and simulation and analysis of massive data sets, as well as dynamical systems, network and graph theory, optimization, control, design of computer and physical experiments, and statistical visualization.

The fall quarter has been devoted to genomics.

The winter quarter will be devoted to communications networks and related models for power systems. The problems associated with designing, engineering, and managing such rapidly evolving systems have shaped much of networking research in the past and are likely to play an even more important role in the future as the scale of the problems addressed extends well beyond what has previously been considered.

The winter program will begin with a short course on “The Internet for Mathematicians” (January 7-9, 2004). Steven H. Strogatz will open the program with a public lecture titled “Sync: The Emerging Science of Spontaneous Order”. The course is immediately followed by a one-day tutorial “Measurement, Modeling and Analysis of the Internet” (January 11, 2004) and then by a workshop “Measurement, Modeling and Analysis of the Internet” (January 12-16, 2004). The winter quarter will include two other workshops, “Robustness in Complex Systems” (February 9-13, 2004) and “Control and Pricing in Communication and Power Networks” (March 8-13, 2004). Each workshop is preceded by a one-day tutorial.


To request an invitation for one of the workshops, tutorials, or short courses, point to http://www.ima.umn.edu/docs/reg_form1.html.

The theme of the 2004–2005 program is “Mathematics of Materials and Macromolecules: Multiple Scales, Disorder, and Singularities” (http://www.ima.umn.edu/matter/). Opportunities for participation include postdoctoral positions, long term visits by senior mathematicians, and the “New Directions” program. This latter program, recently funded by the National Science Foundation, is aimed at established, mid-career mathematicians interested in expanding their research programs in new, interdisciplinary directions. All of these opportunities are described at http://www.ima.umn.edu/docs/membership.html. Online application forms can be found there.

As another aspect of the new “New Directions” program, in June 2004 the IMA will host a two-week intensive short course to provide mathematicians with the basic knowledge prerequisite in computational topology. The lecturers are Herbert Edelsbrunner and John Harer, both of Duke University. For more information, see http://www.ima.umn.edu/new-directions/2004NDcourse.html.

For further information, write to staff@ima.umn.edu.

—IMA Announcement

ANNOUNCEMENT

CANADIAN NUMBER THEORY ASSOCIATION VIII MEETING
Plenary Lectures, Special Sessions and Contributed Talks
June 20–25, 2004
University of Toronto

Supported by The Fields Institute and ICORE
For more information see:
www.fields.utoronto.ca/programs/scientific/03-04/CNTAS/

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For Your Information

IMU Email Newsletter Launched

The International Mathematical Union (IMU) has launched a bimonthly email newsletter entitled IMU-Net.

The newsletter aims to improve communication between the IMU and the worldwide mathematical community by reporting decisions and recommendations of the IMU and by highlighting issues under discussion. In addition, IMU-Net will report on major international mathematical events and developments and on other topics of general mathematical interest. The editor of IMU-Net is Mireille Chaleyat-Maurel of the Université René Descartes in Paris.

There are two ways to subscribe to IMU-Net. One way is to go to http://www.mathunion.org/IMU-Net and click the “Subscribe” button. The other way is to send an email to imu-net-request@mathunion.org with the subject-line: “subscribe”.

—From an IMU announcement

Report on Large-Scale Simulation

In August 2003 in Arlington, Virginia, the Office of Science of the Department of Energy (DOE) issued a report, A Science-Based Case for Large-Scale Simulation, informally called SCAleS. This report makes recommendations for investments by the DOE in various research areas, including the mathematical sciences, that support large-scale simulations.

The executive summary of the report states: “The ingredients required for success in advancing scientific discovery are insights, models, and applications from scientists; theory, methods, and algorithms from mathematicians; and software and hardware infrastructure from computer scientists.” One of the chapters of the report, “Enabling Mathematics and Computer Science Tools”, describes some of the mathematical tools used in large-scale simulations.

The SCAleS report makes recommendations for increased investment by the DOE in all aspects of large-scale simulations used in research in science and engineering, including algorithm research and other mathematical topics. The report recommends new investments to combine the power of scientific modeling, mathematical algorithms, computer architecture, and software development. Multidisciplinary teams, including mathematical scientists, are needed to bring the full capacity of computing power to bear on outstanding scientific problems, the report states.

Volume 1 of the SCAleS report is on the Web at http://www.pnl.gov/scales/; when ready, Volume 2 will also be posted at this site. Further information may be found in an article by one of the editors of the SCAleS report, David Keyes of Columbia University, which appeared in the September 2003 issue of SIAM News.

—Allyn Jackson
Inside the AMS

AMS Washington Events Showcase Mathematics

CNSF Exhibition
Kenneth M. Golden, University of Utah, was the AMS exhibitor in the ninth annual exhibition of the Coalition for National Science Funding (CNSF), held June 17, 2003. Golden presented a lively exhibit on “Mathematics of Sea Ice”, with videos of his expeditions to the Antarctic and the Arctic, and attracted a constant stream of Congressional staff and Members of Congress during the reception. The exhibition, held in the Rayburn Office Building on Capitol Hill in Washington, D.C., drew a record attendance of over 300 visitors, including Rita Colwell, director of the National Science Foundation.

The CNSF is an alliance of over ninety scientific and professional societies and universities that have banded together with the goal of increasing the budget of the National Science Foundation (NSF). The purpose of the CNSF exhibition is to provide a forum where Congressional representatives and their staffs can learn about scientific and engineering research being funded by the NSF. Samuel M. Rankin III, director of the AMS Washington Office, is the chair of the CNSF, and this year’s exhibition and reception were organized by AMS staff.

Thirty-one organizations and universities set up display booths and brought in scientists and engineers to talk about their work. The informal setting provided plenty of opportunity for one-on-one contact.

AMS Congressional Lunch Briefing
"Mathematics is biology’s next microscope, only better; biology is mathematics’ next physics, only better" was the provocative title of the July 10, 2003, AMS Congressional Lunch Briefing on Capitol Hill, given by Joel E. Cohen (Laboratory of Populations, Rockefeller and Columbia Universities). Cohen drew a capacity crowd for this, the seventh in the series of annual mathematics briefings for members of Congress and congressional staff members. This year’s briefing was cosponsored by Congressman Vernon Ehlers (R-MI). Jane M. Hawkins (University of North Carolina, Chapel Hill), incoming chair of the AMS Committee on Science Policy, welcomed guests on behalf of the AMS.

The abstract of Cohen’s talk reads: “In the late 17th century, microscopes caused a revolution in biology by revealing otherwise invisible worlds that were previously unsuspected. Mathematics (broadly interpreted) can reveal otherwise invisible worlds in all kinds of biological data, not only optical. In the past, physical problems stimulated enormous advances in mathematics, such as geometry and calculus. Biology can stimulate the creation of new realms of mathematics. We will survey the past, present and future of interactions between biology and mathematics."

— Monica Foulkes, AMS Washington Office

Fan China Exchange Program
The Society’s Fan China Exchange program awards grants to support collaborations between Chinese and U.S./Canadian researchers. The funds are made possible through a generous gift made in 1999 to the AMS by Ky and Yu-Fen Fan.

The October 2003 issue of the Notices carried the names of the 2003 Fan Exchange awardees. Since that announcement appeared, one more award for 2003 has been made. Jiping Zhang of the School of Mathematical Sciences at Peking University received an award for a two-week visit by Luis Caffarelli of the University of Texas at Austin.

— Allyn Jackson

AMS Launches New Members-Only Email Service
In September 2003, the AMS launched a new members-only email service called Headlines & Deadlines. Subscribers to Headlines & Deadlines will receive twice-a-month emails containing news, announcements about events, calls for
proposals, and alerts about upcoming deadlines for fellowship and grant applications and meetings registration. Headlines & Deadlines will also notify members about the Web posting of new issues of Notices and of the monthly AMS website feature “What's New in Mathematics.”

Members can sign up for Headlines & Deadlines at http://www.ams.org/enews.

—Allyn Jackson

Monica Foulkes Retires

Monica Foulkes, a longtime AMS employee who spent the past decade working at the AMS Washington Office, retired in September 2003. She wore several hats during her time with the AMS, and many members and staff came to appreciate her conscientiousness, efficiency, and intelligence.

Monica started at the AMS in 1986 as an assistant to associate executive director James Maxwell. One of her major tasks was working on the Annual Survey, whose completeness, reliability, and accuracy is due in no small part to her attention to detail. Just around the time that young mathematicians began to have trouble on the job market, Monica was working with the Joint Committee on Employment Opportunities and assisting with the Employment Register, where her cheerful competence soothed tensions of jobseekers and employers alike. In 1991 and 1992, she spent a good deal of time working with the Task Force on Employment. For a number of years she prepared the proposals for the National Science Foundation grants for the AMS conference series.

In 1992, when the AMS opened its Washington Office, Monica took the job as assistant to the director of the office. During her years in Washington, Monica developed a keen sense of how that complex city operates. She played a vital role in coalition activities, especially with the Coalition for National Science Funding (CNSF). Other societies in Washington came to depend on Monica’s help, whether it be for scheduling, providing mail lists, information, or other logistical help. That she will be missed by these societies was evident when representatives of several of these societies attended her recent retirement reception held in the AMS Washington Office.

“I will miss Monica very much when she retires,” remarked Samuel M. Rankin III, the current director of the Washington Office. “We have developed into a great team and, I believe, established a vital D.C. office for the AMS. Monica knows the ins and outs of Washington and how to get things done here. She has been an excellent resource for me and has provided me with the core support necessary to be successful in D.C. I have come to depend on her judgment and savvy.”

In everything she did, in every new challenge she mastered, Monica brought a deep sense of responsibility. She took her work seriously—but not too seriously, as those who know her sense of humor can attest. She will be greatly missed by staff and members alike.

—Allyn Jackson

Deaths of AMS Members

ARMAND BOREL, of the Institute for Advanced Study, NJ, died on August 11, 2003. He was a member of the Society for 50 years.

EVELYN HULL BOYLE, of Rye, NY, died on April 28, 2003. She was a member of the Society for 68 years.

JOAQUIN BUSTOZ, of Arizona State University, died on August 13, 2003. He was a member of the Society for 37 years.

JAMES P. CRAWFORD, of Lafayette College, PA, died on May 8, 2003. He was a member of the Society for 39 years.

HUBERT DELANGE, of Bures-sur-Yvette, France, died on July 25, 2003. He was a member of the Society for 56 years.

MATTES R. ESSEN, retired from Uppsala University, Sweden, died on May 10, 2003. He was a member of the Society for 35 years.

DAVID M. KRABILL, of Toledo, OH, died on June 23, 2003. He was a member of the Society for 61 years.

EDITH H. LUCHINS, of Bronx, NY, died on November 18, 2002. She was a member of the Society for 57 years.

HAIM REINGOLD, of Chicago, IL, died on September 6, 2003. He was a member of the Society for 66 years.

HERMANN V. WALDINGER, of New York, NY, died on July 23, 2003. He was a member of the Society for 54 years.
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.tamu.edu in the case of the editor and notices@ams.org in the case of the managing editor. The fax numbers are 979-845-6028 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines


December 1, 2003: Applications for funding to attend MSRI workshop on Symplectic Geometry and Mathematical Physics. See http://www.msri.org/.


December 1, 2003: Applications for AMS Centennial Fellowships. See http://www.ams.org/employment/centflyer.html or contact Professional Services Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294; email: prof-serv@ams.org; telephone: 800-321-4267, extension 4107, or 401-455-4107.

December 1, 2003: Submissions for Sunyer i Balaguer Prize. See http://www.crm.es/home.htm; email: crm@crm.es.


December 15, 2003: Applications for AMS Epsilon Fund grants. See http://www.ams.org/careers-edu/epsilon.html or contact Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294; email: prof-serv@ams.org; telephone: 800-321-4267, extension 4107, or 401-455-4107.

Where to Find It
A brief index to information that appears in this and previous issues.

AMS Bylaws—November 2003 p. 1283
AMS Email Addresses—November 2003, p. 1266
AMS Ethical Guidelines—June/July 2002, p. 706
AMS Officers 2002 and 2003 (Council, Executive Committee, Publications Committees, Board of Trustees)—May 2003, p. 594
AMS Officers and Committee Members—October 2003, p. 1115
Conference Board of the Mathematical Sciences—September 2003, p. 945
Information for Notices Authors—June/July 2003, p. 706
Mathematics Research Institutes Contact Information—August 2003, p. 821
National Science Board—January 2003, p. 64
New Journals for 2002—June/July 2003, p. 708
NRC Board on Mathematical Sciences and Their Applications—March 2003, p. 383
NRC Mathematical Sciences Education Board—April 2003, p. 489
NSF Mathematical and Physical Sciences Advisory Committee—February 2003, p. 261
Program Officers for Federal Funding Agencies—October 2003, p. 1107 (DoD; DoE); December 2003, p. 1429 (NSF Program Officers)
Charles Street, Providence, RI 02904; telephone: 800-321-4267, extension 4105, or 401-455-4105; email: prof-serv@ams.org.

December 17, 2003: Applications for NRC-Ford Foundation Postdoctoral Fellowships. See “Mathematics Opportunities” in this issue.


December 31, 2003: Entries for Cryptologia paper competitions. See http://www.dean.usma.edu/math/pubs/cryptologia/ or contact Cryptologia, Department of Mathematical Sciences, United States Military Academy, West Point, NY 10996; email: Cryptologia@usma.edu.


January 15, 2004: Nominations for Popov Prize. Contact Ronald A. DeVore, Director, Industrial Mathematics Institute, Department of Mathematics, University of South Carolina, Columbia, SC 29208.


February 1, 2004: Applications for AWM Travel Grants and AWM Mentoring Travel Grants. See http://www.awm-math.org/travelgrants.html; or contact Association for Women in Mathematics, 4114 Computer and Space Sciences Building, University of Maryland, College Park, MD 20742-2461; telephone 301-405-7892; email: awm@math.umd.edu.

February 1, 2004: Nominations for European Mathematical Society prizes. See http://www.math.kth.se/4ecm/nomination.html, or write to: 4ECM Organizing Committee, Professor Ari Laptev, Department of Mathematics, Royal Institute of Technology, SE-100 44 Stockholm, Sweden; email: laptev@math.kth.se or uuunur@nur.usr.pu.ru.


May 1, 2004: Applications for AWM Travel Grants. See http://www.awm-math.org/travelgrants.html; or contact Association for Women in Mathematics, 4114 Computer and Space Sciences Building, University of Maryland, College Park, MD 20742-2461; telephone 301-405-7892; email: awm@math.umd.edu.


NSF Division of Mathematical Sciences

Listed below are names, email addresses, and telephone numbers for the program directors for the coming academic year in the Division of Mathematical Sciences of the National Science Foundation.

Algebra, Number Theory, and Combinatorics
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Reference and Book List

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Joanna Kania-Bartoszynska  
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703-292-8613  
kmcdonal@nsf.gov  

Deborah F. Lockhart (acting)  
703-292-4858  
dlockhart@nsf.gov  

Administrative Officer  
Tyzcer L. Henson  
703-292-4852  
thenson@nsf.gov  


NSF Mathematics Education Staff  
The Directorate for Education and Human Resources (EHR) of the National Science Foundation (NSF) sponsors a range of programs that support educational projects in mathematics, science, and engineering. Listed below is contact information for those EHR program officers whose field is the mathematical sciences or mathematics education. These individuals can provide information about the programs they oversee, as well as information about other EHR programs of interest to mathematicians. The postal address is: Directorate for Education and Human Resources, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230. The EHR Web page is at http://www.nsf.gov/ehr.  

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Book List

The Book List highlights books that have mathematical themes and are aimed at 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-book1list@ams.org.

*Added to “Book List” since the list's last appearance.


Reference and Book List


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 and that additional information on the number of Ph.D.’s granted to women would also be collected using the AMS-IMS-MAA 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 eighteenth reporting of this information. Updated reports will appear annually in the Notices.

### Members of the AMS Residing in the U.S.

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### Ph.D.'s Granted to U.S. Citizens

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### Invited Hour Address Speakers at AMS Meetings (1993–2002)

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<tr>
<td>Total checked</td>
<td>571</td>
<td>85%</td>
<td>14%</td>
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### Speakers at Special Sessions at AMS Meetings (1998–2002)

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<tr>
<td>Total checked</td>
<td>12,700</td>
<td>77%</td>
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### Percentage of Women Speakers in AMS Special Sessions by Gender of Organizers (2002)

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<th>Male</th>
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<th>Unknown</th>
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<tr>
<td>Total number of speakers:</td>
<td>1,643</td>
<td>66%</td>
<td>13%</td>
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### Special Sessions with at Least One Woman Organizer

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<tr>
<td>Total number of speakers:</td>
<td>825</td>
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### Special Sessions with No Women Organizers

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<tr>
<td>Total number of speakers:</td>
<td>1,643</td>
<td>76%</td>
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### Members of Editorial Boards of AMS Journals

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### Ph.D.'s Granted to U.S. Citizens

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From the AMS Secretary
Add this Cover Sheet to all of your Academic Job Applications

How to use this form

1. Using the facing page or a photocopy, (or visit the AMS web site for a choice of electronic versions at www.ams.org/coversheet/), fill in the answers which apply to all of your academic applications. Make photocopies.

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

The purpose of the cover form is to aid department staff in tracking and responding to each application for employment. Mathematics departments in Bachelor's-, Master's-, and Doctorate-granting institutions are expecting to receive the form from each applicant, along with the other application materials they require.

The AMS suggests that applicants and employers visit the Job Application Database for Mathematicians (www.mathjobs.org), a new electronic resource being offered by the AMS (in partnership with Duke University) for the second year in 2002-03. The system provides a way for applicants to produce printed coversheet forms, apply for jobs, or publicize themselves in the “Job Wanted” list. Employers can post a job listing, and once applications are made, search and sort among their applicants. Note-taking, rating, e-mail, data downloading and customizable EOE functions are available to employers. Also, reference writers can submit their letters online. A paperless application process is possible with this system, however; employers can choose to use any portion of the service. There will be annual employer fees beginning this year. This system was developed at the Duke University Department of Mathematics.

Please direct all questions and comments to: emp-info@ams.org.
### AMS STANDARD COVER SHEET

<table>
<thead>
<tr>
<th>Last Name</th>
<th>First Name</th>
<th>Middle Names</th>
<th>Address through next June</th>
<th>Home Phone</th>
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<tr>
<th>Highest Degree Held or Expected</th>
<th>Granting Institution</th>
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<th>Ph.D. Advisor</th>
<th>Ph.D. Thesis Title (optional)</th>
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**Indicate the mathematical subject area(s) in which you have done research using the Mathematics Subject Classification printed on the back of this form or on the AMS website. Use the two-digit classification which best fits your interests in the Primary Interest line and additional two-digit numbers in the Secondary Interest line.**

<table>
<thead>
<tr>
<th>Primary Interest</th>
<th>Secondary Interests</th>
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**Give a brief synopsis of your current research interests (e.g. finite group actions on four-manifolds). Avoid special mathematical symbols and please do not write outside of the boxed area.**

<table>
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<tr>
<th>Most recent, if any, position held post Ph.D.</th>
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<th>University or Company</th>
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**Indicate the position for which you are applying and position posting code, if applicable**

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<thead>
<tr>
<th>If applying for a position which requires U.S. citizenship or U.S. permanent residency, indicate your eligibility</th>
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<tbody>
<tr>
<td>□ Yes □ No</td>
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**If unsuccessful for this position, would you like to be considered for a temporary position?**

<table>
<thead>
<tr>
<th>□ Yes □ No</th>
<th>If yes, please check the appropriate boxes.</th>
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<tbody>
<tr>
<td></td>
<td>□ Postdoctoral Position □ 2+ Year Position □ 1 Year Position</td>
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**List the names, affiliations, and e-mail addresses of up to four individuals who will provide letters of recommendation if asked. Mark the box provided for each individual whom you have already asked to send a letter.**

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December 2003


Overview: Nonlinear phenomena and the formation of spatio-temporal patterns play an increasingly important role in current research on partial differential equations. Progress in the past quarter-century in the development of equivariant bifurcation theory and the theory of mode interactions and deterministic chaos has made possible a better understanding of spatio-temporal patterns in a wide variety of physical and biological contexts. This workshop will contribute to the thematic program along this important direction of current research and will complement the related Workshop on Patterns in Physics, November 14-18, 2003.

Recent progress in equivariant bifurcation theory for Hamiltonian systems and in particular the Hamiltonian Hopf bifurcation also will be addressed in the proposed workshop, thus providing a sequel to the winter-spring component of the thematic program on PDE's. The workshop will be dedicated to Professor William Langford, one of the pioneering researchers in the field of bifurcation theory in Canada. At the banquet on Friday evening, we will recognize his fundamental contributions and leadership in bifurcation theory and pattern formation, and acknowledge his service to the Canadian mathematical community, on the occasion of his 60th birthday.

Organizers: A. T. L vainiczak (Guelph), W. Nagata (UBC), V. G. LeBlanc (Ottawa), N. Sri Namachchivaya (Illinois at Urbana-Champaign).

Sponsor: The workshop is financially sponsored and hosted by The Fields Institute. Additional financial support is provided by the Department of Mathematics and Statistics, University of Guelph.

Invited Speakers: S. A. Campbell (Waterloo), J. Chadam (Pittsburgh), S.-N. Chow (Georgia Institute of Technology), W. Craig (McMaster), M. Dellnitz (Paderborn), M. Field (Toronto), L. Glass (Centre for Nonlinear Dynamics, McGill), M. Golubitsky (Houston), J. Guckenheimer (Cornell), P. Holmes (Princeton), G. Iooss (Institut Non-Linéaire, Nice), C. Jones (Brown), H. Keller (California Institute of Technology), Y. Kevrekidis (Princeton), B. Keyfitz (Houston), E. Knobloch (Leeds), M. Krupa (New Mexico State), J. Lamb (Imperial College, London), I. Melbourne (Surrey), S. Morris (Toronto), M. Pugh (Toronto), A. Vanderbauwhede (Gent), J. W. Yorke, J. Yorke (Maryland), P. Yu (UWO).

Information: http://www.fields.utoronto.ca/programs/scientific/03-04/bifurcation/.

11-16 Conference on Algebra and Number Theory, The University of Hyderabad, India. (Oct. 2003, p. 1129)

14-16 International Conference on Matrix Analysis and Applications, Nova Southeastern University, Fort Lauderdale, Florida. (Mar. 2003, p. 408)

14-17 International Workshop on Efficient Techniques for Numerical Solutions of Coupled PDES and Applications to Reservoir Simulation, Institute for Studies in Theoretical Physics

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

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

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

In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the Notices prior to the meeting in question. To achieve this, listings should be received in Providence 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, 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 sessions 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/.
January 2004

*2-31 (REVISED) Statistical Methods in Microarray Analysis, Institute for Mathematical Sciences, National University of Singapore.

Program: This is a program of the Institute for Mathematical Sciences at the National University of Singapore. The development and applications of microarray technology give rise to many problems that need to be addressed by the collective knowledge and skills of mathematicians and biologists. This program aims to study the many new statistical methods tailored to microarrays developed in the last few years. Its main objective is to bring together a group of leading researchers in microarrays to discuss their current work and to exchange ideas among themselves as well as with local researchers on the future statistical challenges for microarrays.

Topics: In addition to seminars and invited lectures, the program will consist of a tutorial on background material and a workshop at research level. The tutorial will be held from January 2 to January 6, 2004, and it will be followed by a workshop held throughout the rest of January 2004.

Organizing Committee: T. Speed, chair (Univ. of Calif. at Berkeley and Walter & Eliza Hall Institute of Medical Research, Australia); M.-Y. Leung (Univ. of Texas at El Paso) and L. Zhang (Nat. Univ. of Singapore).

Members: A. Kuk (National Univ. of Singapore), A. Owen (Stanford Univ.), S. Richardson (Imperial College, UK) and W. H. Wong (Harvard Univ.).

Information & Registration: Registration forms for participation in the tutorial or workshop are available at http://www.ims.nus.edu.sg/Programs/microarray/index.htm. Completed forms should be received by the Institute at least one month before commencement of each activity. Registration is free of charge. Institute membership is not required for participation. Institute Membership: Membership application for visiting the Institute under the program is also available from the website above. Members of the Institute do not need to register for specific activities. Contacts: For general enquiries, please email ins@nus.edu.sg while for enquiries on scientific aspects of the program, please email M.-Y. Leung at aleng@nus.edu.sg. More information about the program is at the website http://www.ims.nus.edu.sg/Programs/microarray/index.htm.

*4-5 Call for Papers: Eighth International Symposium on Artificial Intelligence and Mathematics, Ft. Lauderdale, Florida.

Approach: The International Symposium on Artificial Intelligence and Mathematics is the eighth of a biennial series. The series was started by Martin Golumbic, and the editorial board of the Annals of Mathematics and Artificial Intelligence serves as the permanent Advisory Committee. The objective of the symposium is to foster interactions between mathematicians, theoretical CS, and artificial intelligence. The Symposium includes invited speakers, special topic sessions, and presentations of submitted papers.

Invited Speakers: R. Bixby and R. Brafman.

Topics/Organizers: Preferences, R. Brafman, Ben-Gurion Univ., Israel; Portfolio Design for Combinatorial Problems, C. Gomes, B. Selman, Cornell, USA; Artificial Intelligence and Game Theory, K. Leyton-Brown, Stanford, USA, M. Tennenholtz, Technion, Israel.


Information: http://rutcor.rutgers.edu/~amai

5-9 International Workshop on Groups, Geometry and Dynamics, Technion-Israel Institute of Technology, Haifa, Israel.

5-9 Workshop on Large $N$ Limits of $U(N)$ Gauge Theory in Physics and Mathematics, Centre de Recherches Mathématiques, Montréal, Québec, Canada.

7-9 IMA Short Course: The Internet for Mathematicians, University of Minnesota, Minneapolis, Minnesota.


11-14 Thompson's Group at 40 Years, AIM Research Conference Center, Palo Alto, California. (Aug. 2003, p. 846)

12-16 IMA Workshop 4: Measurement, Modeling and Analysis of the Internet, University of Minnesota, Minneapolis, Minnesota. (Mar. 2003, p. 408)

12-17 Percolation, Particle Systems and Random Media, Pontificia Universidad Catolica de Chile, Santiago de Chile, Chile. (Nov. 2003, p. 1314)

12-17 Winter School on Transport Equations and Control Theory for PDEs, Casa della Gioventù, Bressanone (Bolzano), Italy. (Oct. 2003, p. 1128)


19-28 Advanced Course on Ramsey Methods in Analysis, Barcelona, Spain. 
Organizer: Centre de Recerca Matemàtica (crm@crm.es).
Coordinator: J. Bagaria.

19-25 International Educational Conference on Ramsey Methods, Pontificia Universidad Catolica de Chile, Santiago de Chile, Chile. (Nov. 2003, p. 1314)


21-30 Advanced Course on Ramsey Methods in Analysis, Bellaterra (Barcelona), Spain. (Apr. 2003, p. 499)

23-24 Arithmetic Quantum Chaos (MAT Seminar, Montpellier, 2004), University of Montpellier II, Montpellier, France. (Nov. 2003, p. 1314)


29-30 April 2 IMA Short Course: Tools for Modeling and Data Analysis in Finance/Asset Pricing, University of Minnesota, Minneapolis, Minnesota. (Apr. 2003, p. 499)


April 2004

1-May 15 Econometric Forecasting and High-Frequency Data Analysis, Institute for Mathematical Sciences, National University of Singapore, Singapore. (Aug. 2003, p. 847)

2-4 Midwest Several Complex Variables Meeting, University of Western Ontario, London, Ontario, Canada. (Oct. 2003, p. 1128)

3-4 AMS Western Section Meeting, University of Southern California, Los Angeles, California. (May 2003, p. 604)

4-7 Fractal 2004, Vancouver, Canada. (Jun./Jul. 2003, p. 725)

5-8 Joint Meeting of the 56th British Mathematical Colloquium and the 17th Annual Meeting of the Irish Mathematical Society (BMC2004), Queen's University Belfast, Belfast, Northern Ireland. (Oct. 2003, p. 1128)


14-16 Multi-Objective Programming and Goal Programming (MOPG’04), Hammamet, Tunisia. (Nov. 2003, p. 1314)


22-24 SIAM International Conference on Data Mining (SDM04), Hyatt Orlando, Orlando, Florida.

Description: This conference will provide a forum for the presentation of recent results in data mining, including applications,
algorithms, software, and systems. There will be peer reviewed, contributed papers as well as invited talks and tutorials. Best paper awards will be given in different categories. Proceedings of the conference will be available both online at the SIAM website and in hard copy form. In addition, several workshops on topics of current interest will be held on the final day of the conference.

Conference co-chairs: C. Kamath, Lawrence Livermore National Laboratory; D. Skillicorn, Queen's University.

Program co-chairs: U. Dayal, Hewlett-Packard Laboratories; M. W. Berry, University of Tennessee.


Information: email: ross@siam.org.

22-25 2004 ASL Spring Meeting (with APA), Chicago, Illinois.


Topics: This workshop will bring together topologists working in the developing area of "homotopy theory of varieties" with number theorists and algebraic geometers working in subjects related to dessins d'enfants, and expose them to the techniques and ideas of the various subjects involved both in the number theoretic and topological areas.

Application deadline: December 1, 2003.


May 2004

3-5 SIAM Conference on Imaging Science (IS04), Marriott City Center, Salt Lake City, Utah. (Oct. 2003, p. 1128)

3-7 IMA Workshop 8: Model Implementation, Algorithms and Software Issues, University of Minnesota, Minneapolis, Minnesota. (Apr. 2003, p. 499)


4-7 Workshop on Spectral Theory and Automorphic Forms, Centre de Recherches Mathematiques, Montreal, Quebec, Canada. (Aug. 2003, p. 848)

9-12 International Conference on Numerical Combustion (NC04), Hilton Sedona Resort & Spa, Sedona, Arizona. (Nov. 2003, p. 1314)


19-25 The Decidable and the Undecidable in Mathematics Education, Brno University of Technology, Brno, Czech Republic.


24-28 Workshop on Hamiltonian Dynamical Systems (jointly with The Fields Institute), Centre de Recherches Mathematiques, Montreal, Quebec, Canada. (Aug. 2003, p. 848)

28-31 International Conference on Mathematics and its Applications, City University of Hong Kong. (Sept. 2003, p. 1005)
Contact: D. Talay, INRIA, 2004 Routes des Lucioles, BP.93, F-06902, Vallauris, France; email: Denis.Talay@inria.fr.

Information: Regularly updated information can be obtained from the Web page http://www.inria.fr/omega/NC2004.

* 7–11th Conference on Poisson Geometry, University of Luxembourg, Luxembourg City, Grand-Duchy of Luxembourg.

Topics: This conference on Poisson Geometry and related areas will focus on Poisson structures and generalizations, notions of equivalence, normal forms, hamiltonian systems and generalized moment maps, Poisson Lie groups, Poisson groupoids and dynamical Poisson groupoids, Poisson homogeneous and symmetric spaces, Lie and Courant algebroids, deformation quantization.

Invited Speakers: A. Alekseev (Geneva), A. S. Cattaneo (Zurich), R. L. Fernandes (Lisbon), P. Foth (Arizona), J. Grabowski (Warsaw), J. Huebschmann (Lille), J.-H. Lu (Arizona), K. C. H. Mackenzie (Sheffield), Y. Maeda (Keio), P. Monnier (Bordeaux), S. Parmentier (Lyon), O. Riedo (Los Angeles), T. S. Ratiu (Lausanne), P. Severa (Bratislava), I. Vaisman (Haifa), A. Weinstein (Berkeley), P. Xu (Penn State), N. T. Zung (Toulouse) (to be extended).

Organizers: D. Arnal (Dijon), P. Dufour (Montpellier), J. Grabowski (Warsaw), S. Gutt (Brussels), Y. Kosmann-Schwarzbach (Ecole Polytechnique, Palaiseau), P. Lecomte (Liège), Y. Maeda (Keio), C. Molitor-Braun (Luxembourg), V. Ovsienko (Lyon), N. Poncin (Luxembourg), A. Weinstein (Berkeley).


Sponsors: Fonds National de la Recherche (FNR Luxembourg), University of Luxembourg, Société mathématique du Luxembourg.


Description: The conference will provide many opportunities for academicians and professionals from statistics and/or mathematics related fields to interact with members inside and outside our own particular disciplines. Cross-disciplinary submissions with other fields are welcome.

Sponsor: East West Council for Education, Center of Asian Pacific Studies of Peking University.


Information: Hawaii International Conference on Statistics, Mathematics and Related Fields, P.O. Box 75023, Honolulu, HI 96836 USA, fax: (808) 947-2420; telephone: (808) 946-9927; email: statistics@hibiscics.org; http://www.hibiscics.org.


13–18 Algorithmic Number Theory Symposium VI (ANTS-VI), United States Naval Academy, Annapolis, Maryland. (Oct. 2003, p. 1129)

16–19 AIMS' Fifth International Conference on Dynamical Systems and Differential Equations, California State Polytechnic University, Pomona, California. (Aug. 2003, p. 849)


Organizer: Centre de Recerca Matemàtica (crm@crm.es).

Coordinator: G. Lugosi.


* 20–25 Canadian Number Theory Association VIII Meeting, University of Toronto, Toronto, Ontario, Canada.

Program: Plenary Lectures, Special Sessions, Contributed Talks.

Special Sessions: Algebraic Number Theory, A. Weiss (Alberta); Analytic Number Theory, J. Friedlander (Toronto); Arithmetic Algebraic Geometry, R. Ramakrishna (Cornell); Computational Number Theory, H. Williams (Calgary); Diophantine Analysis and Approximation, C. Stewart (Waterloo).

Contributed talks: There is space for a number of contributed talks. Please submit your abstract for consideration.

Information: http://www.fields.utoronto.ca/programs/scientific/03-04/CNT06/.

20–25 8th Symposium on Probability and Stochastic Processes, Universidad de las Americas, Cholula, Puebla, Mexico. (Nov. 2003, p. 1314)


Description: USENIX has always been the place to present groundbreaking research and cutting-edge practices in a wide variety of technologies and environments. We are pleased to announce that in response to your feedback, the 2004 program has been reorganized and expanded. The new format will include additional tutorials, more security breakthroughs, and extra sessions devoted to Linux and Open Source Software. Join the community of programmers, developers, and systems professionals in sharing solutions and fresh ideas.

Information: http://www.usenix.org/events/usenix04/.


Workshop Topics: All topics related to mathematical aspects of wave propagation, scattering and diffraction.

Organizers: Prof. V. M. Babich (PDMI), V. S. Buldyrev (SPbU), Euler Int. Math. Inst.


Information: http://m1.math.spb.edu/00.


July 2004


4–11 The 10th International Congress on Mathematical Education, Copenhagen, Denmark. (Oct. 2003, p. 1129)

* 5–9th International Conference on p-adic Functional Analysis, University Blaise Pascal, Clermont-Ferrand, France.

Description: Lectures will cover all domains on analytic functions in p-adic fields and on p-adic functional analysis.

Scientific Committee: B. Diarra, (Univ. Blaise Pascal, Clermont-Ferrand), A. Escassut (Univ. Blaise Pascal, Clermont-Ferrand), A. Katsaras, (Univ. of Ioannina, Greece), L. Narici (St. John's Univ., Jamaica, NY, USA).


* 5–Eleventh International Conference on Fibonacci Numbers and their Applications, Braunschweig, Germany.

Call for Papers: The purpose of the conference is to bring together people from all branches of mathematics and science with interests in recurrence sequences, their applications and generalizations, and other special number sequences.

Local Organizer: H. Harborth.

Conference Organizer: W. Webb.

International Committee: A. Adelberg (USA), M. Bicknell-Johnson (USA), C. Cooper (USA), Y. Horadam (co-chair)
Mathematics Calendar

(Australia), J. Lahr (Luxembourg), A. Philipou (co-chair) (Greece), G. Phillips (co-chair) (Scotland), A. Shannon (Australia), L. Somer (USA), J. Turner (New Zealand).

Local Committee: J. P. Bode, A. Krenzit, H. Weiss.

Deadline: Papers and abstracts should be submitted in duplicate to W. Webb by May 1, 2004 at: Dept. of Math., Washington State Univ., Pullman, WA 99164-3113; phone 509-335-3150. Electronic submissions, preferably in A₄s-Tex, sent to: email: webb@math.wsu.edu.

Information: Contact H. Harborth at Diskrete Mathematik, T U Braunschweig, 38023 Braunschweig, Germany; phone: 49-531-3917515; 49-531-322213; email: h.harborth@tu-bb.de.

5-9 Graphes et Combinatoire, un Colloque a la Memoire de Claude Berge, Universite Paris 6, Paris, France. (Mar. 2003, p. 409)

5-9 19th "Summer" Conference on Topology and Its Applications, Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, South Africa. (Sept. 2003, p. 1006)

5-10 Non-commutative geometry and representation theory in mathematical physics, Karlstad University, Karlstad, Sweden.

Scope and purpose: To cover an area lying between algebra, geometry and theoretical physics, including topics like: the representation theory of various algebraic structures, non-commutative geometry and C*-algebras, operators, vertex algebras and A-Infinity algebras; conformal field theory and topological field theory; symmetries and statistical properties of low-dimensional quantum systems.

Organizers: J. Fuchs (Karlstad), J. Mickelsson (Stockholm), G. Rozenbloum (Gothenburg), A. Stolin (Gothenburg).


Information: http://a90.ify.kau.se/teofys/ngc-rt/.

5-16 (REVISED) Advanced Course on Automata Groups, Barcelona, Spain. (Apr. 2003, p. 500)

Coordinator: W. Dicks.

Organizer: Centre de Recerca Matematica (crm@crm.es).

Information: http://www.crm.es/AutomataGroups.

11-14 SIAM Conference on the Life Sciences (LS04), Oregon Convention Center, Portland, Oregon.

About the Conference: The life sciences have become increasingly quantitative as new technologies facilitate collection and analysis of vast amounts of data ranging from complete genomic sequences of organisms to satellite imagery of forest landscapes on continental scales. As a consequence, mathematics and computational science have become crucial technologies for the study of complex models of biological processes.

The SIAM Activity Group on Life Sciences brings together researchers who seek to develop and apply mathematical and computational methods in all areas of the life sciences. This conference of the activity group will provide a cross-disciplinary forum for catalyzing mathematical research relevant to the life sciences. It will facilitate rapid diffusion of new mathematical and computational methods in the life sciences, and may stimulate more researchers to work in these important areas.

Conference Themes: The themes of the 2004 conference will include, but are not limited to: Ecology, Environmental and Evolutionary Biology, Genomics, Imaging, Neuroscience, Physiology and Immunology, Structural Biology, Modeling Diseases, Biomatics in Industry.

Invited Plenary Speakers: High-Throughput Structure-Based Drug Discovery for Protein Kinases, S. Burley, Structural GenomiX (SGX), Inc.; Modelling Autoimmune (Type 1) Diabetes, L. Edelstein-Keshet, The University of British Columbia, Canada; Comparative Gene Structure and Gene Expression, T. Gaasterland, Rockefeller University; The Structure and Nonlinear Robustness of Complex Ecological Networks, N. Martinez, San Francisco State University; Locomotion and Pattern Formation in Bacteria, G. Oster, University of California, Berkeley; Modeling the Kinetics of Viral Infections A. Perelson, Los Alamos National Laboratory, Neuronal Dynamics and the Basal Ganglia D. Terman, Ohio State University.


Information: email: ross@siam.org.

19-23 XVIII Escola de Algebra (Eighteenth Algebra School), State University of Campinas (UNICAMP), Campinas, SP/Brazil. (Oct. 2003, p. 1129)

24-28 European Congress on Computational Methods in Applied Sciences and Engineering, Jyväskylä, Finland. (Feb. 2003, p. 295)

25-31 2004 ASL European Summer Meeting (Logic Colloquium '04), Torino, Italy. (Jun./Jul. 2003, p. 725)


26-30 XIV Brazilian Topology Meeting, Campinas, São Paulo, Brazil. (Sept. 2003, p. 1007)

26-31 2004 ASL European Summer Meeting (Logic Colloquium '04), Torino, Italy. (Apr. 2003, p. 500)

August 2004

2-6 First Announcement: The 9th International Conference on Difference Equations and Applications ICDEA-9, University of Southern California, Los Angeles, California.

Main theme: Mathematical Biology under the auspices of the International Society of Difference Equations.

Organizers: R. J. Sacker, chairma n, rsacker@math.ucr.edu; S. L. Iyengar, selaydi@trinity.edu; D. Lutz, lutz@math.sdsu.edu; G. Sell, sell@math.unm.edu.

Information: Further details, including names of the plenary speakers, will be posted on the WWW as they become available. See http://math.ucr.edu/~rsacker or the website of the International Society of Difference Equations, http://www.math.unm.edu/midwestpde.

2-6 Workshop on Dynamics in Statistical Mechanics, Centre de Recherches Mathématiques, Montréal, Québec, Canada. (Aug. 2003, p. 850)


6-7 New Directions in Probability Theory, Fields Institute, Toronto, Canada. (Aug. 2003, p. 850)

9-13 13th USENIX Security Symposium, San Diego, California.

Description: The USENIX Security Symposium brings together researchers, practitioners, system administrators, system programmers, and others interested in the latest advances in security of computer systems.

Information: http://www.usenix.org/events/sec04/.


24-27 International Conference on Nonlinear Operators, Differential Equations and Applications (ICNODEA-2004), Babes-Bolyai University, Cluj-Napoca, Romania. (Sept. 2003, p. 1008)

30-September 3 9th Conference on Differential Geometry and Its Applications, Prague, Czech Republic. (Apr. 2003, p. 500)
Mathematics Calendar

1-6 (REVISED) Sixth Pan-African Congress of Mathematicians, Institute National des Sciences Appliquées et del la Technologie (IN-SAT), Université 7 Novembre à Carthage, Tunis, Tunisia. (May 2003, p. 604)


19-22 The First International Conference on Complex Systems CSIMTA 2004 (Complex Systems Intelligence and Modern Technology Applications), Cherbourg, France. (Oct. 2003, p. 1129)

October 2004

16-17 AMS Southeastern Section Meeting, Vanderbilt University, Nashville, Tennessee. (May 2003, p. 604)

16-17 AMS Western Section Meeting, University of New Mexico, Albuquerque, New Mexico. (May 2003, p. 604)

November 2004

6-7 AMS Eastern Section Meeting, University of Pittsburgh, Pittsburgh, Pennsylvania. (Sept. 2003, p. 1009)

December 2004

5-16 International Workshop on Nonlinear Partial Differential Equations, IPM, Tehran, Iran. (Aug. 2003, p. 850)

17-19 International Conference on Smarandache Algebraic Structures, Indian Institute of Technology, IIT Madras, Chennai-600 036 Tamil Nadu, India. (Aug. 2003, p. 850)

*17-22 The Third International Congress of Chinese Mathematicians, The Chinese University of Hong Kong, Shatin, Hong Kong, P.R. China.

Description: The triennial Congress is hosted by institutions in Mainland China, Taiwan, Hong Kong, and Singapore in a rotating basis. The first two ICCM’s were held in 1998 and 2001 with great success. This third congress, ICCM 2004, will have both plenary and invited talks by distinguished researchers in every major fields, as well as contributed talks and poster sessions. Contributed papers on all major areas of mathematics are solicited. To make the congress a true worldwide gathering, all presentations will be given in English.

Information: ICCM2004, Department of Mathematics, Chinese University of Hong Kong, Shatin, NT, Hong Kong, fax: (852) 2603-5154; tel: (852) 2609-7989; email: iccm2004@math.cuhk.edu.hk; http://www.math.cuhk.edu.hk/conference/iccm2004.

January 2005

5-8 Joint Mathematics Meetings, Hyatt Regency Atlanta & Atlanta Marriott Marquis, Atlanta, Georgia. (Sept. 2002, p. 1001)

New Publications Offered by the AMS

Algebra and Algebraic Geometry

**Vertex Operator Algebras in Mathematics and Physics**

Stephen Berman, University of Saskatchewan, Saskatoon, Canada, Yuly Billig, Carleton University, Ottawa, ON, Canada, and Yi-Zhi Huang and James Lepowsky, Rutgers University, Piscataway, NJ, Editors

Vertex operator algebras are a class of algebras underlying a number of recent constructions, results, and themes in mathematics. These algebras can be understood as "string-theoretic analogues" of Lie algebras and of commutative associative algebras. They play fundamental roles in some of the most active research areas in mathematics and physics. Much recent progress in both physics and mathematics has benefited from cross-pollination between the physical and mathematical points of view.

This book presents the proceedings from the workshop, "Vertex Operator Algebras in Mathematics and Physics", held at The Fields Institute. It consists of papers based on many of the talks given at the conference by leading experts in the algebraic, geometric, and physical aspects of vertex operator algebra theory.

The book is suitable for graduate students and research mathematicians interested in the major themes and important developments on the frontier of research in vertex operator algebra theory.

The item will also be of interest to those working in mathematical physics.

Contents: T. Abe and K. Nagatomo, Finiteness of conformal blocks over the projective line; P. Bantay, Permutation orbifolds and their applications; J. Fuchs and C. Schweigert, Category theory for conformal boundary conditions; R. L. Griess, Jr., GNAVOA, I. Studies in groups, nonassociative algebras and vertex operator algebras; G. Höhn, Genera of vertex operator algebras and three-dimensional topological quantum field theories; Y.-Z. Huang, Riemann surfaces with boundaries and the theory of vertex operator algebras; H. Li, Vertex (operator) algebras are "algebras" of vertex operators; A. Milas, Correlation functions, differential operators and vertex operator algebras; M. Primc, Relations for annihilating fields of standard modules for affine Lie algebras; A. Recknagel, From branes to boundary conformal field theory: Draft of a dictionary; V. Schomerus, Open strings and non-commutative geometry; C. Schweigert and J. Fuchs, The world sheet revisited.

**Fields Institute Communications**, Volume 39


**Representations of Algebraic Groups**

Second Edition

Jens Carsten Jantzen, Aarhus University, Denmark

From reviews of the First Edition:

Very readable ... meant to give its reader an introduction to the representation theory of reductive algebraic groups ...  

—Zentralblatt MATH

Those familiar with [Jantzen's previous] works will approach this new book ... with eager anticipation. They will not be disappointed, as the high standard of the earlier works is not only maintained but exceeded ... very well written and the author has taken great care over accuracy both of mathematical details and in references to the work of others. The discussion is well motivated throughout ... This impressive and wide ranging volume will be extremely useful to workers in the theory of algebraic groups ... a readable and scholarly book.

—Mathematical Reviews

Back in print from the AMS, the first part of this book is an introduction to the general theory of representations of algebraic group schemes. Here, Jantzen describes important basic notions: induction functors, cohomology, quotients, Frobenius kernels, and reduction mod p, among others. The second part
of the book is devoted to the representation theory of reductive algebraic groups and includes topics such as the description of simple modules, vanishing theorems, the Borel-Bott-Weil theorem and Weyl's character formula, and Schubert schemes and line bundles on them.

This is a significantly revised edition of a modern classic. The author has added nearly 150 pages of new material describing later developments and has made major revisions to parts of the old text. It continues to be the ultimate source of information on representations of algebraic groups in finite characteristics.

The book is suitable for graduate students and research mathematicians interested in algebraic groups and their representations.

Contents: Part I. General theory: Schemes; Group schemes and representations; Induction and injective modules; Cohomology; Quotients and associated sheaves; Factor groups; Algebras of distributions; Representations of finite algebraic groups; Representations of Frobenius kernels; Reduction mod $p$; Part II. Representations of reductive groups: Reductive groups; Simple $G$-modules; Irreducible representations of the Frobenius kernels; Kempf's vanishing theorem; The Borel-Bott-Weil theorem and Weyl's character formula; The linkage principle; The translation functors; Filtrations of Weyl modules; Representations of $G_T$ and $G_B$; Geometric reductivity and other applications of the Steinberg modules; Injective $G$-modules; Cohomology of the Frobenius kernels; Schubert schemes; Line bundles on Schubert schemes; Truncated categories and Schur algebras; Results over the integers; Lustzig's conjecture and some consequences; Radical filtrations and Kazhdan-Lustzig polynomials; Tilting modules; Frobenius splitting; Frobenius splitting and good filtrations; Representations of quantum groups; References; List of notations; Index.

Mathematical Surveys and Monographs, Volume 107

December 2003, 576 pages, Hardcover, ISBN 0-8218-3527-0,
2000 Mathematics Subject Classification: 20-02, 20G05; 17B10, 17B56, 22E45, All AMS members $79, List $99, Order code SURV/107N

Analysis

Heat Kernels and Analysis on Manifolds, Graphs, and Metric Spaces

Pascal Auscher, Université Paris-Sud, Orsay, Thierry Coulhon, Université de Cergy-Pontoise, Cergy Pontoise, France, and Alexander Grigor’yan, Imperial College London, Editors

This volume contains the expanded lecture notes of courses taught at the École Normale Superiéure in Paris (2003) and the Henri Poincaré Institute (2004). In the book, leading experts introduce recent research in their fields. The unifying theme is the study of heat kernels in various situations using related geometric and analytic tools.

The book is suitable for graduate students and research mathematicians interested in algebraic groups and their representations.

Contents: Part I. General theory: Schemes; Group schemes and representations; Induction and injective modules; Cohomology; Quotients and associated sheaves; Factor groups; Algebras of distributions; Representations of finite algebraic groups; Representations of Frobenius kernels; Reduction mod $p$; Part II. Representations of reductive groups: Reductive groups; Simple $G$-modules; Irreducible representations of the Frobenius kernels; Kempf's vanishing theorem; The Borel-Bott-Weil theorem and Weyl's character formula; The linkage principle; The translation functors; Filtrations of Weyl modules; Representations of $G_T$ and $G_B$; Geometric reductivity and other applications of the Steinberg modules; Injective $G$-modules; Cohomology of the Frobenius kernels; Schubert schemes; Line bundles on Schubert schemes; Truncated categories and Schur algebras; Results over the integers; Lustzig's conjecture and some consequences; Radical filtrations and Kazhdan-Lustzig polynomials; Tilting modules; Frobenius splitting; Frobenius splitting and good filtrations; Representations of quantum groups; References; List of notations; Index.

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December 2003, 576 pages, Hardcover, ISBN 0-8218-3527-0,
2000 Mathematics Subject Classification: 20-02, 20G05; 17B10, 17B56, 22E45, All AMS members $79, List $99, Order code SURV/107N

Operator Algebras and Mathematical Physics

Jean-Michel Combes, Université de Toulon et du Var, La Garde, France, Joachim Cuntz, University of Münster, Germany, George A. Elliott, University of Toronto, ON, Canada, Gheorghe Nenciu, University of Bucharest, Romania, Heinz Siedentop, Ludwig-Maximilians-Universität München, Germany, and Şerban Strătilă, University of Bucharest, Romania, Editors

This volume presents the proceedings of the conference on Operator Algebras and Mathematical Physics held in Constanta, Romania. The conference gathered experts to examine and discuss the interesting connections between these two areas.

The book contains 24 research and expository papers reflecting a broad variety of topics from both domains: $C^*$-algebras and dynamical systems, geometric and operator algebraic quantization, modular invariants, $q$-commutation
A Companion to Analysis

A Second First and First Second Course in Analysis

T. W. Körner, University of Cambridge, England

This book not only provides a lot of solid information about real analysis, it also answers those questions which students want to ask but cannot figure how to formulate. To read this book is to spend time with one of the modern masters in the subject.

—Steven G. Krantz, Washington University, St. Louis

New Publications Offered by the AMS

T. W. Körner's A Companion to Analysis is a welcome addition to the literature on undergraduate-level rigorous analysis. It is written with great care with regard to both mathematical correctness and pedagogical soundness. Körner shows good taste in deciding what to explain in detail and what to leave to the reader in the exercises scattered throughout the text. And the enormous collection of supplementary exercises in Appendix K, which comprises almost one-third of the whole book, is a valuable resource for both teachers and students.

One of the major assets of the book is Körner's very personal writing style. By keeping his own engagement with the material continually in view, he invites the reader to a similarly high level of involvement. And the witty and erudite asides that are sprinkled throughout the book are a real pleasure.

—Gerald Folland, University of Washington, Seattle

Many students acquire knowledge of a large number of theorems and methods of calculus without being able to say how they work together. This book provides those students with the coherent account that they need. A Companion to Analysis explains the problems that must be resolved in order to procure a rigorous development of the calculus and shows the student how to deal with those problems.

Starting with the real line, the book moves on to finite-dimensional spaces and then to metric spaces. Readers who work through this text will be ready for courses such as measure theory, functional analysis, complex analysis, and differential geometry. Moreover, they will be well on the road that leads from mathematics student to mathematician.

With this book, well-known author Thomas Körner provides accessible and hard-working students a great text for independent study or for an advanced undergraduate or first-level graduate course. It includes many stimulating exercises. An appendix contains a large number of accessible but non-routine problems that will help students advance their knowledge and improve their technique.

Contents: The real line; A first philosophical interlude; Other versions of the fundamental axiom; Higher dimensions; Sums and suchlike; Differentiation; Local Taylor theorems; The Riemann integral; Developments and limitations of the Riemann integral; Metric spaces; Complete metric spaces; Contraction mappings and differential equations; Inverse and implicit functions; Completion; Appendices; Executive summary; Exercises; Bibliography; Index.

Graduate Studies in Mathematics, Volume 62

Convex Analysis: Theory and Applications
G. G. Magaril-Il'yaev, Central Research Institute of Complex Automation, Moscow, and V. M. Tikhomirov, Moscow State University

This book is an introduction to convex analysis and some of its applications.

It starts with basic theory, which is explained within the framework of finite-dimensional spaces. The only prerequisites are basic analysis and simple geometry. The second chapter presents some applications of convex analysis, including problems of linear programming, geometry, and approximation. Special attention is paid to applications of convex analysis to Kolmogorov-type inequalities for derivatives of functions in one variable.

The book can be used for an advanced undergraduate or graduate-level course on convex analysis and its applications. The only code framework of finite-dimensional spaces. The only results on geometry and convex analysis in sion 52-01, 46N10; 47N10, All AMS members $28, List $35, Order code MMONO/222N.

Applications

Quantum Control: Mathematical and Numerical Challenges
André D. Bandrauk, Université de Sherbrooke, QC, Canada, Michel C. Delfour, Université de Montréal, QC, Canada, and Claude Le Bris, Ecole Nationale des Ponts et Chaussées, Marne-la-vallée, France, Editors

An entirely new branch of science now known as Laser Control of Molecular Processes is steadily making an impact on the experimental and technological worlds, with internationally distinguished scientists making many outstanding contributions. In parallel, mathematicians from control theory and numerical simulation are getting progressively involved and making their contributions to this scientific endeavor.

This volume presents the proceedings of the workshop, “Quantum Control: Mathematical and Numerical Challenges”, held at the Centre de recherches mathématiques of the Université de Montréal (CRM). The workshop concentrated on advanced numerical methods and new mathematical control and optimization approaches and tools for the quantum control of matter at the molecular level using current laser technology. It brought together mathematicians, theoretical chemists, and physicists working in the area of control and optimization of systems to address the outstanding numerical and mathematical problems.

The volume is suitable for graduate students and research mathematicians interested in mathematical methods of control of molecular processes. It will also be useful to chemical engineers and chemists working in control and optimization of systems.

Contents: O. Atabek and C. M. Dion, Molecular alignment and orientation: From laser-induced mechanisms to optimal control; A. Auger, A. Ben-Haj-Yedder, and M. Schoenauer, Overview and software guide of evolutionary algorithms; A case study in quantum control; A. D. Bandrauk, F. Légaré, and H. T. Yu, Laser control of molecular states—Nonperturbative examples; V. S. Batista and P. Brumer, Coherent control: Principles and semiclassical implementations; G. Chen, D. A. Church, B.-G. Englert, and M. S. Zubairy, Mathematical models of contemporary elementary quantum computing devices; M. C. Delfour, Addendum and remarks on doubly conservative numerical schemes for the nonlinear Schrödinger equation and its control; R. Ilner, H. Lange, and H. Teismann, A note on the exact internal control of nonlinear Schrödinger equations; C. Le Bris, Y. Maday, and G. Turinici, Towards efficient numerical approaches for quantum control; H. Lefebvre-Brion, Multichannel quantum defect study of the control in the frequency domain: Example of HI; Y. Ohtsuki and H. Rabitz, Development of solution algorithms for quantum optimal control equations in product spaces; X.-G. Wang and T. Carrington, Jr., Using contracted basis functions to solve the Schrödinger equation; E. Zuazua, Remarks on the controllability of the Schrödinger equation.

CRM Proceedings & Lecture Notes, Volume 33
January 2004, 211 pages, Softcover, ISBN 0-8218-3330-8, 2000 Mathematics Subject Classification: 49J20, 81V10, 81V80, 78A60, 81P68; 35Q40, 37N20, 46N50, 47N50, All AMS members $49, List $61, Order code CRMP/33N.

Stochastic Models
José M. González-Barrios, Universidad Nacional Autónoma de México, Jorge A. León, Instituto Politécnico Nacional, México, and Ana Meda Universidad Nacional Autónoma de México, Editors

The volume includes lecture notes and research papers by participants of the Seventh Symposium on Probability and Stochastic Processes held in Mexico City. The lecture notes introduce recent advances in stochastic calculus.
with respect to fractional Brownian motion, principles of large deviations and of minimum entropy concerning equilibrium prices in random economic systems, and give a complete and thorough survey of credit risk theory.

The research papers cover areas such as financial markets, Gaussian processes, stochastic differential equations, stochastic integration, quantum dynamical semigroups, self-intersection local times, etc.

Readers should have a basic background in probability theory, stochastic integration, and stochastic differential equations. The book is suitable for graduate students and research mathematicians interested in probability, stochastic processes, and risk theory.

This item will also be of interest to those working in probability. This volume is a joint publication of the American Mathematical Society and the Sociedad Matemática Mexicana. Members of the SMM may order directly from the AMS at the SMM member price.


Contemporary Mathematics, Volume 336
December 2003, 272 pages, Softcover, ISBN 0-8218-3466-5, LC 2003062763, 2000 Mathematics Subject Classification: 60E15, 60F10, 60G15, 60G50, 60H05, 60H10, 60H15, 60J60, 91B26, 91B30, All AMS members $35, List $69, Order code CONM/336N

Differential Equations

Symbolic Dynamics and its Applications
Susan G. Williams, University of South Alabama, Mobile, Editor

Symbolic dynamics originated as a tool for analyzing dynamical systems and flows by discretizing space as well as time. The development of information theory gave impetus to the study of symbol sequences as objects in their own right. Today, symbolic dynamics has expanded to encompass multi-dimensional arrays of symbols and has found diverse applications both within and beyond mathematics. This volume is based on the AMS Short Course on Symbolic Dynamics and its Applications. It contains introductory articles on the fundamental ideas of the field and on some of its applications. Topics include the use of symbolic dynamics techniques in coding theory and in complex dynamics, the relation between the theory of multi-dimensional systems and the dynamics of tilings, and strong shift equivalence theory.

Contributors to the volume are experts in the field and are clear expositors. The book is suitable for graduate students and research mathematicians interested in symbolic dynamics and its applications.

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

Contents: S. G. Williams, Introduction to symbolic dynamics; B. Marcus, Combining modulation codes and error correcting codes; P. Blanchard, R. L. Devaney, and L. Keen, Complex dynamics and symbolic dynamics; D. Lind, Multi-dimensional symbolic dynamics; E. A. Robinson, Jr., Symbolic dynamics and tilings of R^d; J. B. Wagoner, Strong shift equivalence theory; Index.

Proceedings of Symposia in Applied Mathematics, Volume 60
Discrete Mathematics and Combinatorics

Lectures on Generating Functions
S. K. Lando, Independent University of Moscow

This book introduces readers to the language of generating functions, which nowadays, is the main language of enumerative combinatorics. The book starts with definitions, simple properties, and numerous examples of generating functions. It then discusses topics such as formal grammars, generating functions in several variables, partitions and decompositions, and the exclusion-inclusion principle. In the final chapter, the author describes applications to enumeration of trees, plane graphs, and graphs embedded in two-dimensional surfaces.

Throughout the book, the author motivates readers by giving interesting examples rather than general theories. It contains numerous exercises to help students master the material. The only prerequisite is a standard calculus course. The book is an excellent text for a one-semester undergraduate course in combinatorics.

Contents: Formal power series and generating functions. Operations with formal power series. Elementary generating functions; Generating functions for well-known sequences; Unambiguous formal grammars. The Lagrange theorem; Analytic properties of functions represented as power series and their asymptotics of their coefficients; Generating functions of several variables; Partitions and decompositions; Dirichlet generating functions and the inclusion-exclusion principle; Enumeration of embedded graphs; Final and bibliographical remarks; Bibliography; Index.

Student Mathematical Library, Volume 23

Symmetric Functions and Combinatorial Operators on Polynomials
Alain Lascoux, Institut Gaspard Monge, Université de Marne-la-Vallée, France

The theory of symmetric functions is an old topic in mathematics which is used as an algebraic tool in many classical fields. With λ-rings, one can regard symmetric functions as operators on polynomials and reduce the theory to just a handful of fundamental formulas.

One of the main goals of the book is to describe the technique of λ-rings. The main applications of this technique to the theory of symmetric functions are related to the Euclid algorithm and its occurrence in division, continued fractions, Padé approximants, and orthogonal polynomials.

Putting the emphasis on the symmetric group instead of symmetric functions, one can extend the theory to non-symmetric polynomials, with Schur functions being replaced by Schubert polynomials. In two independent chapters, the author describes the main properties of these polynomials, following either the approach of Newton and interpolation methods or the method of Cauchy.

The last chapter sketches a non-commutative version of symmetric functions, using Young tableaux and the plactic monoid.

The book contains numerous exercises clarifying and extending many points of the main text. It will make an excellent supplementary text for a graduate course in combinatorics.

Contents: Symmetric functions; Symmetric functions as operators and λ-rings, Euclidean division; Reciprocal differences and continued fractions; Division; Symmetrizing operators; Orthogonal polynomials; Schubert polynomials; The ring of polynomials as a module over symmetric polynomials; The plactic algebra; Complements; Solutions of exercises; Bibliography; Index.

CBMS Regional Conference Series in Mathematics, Number 99
December 2003, 268 pages, Softcover, ISBN 0-8218-2871-1, 2000 Mathematics Subject Classification 05E05, 05E10, 14M15, 20C30, 41A21, 42C05, All Individuals $44, List $55, Order code CBMS/99N

General and Interdisciplinary

Grothendieck-Serre Correspondence
Bilingual Edition

This extraordinary volume contains a large part of the mathematical correspondence between A. Grothendieck and J.-P. Serre. It forms a vivid introduction to the development of algebraic geometry during the years 1955-1965. During this period, algebraic geometry went through a remarkable transformation, and Grothendieck and Serre were among central figures in this process.

In the book, the reader can follow the creation of some of the most important notions of modern mathematics. The letters also reflect the mathematical and political atmosphere of this period. They are supplemented by J.-P. Serre’s notes, which give explanations, corrections, and references to further results.

The book is a unique bilingual (French and English) volume. The original French text is supplemented here by the English trans-
This series is published in cooperation with the Mathematical Association of America.


CBMS Issues in Mathematics Education, Volume 12
December 2003, 206 pages, Softcover, ISBN 0-8218-3302-2, 2000 Mathematics Subject Classification: 00-XX, 97-XX, All Individuals $39, List $49, Order code CBMATH/12N

This fifth volume of Research in Collegiate Mathematics Education (RCME) presents state-of-the-art research on understanding, teaching, and learning mathematics at the post-secondary level. The articles in RCME are peer-reviewed for two major features: (1) advancing our understanding of collegiate mathematics education, and (2) readability by a wide audience of practicing mathematicians interested in issues affecting their own students. This is not a collection of scholarly arcana, but a compilation of useful and informative research regarding the ways our students think about and learn mathematics.

The volume begins with a study from Mexico of the cross-cutting concept of variable followed by two studies dealing with aspects of calculus reform. The next study frames its discussion of students’ conceptions of infinite sets using the psychological work of Efraim Fischbein on (mathematical) intuition. This is followed by two papers concerned with APOS theory and other frameworks regarding mathematical understanding. The final study provides some preliminary results on student learning using technology when lessons are delivered via the Internet.

Whether specialists in education or mathematicians interested in finding out about the field, readers will obtain new insights about teaching and learning and will take away ideas they can use.

This volume covers material presented at three sessions of the AMS special session on Riemannian and Lorentzian geometries in Baltimore. Topics covered include classification of curvature-related operators, curvature-homogeneous Einstein 4-manifolds, linear stability/instability singularity and hyperbolic operators of spacetimes, spectral geometry of holomorphic manifolds, cut loci of nilpotent Lie groups, conformal geometry of almost Hermitian manifolds, and also submanifolds of complex and contact spaces.

This volume can serve as a good reference source and provide indications for further research. It is suitable for graduate students and research mathematicians interested in differential geometry.

Topological and Geometric Aspects of Manifolds

Gordana Matić and Clint McCrory, University of Georgia, Athens, Editors

Since 1961, the Georgia Topology Conference has been held every eight years to discuss the newest developments in topology. The goals of the conference are to disseminate new and important results and to encourage interaction among topologists who are in different stages of their careers. Invited speakers are encouraged to aim their talks to a broad audience, and several talks are organized to introduce graduate students to topics of current interest. Each conference results in high-quality surveys, new research, and lists of unsolved problems, some of which are then formally published. Continuing in this 40-year tradition, the AMS presents this volume of articles and problem lists from the 2001 conference. Topics covered include symplectic and contact topology, foliations and laminations, and invariants of manifolds and knots.

Articles of particular interest include John Etnyre's, "Introductory Lectures on Contact Geometry," which is a beautiful expository paper that explains the background and setting for many of the other papers. This is an excellent introduction to the subject for graduate students in neighboring fields. Etnyre and Lenhard Ng's "Problems in Low-Dimensional Contact Topology" and Danny Calegari's extensive paper, "Problems in Foliations and Laminations of 3-Manifolds," are carefully selected problems in keeping with the tradition of the conference. They were compiled by Etnyre and Ng and by Calegari with the input of many who were present. This book provides material of current interest to graduate students and research mathematicians interested in the geometry and topology of manifolds.

Contents: J. Roberts, Rozansky-Witten theory; C. Connell and B. Farb, Some recent applications of the barycenter method in geometry; S. Bigelow, The Lawrence-Krammer representation; W. H. Meeks III, Topological properties of properly embedded minimal surfaces in \( \mathbb{R}^3 \); J. B. Etnyre, Introductory lectures on contact geometry; V. Colin, E. Giroux, and K. Honda, On the coarse classification of tight contact structures; P. Ghiggini and S. Schönenberger, On the classification of tight contact structures; M. Symington, Four dimensions from two in symplectic topology; H. U. Boden, C. M. Herald, and P. Kirk, On the integer valued \( SU(3) \) Casson invariant; P. M. N. Feehan and T. G. Leness, On Donaldson and Seiberg-Witten invariants; J. S. Carter and M. Saito, Quandle homology theory and cocycle knot invariants; T. Li, Boundary train tracks of laminar branched surfaces; S. Schleimer, Strongly irreducible surface automorphisms; D. Calegari, Problems in foliations and laminations of 3-manifolds; J. B. Etnyre and L. L. Ng, Problems in low-dimensional contact topology.

Proceedings of Symposia in Pure Mathematics, Volume 71
Complex Cobordism and Stable Homotopy Groups of Spheres
Second Edition
Douglas C. Ravenel, University of Rochester, NY

From reviews of the First Edition:
This book on the Adams and Adams-Novikov spectral sequence and their
applications to the computation of the stable homotopy groups of spheres is
the first which does not only treat the definition and construction but leads
the reader to concrete computations. It contains an overwhelming amount of
material, examples, and machinery ... The style of writing is very fluent, pleasant
to read and typical for the author, as everyone who has read a paper written by
him will recognize ... this is a very welcome book ...—Zentralblatt MATH
This book provides a substantial introduction to many of the
current problems, techniques, and points of view in homotopy theory ... gives
a readable and extensive account of methods used to study the stable homotopy
groups of spheres. It can be read by an advanced graduate student, but experts
will also profit from it as a reference ... fine exposition.—Mathematical Reviews
Since the publication of its first edition, this book has served
as one of the few available on the classical Adams spectral
sequence and is the best account on the Adams-Novikov spectral
sequence. This new edition has been updated in many
places, especially the final chapter, which has been completely
rewritten with an eye toward future research in the field. It
remains the definitive reference on the stable homotopy
groups of spheres.
The first three chapters introduce the homotopy groups
of spheres and take the reader from the classical results to the
field through the computational aspects of the classical Adams
spectral sequence and its modifications, which are the main
tools topologists have to investigate the homotopy groups
of spheres. Nowadays, the most efficient tools are the Brown-
Peterson theory, the Adams-Novikov spectral sequence, and
the chromatic spectral sequence, a device for analyzing
the global structure of the stable homotopy groups of spheres and
relating them to the cohomology of the Morava stabilizer
groups. These topics are described in detail in Chapters 4 to 6.
The revamped Chapter 7 is the computational payoff of the
book, yielding a lot of information about the stable homotopy
group of spheres. Appendices follow, giving self-contained
accounts of the theory of formal group laws and the homological
algebra associated with Hopf algebras and Hopf
algebroids.
The book is intended for anyone wishing to study computational
stable homotopy theory. It is accessible to graduate
students with a knowledge of algebraic topology and recom-
ended to anyone wishing to venture into the frontiers of the
subject.
Contents: An introduction to the homotopy groups of spheres;
Setting up the Adams spectral sequence; The classical Adams
spectral sequence; BP-theory and the Adams-Novikov spectral
sequence; The chromatic spectral sequence; Morava stabilizer
algebras; Computing stable homotopy groups with the Adams-
Novikov spectral sequence; Hopf algebras and Hopf
algebroids; Formal group laws; Tables of homotopy groups of
spheres; Bibliography; Index.

Mathematical Physics

Special Functions, KZ Type Equations, and Representation Theory
Alexander Varchenko, University of North Carolina, Chapel Hill

The last twenty years have seen an active interaction between mathe-
matics and physics. This book is devoted to one of the new areas which deals with mathemat-
ical structures related to conformal field theory and its
q-deformations. In the book, the author discusses the inter-
play between Knizhnik–Zamolodchikov type equations, the
Bethe ansatz method, representation theory, and geometry of
multi-dimensional hypergeometric functions.

This book aims to provide an introduction to the area and
expose different facets of the subject. It contains construc-
tions, discussions of notions, statements of main results, and
illustrative examples. The exposition is restricted to the
simplest case of the theory associated with the Lie algebra $\mathfrak{sl}_2$.

This book is intended for researchers and graduate students
in mathematics and in mathematical physics, in particular to
those interested in applications of special functions.

This item will also be of interest to those working in analysis.

Contents: Hypergeometric solutions of KZ equations; Cycles of
integrals and the monodromy of the KZ equation; Selberg integral,
determinant formulas, and dynamical equations; Critical
points of master functions and the Bethe ansatz; Elliptic
hypergeometric functions; q-hypergeometric solutions of qKZ
equations; Bibliography; Index.

CBMS Regional Conference Series in Mathematics, Number 98
2000 Mathematics Subject Classification: 14Dxx, 22Exx, 33Cxx;
39Axx, 81Rxx, 82Bxx, All Individuals $28, List $35, Order
code CBMS/98N
Number Theory

**Absolute CM-Periods**

Hiroyuki Yoshida, Kyoto University, Japan

The central theme of this book is an invariant attached to an ideal class of a totally real algebraic number field. This invariant provides us with a unified understanding of periods of abelian varieties with complex multiplication and the Stark-Shintani units. This is a new point of view, and the book contains many new results related to it.

To place these results in proper perspective and to supply tools to attack unsolved problems, the author gives systematic expositions of fundamental topics. Thus the book treats the multiple gamma function, the Stark conjecture, Shimura's period symbol, the absolute period symbol, Eisenstein series on $GL(2)$, and a limit formula of Kronecker's type. The discussion of each of these topics is enhanced by many examples. The majority of the text is written assuming some familiarity with algebraic number theory. About thirty problems are included, some of which are quite challenging.

The book is intended for graduate students and researchers working in number theory and automorphic forms.

**Contents:** Introduction; Multiple gamma function and its generalizations; The Stark-Shintani conjecture; Absolute CM-periods; Explicit cone decompositions and applications; Applications of a limit formula of Kronecker's type; Eisenstein series on $GL(2)$; On higher derivatives of $L$-functions; Transcendental property of CM-periods; References; Index.

**Mathematical Surveys and Monographs,** Volume 106


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Graduate Studies in Mathematics

This series contains books designed for classroom use. They are recommended course texts or are suitable for supplementary reading or independent study.

Representations of Finite and Compact Groups
Barry Simon, California Institute of Technology, Pasadena
Volume 10; 1996; 206 pages; Hardcover; ISBN 0-8218-0453-7; List $36; Sale price $18; Order code GSM/10

Mixed Motives
Marc Levine, Northeastern University, Boston, MA
Volume 57; 1998; 515 pages; Hardcover; ISBN 0-8218-6785-4; List $114; Sale price $34; Order code SURV/57

A Century of Mathematics in America
Peter Duren, University of Michigan, Ann Arbor, Editor
Volume 1; 1986; 477 pages; Hardcover; ISBN 0-8218-0313-4; List $78; Sale price $32; Order code HMA/1
Volume 2; 1986; 565 pages; Hardcover; ISBN 0-8218-0315-0; List $91; Sale price $36; Order code HMA/2
Volume 3; 1986; 675 pages; Hardcover; ISBN 0-8218-0318-4; List $96; Sale price $39; Order code HMA/3
Set; 1986; 1545 pages; Hardcover; ISBN 0-8218-0318-6; List $284; Sale price $94; Order code HMA/SET

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The titles in this series offer interesting historical perspectives on the people and communities that have profoundly influenced the development of mathematics.

Poincaré and the Three Body Problem
June Barrow-Green, The Open University, Milton Keynes, UK
Volume 1; 1997; 272 pages; Paperback; ISBN 0-8218-0387-2; List $41; All AMS members $33; Sale price $21; Order code HMA/11

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Titles in this series feature well-written, challenging expository works that capture the fascination and usefulness of mathematics.

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Basic Analysis:

Japanese Grade 11
Kunihiko Kodaira, Editor
Volume 11; 1996; 184 pages; Softcover; ISBN 0-8218-0598-0; List $33; Sale price $18; Order code MAWRLD/11

Translations of Mathematical Monographs

This series of translations contains works of advanced mathematical research and exposition primarily translated from Japanese and Russian.

Local Properties of Distributions of Stochastic Functionals
Yu. A. Davydov, University of Lille I, Villeneuve d’Ascq, France, M. A. Lifshits, MANCOMTECH Training Center, St. Petersburg, Russia, and N. V. Smorodina, Radiation Hygiene Institute, St. Petersburg, Russia
Volume 173; 1998; 184 pages; Hardcover; ISBN 0-8218-0584-3; List $79; Sale price $38; Order code MMONO/173

Nonstandard Methods in Commutative Harmonic Analysis
E. I. Gordon, Nazarbayev Novgorod State University, Russia
Volume 164; 1997; 166 pages; Hardcover; ISBN 0-8218-0419-7; List $104; Sale price $31; Order code MMONO/164
ALABAMA

AUBURN UNIVERSITY MONTGOMERY
School of Sciences
Dean

Nominations and applications are invited for the position of Dean of the School of Sciences for appointment effective August 15, 2004.

The University: Founded in 1967, Auburn University Montgomery (AUM) is the metropolitan campus of Auburn University with approximately 5,400 students and 200 faculty in five academic schools: Business, Education, Liberal Arts, Nursing, and Sciences. AUM serves a diverse student population. Montgomery is the state capital and enjoys progressive leadership focused on revitalization of the historic downtown. There are significant cultural attractions including the Alabama Shakespeare Festival, a world-class museum, a natural habitat zoo, and an independent film theater.

The School of Sciences: The School of Sciences offers undergraduate degree programs in six academic departments: Biology, Justice and Public Safety, Mathematics, Physical Science, Political Science, and Public Administration, and Psychology. Courses are also offered in support of a variety of pre-professional programs, including engineering, law, and health sciences. Master's degrees are offered in Justice and Public Safety, Political Science, Psychology, and Public Administration. In addition, there is a joint Ph.D. program with Auburn University in Public Administration and Public Policy. The School of Sciences has 57 full-time faculty and approximately 1,000 undergraduate and graduate majors. See sciences.aum.edu for further information.

Position Description: The successful candidate will provide energetic leadership in promoting quality undergraduate and graduate teaching, supporting and fostering faculty research, and creating strong links to the community. The dean is expected to work with faculty and other academic administrators, and will have major responsibilities in academic planning, fund-raising, and personnel management, and will be active in engaging community leaders to establish partnerships that will enhance the school's programs.

Qualifications: All candidates must hold an earned doctoral degree, have administrative experience in higher education, and a record of achievements that merits appointment as full professor in one of the school's academic departments. Preferred qualifications include a record of obtaining external funding and a demonstrated ability to integrate a diverse range of disciplines into a cohesive whole.

Applications: Applicants must submit a letter of application, including a statement of philosophy about leadership in a School of Sciences; a vita; and names, addresses, and telephone numbers of four professional references to: Barbara S. Witt, Chair, Search Committee for Dean of School of Sciences, 101 Moore Hall, Auburn University Montgomery, P.O. Box 244023, Montgomery, Alabama 36124-4023. Screening of applicants will begin on November 3, 2003, and continue until the position is filled. Auburn University Montgomery is an Equal Opportunity Employer and seeks diversity in its faculty, administration, staff, and student populations. Applications from women and minorities are encouraged. Applicant must be eligible to work in the United States.

Suggested uses for classified advertising are positions available, items for sale, services available, and more.

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Qualifications: Evidence of, or potential for, teaching excellence, conducting scholarly activities, directing master's candidates, working with diverse student body. Review begins 1/12/2004, and continues until position is filled or closed. Submit application form indicating position, curriculum vitae, teaching philosophy, statement of research statement, undergraduate and graduate transcripts, minimum of three recent reference letters. Package must address background and interest in all qualifications, and may be examined by all department tenure-track faculty. Send to: Faculty Search Committee, Math Dept., Cal Poly Pomona, 3801 W. Temple Ave., Pomona, CA 91768-4007; 909-869-4008; fax: 909-869-4904; email: matt@calpoly.edu; http://www.calpoly.edu/math/position.AA/EOE.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Department of Mathematics

Subject to availability of resources and administrative approval, the following positions are available for the 2004-05 academic year.

1. Several E. R. Hedrick Assistant Professorships. Salary is $53,200. Three-year appointment. Teaching load: four quarters per year, which may include one advanced course in the candidate's field.

2. Several Research Assistant Professorships in Computational and Applied Mathematics (CAM). Salary is $53,200. Three-year appointment. Teaching load: normally reduced to two or three quarters per year. Research funding is available, and may include one advanced course in the candidate's field.

3. Several Assistant Adjunct Professorships or Lectureships in the Program in Computing (PIC). Applicants for the adjunct position must show very strong promise in teaching and research in an area related to computing. Teaching load: four one-quarter programming courses each year and one seminar every two years. One-year initial appointment, with the option of applying for renewal for a second year and possibly longer, up to a maximum service of four years. Salary is $56,800. Applicants for the lectureship must show very strong promise in the teaching of programming. An M.S. in Computer Science or equivalent degree is preferred. Teaching load: six one-quarter programming courses per year. One-year appointment, probably renewable one or more times, depending on the needs of the program. Salary is $43,152 or more, depending on experience.

4. Several VIGRE Assistant Professorships. Hedrick, CAM, or PIC applicants who are U.S. citizens or permanent residents may also apply for a VIGRE Assistant Professor position. Three-year appointment. Salary is $53,200. The successful recipient will receive a summer stipend of $6,500 for two summers and $2,500 per year for travel, equipment, and supplies for three years. Teaching load: 3 courses per year.


6. Several visiting instructorships.

For more details, see http://www.math.ucla.edu/search. To apply, complete the application on the website, or send e-mail to math@math.ucla.edu, or write to: Staff Search, Department of Mathematics, University of California, Los Angeles, CA 90095-1555. Preference will be given to applications completed by January 5, 2004. UCLA is an Equal Opportunity/Affirmative Action Employer. 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.

CALIFORNIA STATE UNIVERSITY NORTH RIDGE
Department of Mathematics

The Department of Mathematics invites applications for a tenure-track position, joint between the two departments, starting date is July 1, 2004. The position is in a general area of stochastic analysis. Candidates with interest in financial mathematics are strongly encouraged to apply. Qualifications: research and teaching excellence and Ph.D. in statistics, mathematics, or relevant field. Submit resume, statement of research and teaching objectives, the AMS cover sheet (available at http://www.ams.org), and four letters of reference (at least one of which is directed towards teaching). Mailing address: Mathematics, Department of Mathematics, California State University, 1811 North Campus Drive, Northridge, CA 91330-3110. Applications will be considered until position is filled. Candidates who contribute to the diversity and excellence of the academic community through research, teaching, and service are particularly encouraged to apply. Additional information at http://www.mathjobs.org. UNIVERSITY OF CALIFORNIA, SANTA BARBARA
Department of Statistics and Applied Probability
Department of Mathematics

The Department of Statistics and Applied Probability and the Department of Mathematics invite applications for an open-level position, joint between the two departments. Starting date is July 1, 2004. The position is in a general area of stochastic analysis. Candidates with interest in financial mathematics are strongly encouraged to apply. Qualifications: research and teaching excellence and Ph.D. in statistics, mathematics, or relevant field. Submit resume, statement of research and teaching objectives, the AMS cover sheet (available at http://www.ams.org), and four letters of reference (at least one of which is directed towards teaching). Mailing address: Mathematics, Department of Mathematics, California State University, 1811 North Campus Drive, Northridge, CA 91330-3110. Applications will be considered until position is filled. Candidates who contribute to the diversity and excellence of the academic community through research, teaching, and service are particularly encouraged to apply. Additional information at http://www.mathjobs.org.
UNIVERSITY OF CALIFORNIA, SANTA CRUZ
Mathematics Department

The mathematics department at the University of California, Santa Cruz, is recruiting for: one tenure-track position for assistant professor in the area of analysis. The position will begin fall 2004. The teaching load is four one-quarter courses per year. Appointees will be expected to teach, pursue their research, and perform some department and university service. Minimum qualifications: Ph.D. or equivalent by 6/30/04 in mathematics or physics; demonstrated achievements or potential for excellence in research, teaching, and professional service. The campus is especially interested in candidates who can contribute to the diversity and excellence of the academic community through their research, teaching, and/or service. Salary: $46,300-$51,700 (step and salary commensurate with experience). Deadline: Application materials and letters of reference must be received by January 5, 2004.

Applicants should send a curriculum vitae; a summary of research and teaching experience; and four letters of recommendation, with at least one letter addressing teaching experience and ability (all letters will be treated as confidential documents). Please direct your letter writers to the UCSC Confidentiality Statement at http://www2.ucsc.edu/ahr/policies/confstm.htm. All applications should be sent to: Recruitment Committee, Mathematics Department, University of California, Santa Cruz, CA 95064. Please refer to provision #517-04 in your reply. Inquiries (not applications) can be sent to mathrec@ucsc.edu. UCSC is an EEO/AA Employer. See http://www.math.ucsc.edu/Current.html for complete job description.

UNIVERSITY OF CALIFORNIA, SAN DIEGO
Department of Mathematics

University of California, San Diego, Professorships: The Department of Mathematics of the University of California, San Diego (http://www.math.ucsd.edu/) is seeking outstanding candidates for up to seven faculty positions to start July 2004. One of these positions is for a very senior full professor with a distinguished record of research and teaching and is open to applicants in all areas of mathematics. The strongly preferred level for the other positions is at the assistant professor level, but applicants with all levels of experience from assistant professor to full professor will be considered.

Applicants should hold a Ph.D. in mathematics or a related field and should show outstanding promise and/or accomplishments in both research and teaching. Areas of special interest in applied mathematics include statistics, bioinformatics, and scientific computation. Areas of special interest in pure mathematics include geometry, probability, representation theory and topology. However, we encourage applications from any area of pure or applied mathematics. Level of appointment will be based on qualifications with appropriate salary per UC pay scales.

To apply for any of these positions, please submit your placement file including an AMS standard cover page, curriculum vitae, and publications; and arrange for three letters of reference to be sent under separate cover to the "Faculty Search Committee", Department of Mathematics-0112F, University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92037-112F. Please indicate primary research area (field and #) using the AMS Mathematical Review Classification List.

Applications received by January 2, 2004, will receive thorough consideration. All supporting material must be received no later than January 9, 2004. In compliance with the Immigration Reform and Control Act of 1986, individuals offered employment by the University of California will be required to show documentation to prove identity and authorization to work in the United States before hiring can occur. UCSD is an Equal Opportunity/Affirmative Action Employer with a strong institutional commitment to the achievement of diversity among its faculty and staff.

UNIVERSITY OF CALIFORNIA, RIVERSIDE
Department of Mathematics

Faculty Positions in Algebra, Analysis, Combinatorics, Topology (Tenure-Track)

Applications and nominations are invited for three tenure-track faculty positions (Assistant/Associate Professorships) beginning July 1, 2004 from the following areas: (1) Algebra (e.g., Algebraic Geometry, Commutative Algebra, Lie Algebra, etc.) (2) Analysis (e.g., Differential Equations, Nonlinear Analysis, Probability Theory, Harmonic Analysis, Complex Analysis, Functional Analysis, Operator Algebra, Mathematical Analysis, Applied Analysis, etc.) (3) Combinatorics (e.g., Algebraic, Differential, Geometric, Symplectic, and Low Dimensional Topology, etc.)

A doctorate in mathematics is required. Tenure-track applicants are expected to have demonstrated outstanding teaching and research, normally including major contributions beyond the doctoral dissertation. Responsibilities of these positions include teaching undergraduate and graduate level courses and seminars, conducting scholarly research, and participating in departmental and university service activities. Established criteria of the University of California will determine salary and level of appointment. To assure full consideration, applicants should send their curriculum vitae, including a list of publications, and have a minimum of three letters of recommendation sent to the address given below, which must be received by Thursday, January 15, 2004. All letters of recommendation are governed by University regulations and laws concerning confidentiality (see Academic Personnel Manual 160—http://www.ucop.edu/acadadv/acadpers/apm/apm-160.pdf). 2003/04

Faculty Search Committee

Department of Mathematics
University of California, Riverside
Riverside, CA 92521-0135

Classified Advertisements

NOTICES OF THE AMS 1457

DECEMBER 2003
AMS standardized application form and to indicate their subject area using the AMS subject classification numbers. The University of California, Riverside is an Affirmative Action/Equal Opportunity Employer. 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.

UNIVERSITY OF SAN FRANCISCO
Department of Mathematics

The Department of Mathematics at the University of San Francisco (USF) invites applications for a tenure-track assistant professor position, starting fall 2004. All research areas are acceptable; evidence of superior teaching ability is required. USF is an AAEOE. For details, please see: http://www.usfca.edu/hr.

UNIVERSITY OF SOUTHERN CALIFORNIA
Department of Mathematics

The Department of Mathematics at the University of Southern California expects one tenure-track position at the assistant or associate professor level to be available for the fall of 2004. Applications in any area of mathematics will be considered, but the department has a preference for geometry in the wide sense of the word. In addition, there may be several visiting and postdoctoral positions. Applicants must show exceptional promise in research and teaching.

To apply, please submit the following materials in a single package: letter of application and curriculum vitae (including your email address, telephone and fax numbers), preferably with the standardized AMS Cover Sheet. Candidates should also arrange for three letters of recommendation to be sent. All materials should be mailed to:

Mathematics Search Committee
University of Southern California
Department of Mathematics
DBR 141
Los Angeles, CA 90089-1113

Review of applications will begin November 15, 2003.

Additional information about the USC Department of Mathematics can be found on the Web at http://math.usc.edu.

USC is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF CALIFORNIA, IRVINE
Department of Mathematics

Irvine, CA 92697-3875

Applications are invited for up to four tenure or tenure-track positions in all areas of pure and applied mathematics. Appointment will be effective July 1, 2004, or later. A distinguished record in both research and teaching is required for tenure positions. Tenure-track applicants must demonstrate excellence and potential in research and teaching. Application materials should be sent to the Recruiting Committee at the above address, and should include (1) a curriculum vitae, (2) a list of publications with those publications appearing in refereed journals so noted, description of research, and ensure that at least three letters of recommendation be sent to the above address.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

COLORADO

UNIVERSITY OF COLORADO AT BOULDER
Department of Applied Mathematics
Assistant, Associate or Full Professor

We invite applications for a tenure or tenure-track position, to begin in August 2004 or sooner. Applicants at all levels will be considered, but Ph.D. is required. Strong preference will be given to candidates with demonstrated research expertise in applied analysis, especially as analysis intersects the other research areas of the department. These areas of research include computational mathematics, dynamical systems, nonlinear waves, analysis of differential equations, physical applied mathematics, statistics and applied probability, and mathematical biology. Further information about the department can be found at: http://amath.colorado.edu. Excellence in teaching is also expected. Applicants should send a letter of application, a current curriculum vitae, a statement of research interests, and an AMS cover sheet (ee: http://www.ams.org/cover_sheet/) to Chair of Analysis Committee, Department of Applied Mathematics, University of Colorado, Boulder, CO, 80309-0526. Three letters of recommendation should also be sent to this address. This is a continuation of an existing search, which will end when the position is filled. The University of Colorado at Boulder is committed to diversity and equality in education and employment.

CONNECTICUT

FAIRFIELD UNIVERSITY
Assistant Professor Mathematics

The Department of Mathematics and Computer Science at Fairfield University invites applications for a tenure-track assistant professorship in mathematics to begin in September 2004. A doctorate in mathematics is required. Strong evidence of research potential, demonstrated success in classroom instruction and a solid commitment to teaching are essential.

Fairfield University, the Jesuit University of Southern New England, is a comprehensive university with about 3,000 undergraduates and a strong emphasis on liberal arts education. Fairfield’s Department of Mathematics and Computer Science consists of fourteen full-time faculty members. The teaching load is three courses/nine credits per semester. Fairfield offers a very competitive benefits package. The picturesque campus is located on Long Island Sound in southwestern Connecticut about 50 miles from New York City. Fairfield is an Affirmative Action/Equal Opportunity
AMERICAN UNIVERSITY
Department of Mathematics and Statistics

Mathematics or statistics. Tenure-track assistant professor, American University, beginning Fall 2004. American University is an Affirmative Action/Equal Opportunity Employer, committed to a diverse faculty, staff, and student body. Minority and women candidates are encouraged to apply. For position information and application instructions, see http://www.mathstat.american.edu/positions, or contact the Department of Mathematics and Statistics at 202-885-3120.

DISTRICT OF COLUMBIA
YALE UNIVERSITY
Josiah Willard Gibbs
Instructorships/Assistant Professorships

Description: Offered to men and women with the doctorate who show definite promise in research in pure mathematics. Applications from women and members of minority groups are welcome. Appointments are for two/three years. The teaching load is kept light to allow ample time for research. This will consist of three one-semester courses. Part of the teaching duties over the term of the appointment may consist of a one-semester course at the graduate level in the general area of the instructor's research. Grant amount: The 2004-2005 salary will be at least $52,800. Deadline: January 1, 2004. Application information: Inquiries and applications can be obtained at the website http://www.math.yale.edu/. Inquiries and application supporting documents should be sent to the Gibbs Committee, Department of Mathematics, Yale University; via email: gibbs.committee@math.yale.edu. Yale University is an Affirmative Action/Equal Opportunity Employer.

GA
AUGUSTA STATE UNIVERSITY
Department of Mathematics and Computer Science

The department invites applications for three positions to begin fall 2004: A) a tenure-track position at the assistant professor or associate professor level, B) a tenured-track position at the assistant professor level, and C) a non-tenure-track position at the lecturer level. Position A requires a Ph.D. in mathematics with preference given to candidates whose field of study is analysis. Position B requires a master's degree in mathematics with preference given to candidates possessing a Ph.D. in mathematics. Position C requires a master's degree in mathematics and is pending funding. Preference in position B or C will be given to candidates able to teach introductory statistics. For further information, including instructions for applicants, visit our website http://www.aug.edu/mcs. Questions may be addressed via email to Dr. Jim Benedict at jbenedic@aug.edu. Augusta State University is an Affirmative Action and an Equal Opportunity Institution.

IL
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 and whose work shows remarkable promise in mathematical research and teaching. The appointment 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. For applicants who are U.S. citizens or permanent residents, there is the possibility of additional resources for summer support and travel from the department's VIGRE grant.
2. 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. The appointment is for three years, and the teaching obligation is three one-quarter courses per year.
3. Postdoctoral Research Associate: This is open to mathematicians who have recently completed or will soon complete a doctorate in mathematics and who will work in applied mathematics. These appointments are for up to two years. There is no teaching obligation.

Applicants will be considered for any of the positions above that seem appropriate. Complete applications consist of (a) an AMS cover sheet; (b) a curriculum vitae (including citizenship information); (c) three or more letters of reference, including one which addresses teaching ability; and (d) a description of previous research and plans for future research, including a brief (200 words or less) summary of your research interests.

Applicants should provide CVs, with at least three recommenders' names, and have recommendation letters sent to:
Chair, Screening Committee
Department of Mathematics
and Computer Science
Emory University
Atlanta GA 30322

Screening of applications will begin on 1 January 2004.

Informal inquiries are welcome; please see our Webpage at http://www.mathcs.emory.edu/News/Dps for further details.

Emory University is an Affirmative Action/Equal Opportunity Employer.

YALE UNIVERSITY

Josiah Willard Gibbs

Instructorships/Assistant Professorships

Classified Advertisements
strongly and actively committed to diversity within its community.

UNIVERSITY OF NOTRE DAME
Notre Dame, IN 46556
Department of Mathematics
Regular Position in Algebra

The Department of Mathematics of the University of Notre Dame invites applications for a position in algebra with a particular emphasis in number theory, representation theory, and arithmetic geometry, to start on August 24, 2004. Candidates at any rank will be considered. The teaching load is one course per semester and two courses the other semester. The salary is competitive. Applications, including a curriculum vitae, a letter of application, and a completed AMS Standard Cover Sheet, should be sent to Steven A. Buechler, chair, at the above address. Applicants should also arrange for at least three letters of recommendation to be sent to the chair. These letters should address the applicant's research accomplishments and supply evidence that the applicant has the ability to communicate articulately and teach effectively. Notre Dame is an Equal Opportunity Employer. Women and minorities are urged to apply. The evaluation of candidates will begin December 1, 2004. Information about the department is available at http://www.math.nd.edu/math/.

IOWA

IOWA STATE UNIVERSITY
Department of Mathematics

The Department of Mathematics anticipates having two tenure-track positions. These positions will be either at the Assistant Professor level, or more experienced candidates could be hired at the Associate level.

Applications are invited for positions in the area of Numerical Analysis/Scientific Computation. Candidates in this area with theoretical and/or application oriented research programs will be all considered.

Applications are also invited for positions in the area of Probability and stochastic processes.

For detailed information about the department, visit our Web site at http://www.math.iastate.edu.

The teaching load for un-tenured faculty is three courses per year. For Assistant Professor a Ph.D. in mathematics or related discipline by the start date of the position, and an excellent record in research and teaching are required. We prefer applicants with two to four years of experience beyond the Ph.D., normally achieved through a postdoctoral position.

For Associate Professor, in addition to the above, a superior record in research and teaching is expected. Applicants must submit a vita and a brief statement describing their research accomplishments and plans. They must also arrange for four (4) letters of recommendation, one (1) of which must address the applicant's teaching ability and experience. Mail to: Search Committee, Department of Mathematics, 400 Carver, Iowa State University, Ames, IA 50011-2064. Please indicate whether application is for Numerical Analysis or Probability Theory. Application Deadline is January 15, 2004. Iowa State University is an affirmative action/equal opportunity employer and strongly encourages women and members of underrepresented groups to apply.

University of Chicago is an Equal Opportunity/Affirmative Action Employer.

INDIANA

BALL STATE UNIVERSITY
Muncie, Indiana
Department of Mathematical Sciences
Assistant Professor of Applied Mathematics

Applications are invited for a tenure-track position in applied mathematics available August 20, 2004. Duties include: teaching approximately eight to nine hours per semester, predominantly at the undergraduate level; research in mathematics; and professional service. Salary and benefits are competitive and commensurate with qualifications. In addition, one or more temporary positions may be available, pending budgetary approval. Additional benefits for first-year faculty are negotiable.

Minimum qualification: All requirements for a doctorate in mathematics completed by August 1, 2004. Preferred qualification: Research interests compatible with the needs and interests of the department, especially numerical analysis, computational methods, and financial mathematics.

The Department of Mathematical Sciences includes faculty in pure and applied mathematics, financial mathematics, statistics, actuarial science, and mathematics education. The department offers a range of academic programs leading to B.A., B.S., M.A., M.S., and M.A.E. degrees in those areas. The bachelor's degrees in mathematics include options in mathematics, statistics, financial mathematics, and applied mathematics-physics. More information about the department, its programs, and its faculty is available at http://www.bsu.edu/web/math/.

An applicant's file is complete when all of the following have been sent: 1) letter of application; 2) AMS Standard Cover Sheet available from the AMS or the department; 3) curriculum vitae; 4) research summary; 5) three letters of reference at least one of which substantially addresses the candidate's teaching ability and performance; and 6) copy of graduate transcripts showing highest degree earned to: Giray Okten, Chair, Mathematics Search Committee, Department of Mathematical Sciences, Ball State University, Muncie, IN 47306. (Tel: 765-285-8640; fax: 765-285-1721; email: research@math.bsu.edu. Review of completed applications will begin December 15, 2003, and will continue until the position is filled. Applicants should also notify the search committee chair if they plan to attend the 2004 AMS/MAA Joint Meetings in Phoenix.

Ball State University is an Equal Opportunity, Affirmative Action Employer and is
Search, Statistics & Actuarial Science, Univ. of Iowa, Iowa City, IA 52242; http://www.stat.uiowa.edu. Women and minorities are encouraged to apply. The University of Iowa is an Affirmative Action Equal Opportunity Employer.

GRINNELL COLLEGE
Department of Mathematics and Computer Science
Tenure-Track Position in Mathematics
Grinnell College invites applications for a tenure-track position as assistant professor of mathematics starting fall 2004. All specialties will be considered; however, applicants whose specialty is an area of algebra, geometry, or number theory may be given special consideration. A Ph.D. in mathematics is expected. Grinnell College is a highly selective liberal arts college that seeks outstanding teacher-scholars for its faculty, rewards excellence in teaching, and is generous in its support of scholarship. For more information, see http://www.math.grinnell.edu/2003-math.

Please include a statement describing your interests in developing as a teacher and scholar in an undergraduate liberal arts environment that emphasizes close student-faculty interaction and values diversity. Send a cover sheet, curriculum vitae, undergraduate and graduate transcripts (copies acceptable), and three letters of recommendation to: Mathematics Search Committee, Department of Mathematics and Computer Science, 1116 8th Avenue, Grinnell College, Grinnell, IA 50112; email: Thomson@grinnell.edu; 641-269-3169; fax: 641-269-4285. Review of applications will begin November 1, 2003, and will continue until position is filled.

Grinnell College is an Equal Opportunity/Affirmative Action Employer committed to attracting and retaining highly qualified individuals who collectively reflect the diversity of the nation. No applicant shall be discriminated against on the basis of race, national or ethnic origin, age, gender, sexual orientation, marital status, religion, creed, or disability.

KANSAS STATE UNIVERSITY
Department of Mathematics
Subject to budgetary approval, applications are invited for tenure-track positions commencing August 15, 2004; rank and salary commensurate with qualifications. The department seeks candidates whose research interests mesh well with current faculty. The department has research groups in the areas of analysis, algebra, geometry/topology, and differential equations. Applicants must have strong research credentials as well as strong accomplishment or promise in teaching. Letter of application, current vita, description of research, and at least three letters of reference evaluating teaching accomplishments and potential. Offers may begin by December 1, 2003, but applications for positions will be reviewed until February 1, 2004, or until positions are closed. AA/EOE.

WICHITA STATE UNIVERSITY
Department of Mathematics and Statistics
Applications are invited for a tenure-eligible assistant professor in mathematics, starting August, 2004. (Position contingent on available funding.) Required Qualifications: Ph.D. in mathematics, active in research and strong research potential, strong commitment to excellence in teaching, effective communication skills, and successful experience with diverse populations. Preference given to classroom teaching experience, research area closely related to our doctoral program in mathematics or consonant with our current faculty progress toward a strong research record, and experience developing externally funded research grants. Women and minorities are especially urged to apply. Deadline for receipt of complete application package: 01/15/04, position remains open until filled. Send CV, statements about teaching and research, and have three references send letters to: Professor Stephen W. Brady, Search Committee Chair, Department of Mathematics & Statistics, Wichita State University, Wichita, KS 67260-0033, USA; email: brady@math.wichita.edu; fax: 316-978-3748. AA/EOE.

MARYLAND
UNITED STATES NAVAL ACADEMY
Department of Mathematics
The USNA Mathematics Department anticipates at least one tenure-track position (subject to approval and funding) at the assistant professor or associate professor level, depending on qualifications, to start in August 2004. See Website http://www.usna.edu/MathDept/website/Hire.htm for full information. Tel: 410-293-6701; fax: 410-293-4883; email: ang@usna.edu. The United States Naval Academy is an Affirmative Action/Equal Employment Opportunity Employer and provides reasonable accommodations to applicants with disabilities.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics
Applied Mathematics
Applications are invited for a limited number of positions in applied mathematics, including numerical analysis, scientific computation, and applied mathematics, starting fall 2004. Available positions may include instructorships, lecturerships, assistant professorships, and possibly higher levels. Appointment will be made mainly on the basis of demonstrated research accomplishments and potential. Complete applications should be received by January 5. To apply, please send a vita with a description of your recent research and research plans, and arrange to have three letters of reference sent. Address: Committee on Applied Mathematics, Room 2-345, Department of Mathematics, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139-4307. M.I.T. is an Equal Opportunity/Affirmative Action Employer. (For more information about the position and institution: http://www-math.mit.edu.)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics
C. L. E. Moore Instructorships in Mathematics
These positions are open to mathematicians with doctorates who show definite promise in research. The teaching load will be nine hours for the academic year. Applications should be complete by January 5. Applicants should arrange to have sent (a) a vita, (b) three letters of reference, (c) a description of the research in their thesis, and (d) a research plan for the next year to: Pure Mathematics Committee, Massachusetts Institute of Technology, Room 2-263, Cambridge, MA 02139-4307. M.I.T. is an Equal Opportunity/Affirmative Action Employer. (For more information about the position or institution: http://www-math.mit.edu.)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics
Pure Mathematics
The Department of Mathematics may make appointments, at the level of lecturer and assistant professor or higher, in pure mathematics for the year 2004-05. The teaching load will be nine hours for the academic year (eight hours for assistant professor appointments). These positions are open to mathematicians with doctorates who show definite promise in
research. Applications should be complete by January 5. Applicants should arrange to have sent (a) vita, (b) three letters of reference, (c) a description of their most recent research, and (d) a research plan for the immediate future to: Pure Mathematics Committee, Massachusetts Institute of Technology, Room 2-203, 77 Massachusetts Ave., Cambridge, MA 02139-4307. MIT is an Equal Opportunity/Affirmative Action Employer. (For more information about the position or institution: http://www-math.mit.edu)

WORCESTER POLYTECHNIC INSTITUTE
Department of Mathematical Sciences
Faculty Positions in
Applied Mathematics

The Worcester Polytechnic Institute (WPI) Department of Mathematical Sciences invites applications for faculty positions to begin in the fall of 2004 at the assistant professor level. Exceptionally well-qualified candidates may be considered for appointment at higher rank. An earned Ph.D. or equivalent degree is required. Successful candidates must demonstrate strong research potential and evidence of quality teaching. Applications are invited from all areas of applied and computational mathematics compatible with those represented in the department: partial differential equations, applied probability, financial mathematics, applied and computational mathematics, and discrete mathematics. WPI is a private and highly selective technological university with an enrollment of 2,700 undergraduates and about 1,100 full and part-time graduate students. Worcester, New England’s third largest city, offers ready access to the diverse economic, cultural and recreational resources of the region. The Mathematical Sciences Department has 24 tenured/tenure-track faculty and supports B.S., M.S., and Ph.D. programs in applied and computational mathematics and applied statistics. For additional information, see http://www.wpi.edu/math. Qualified applicants should send a detailed curriculum vitae, a brief statement of specific teaching and research objectives, and three letters of recommendation at least one of which addresses teaching potential, to: Math Search Committee, Mathematical Sciences Department, WPI, 100 Institute Road, Worcester, MA 01609-2280, USA. Applications will be considered on a continuing basis until all positions are filled. Review of applications will begin January 1, 2004. To enrich education through diversity, WPI is an Affirmative Action/Equal Opportunity Employer.

MICHIGAN
CENTRAL MICHIGAN UNIVERSITY
Mathematics Department Chair

The Department of Mathematics invites applications for the position of chair, beginning in fall 2004. Applicants must have a Ph.D. in mathematics, math education, statistics, or a closely related field and academic credentials qualifying for appointment at the assistant professor level. Applicants are also expected to have a strong, on-going teaching record, excellence in teaching, demonstrated administrative ability, a commitment to faculty development, effective communication skills, openness to instructional innovation, and a strong interest in the continued development of our Ph.D. program. Preference is given to candidates who have experience with successful grant writing, curriculum development, expository writing, or involvement with professional organizations.

Central Michigan University has an enrollment of 19,500, and the department has 32 tenure-track faculty. The departmental research profile is diverse, with expertise in pure and applied mathematics, mathematics education, and statistics. The department offers bachelor’s degrees in mathematics, mathematics education, statistics, actuarial science; master’s degrees in mathematics and mathematics education; and a Ph.D. in mathematics with a concentration in college teaching. Further information available at http://www.cmich.edu/units/math.

Submit letter of application, resume, copies of transcripts, statement of teaching philosophy, statement of leadership philosophy, and at least three letters of recommendation to: Search Committee, Department of Mathematics, Central Michigan University, Mt. Pleasant, MI 48859. Applications accepted and considered until position is filled. Review of applications begins November 5, 2003. CMU, an AA/EO Institution, strongly and actively strives to increase diversity within its community (see http://www.cmich.edu/aaceo).

HILLSdale COLLEGE
Hillsdale, MI
Department of Mathematics and
Computer Science

Two positions available: (1) applied mathematics and (2) mathematics.
Applications are invited for positions in applied mathematics and in mathematics. Both positions are entry-level tenure-track positions, with initial appointments made at the assistant professor level beginning in August 2004.

1. Candidates for the applied mathematics position are required to have a Ph.D. in mathematics with a specialty in applied mathematics and be willing to teach mathematical modeling, differential equations, numerical analysis, and vector analysis in addition to other undergraduate mathematics courses.

2. Candidates for the mathematics position are required to have a Ph.D. in mathematics and be willing to teach various undergraduate mathematics courses.

Candidates for either position must have a strong commitment to excellence in teaching undergraduate mathematics. Duties for each position include a 12-hour (three course) teaching load per semester, which will include teaching all levels of undergraduate mathematics, academic advising, college service, and continued mathematical activity.

Hillsdale College, founded in 1844, is an independent, coeducational four-year liberal arts college of 1,200 students. Hillsdale has traditionally upheld two concepts: academic excellence and institutional independence. For additional college information visit our website: http://www.hillsdale.edu.

Send a letter of application that includes a personal statement addressing the applicant’s teaching philosophy and qualifications for the position, curriculum vitae, graduate transcript, a short summary of teaching evaluations, and at least three letters of recommendation to: Professor Mark J. Watson, Chair, Department of Mathematics and Computer Science, Hillsdale College, Hillsdale, MI 49242. Review of applications will begin November 1, 2003, and will continue until the positions are filled or closed. EOE.

MICHIGAN STATE UNIVERSITY
East Lansing, MI 48824
proMSc Program in
Industrial Mathematics

Direct your students toward one of the professional M.Sc. programs. Industry needs business-savvy mathematicians. See http://www.scientomasters.com/.

UNIVERSITY OF MICHIGAN
Department of Mathematics

Pending authorization, the department anticipates having one or more openings at the tenure-track or tenure level. Candidates should hold a Ph.D. in mathematics or a related field, and should show outstanding promise and/or accomplishments in both research and teaching. Applications are encouraged from any area of pure, applied, computational, or interdisciplinary mathematics, including mathematics education, mathematical biology, theoretical computer science, scientific computation, and actuarial or finan-
cial mathematics. Salaries are competitive and are based on credentials. Applicants should send a CV, bibliography, descriptions of research and teaching experience, and have three or four letters of recommendation, at least one of which addresses the candidate’s teaching experience and capabilities, sent to: Personnel Committee, University of Michigan, Department of Mathematics, 2074 East Hall, Ann Arbor MI 48109-1109. Applications are considered on a continuing basis but candidates are urged to apply by November 1, 2003. Inquiries may be made by email to: math-fac-search@umich.edu. More detailed information regarding the department may be found on our Website: http://www.math.lsa.umich.edu. Women and minority candidates are encouraged to apply. The university is responsive to the needs of dual career couples.

MINNESOTA

UNIVERSITY OF MINNESOTA-MINNEAPOLIS
School of Mathematics

Dunham Jackson Assistant Professor

This is a three-year appointment from fall semester, 2004, through spring semester, 2007, with a teaching load of three one-semester courses per academic year. Outstanding research and teaching abilities are required. Preference will be given to applicants whose research interests are compatible with those of the school. Applicants should have received a Ph.D. in mathematics no earlier than Jan. 1, 2003, and no later than August 25, 2004. Summer school teaching may be available during the summers of 2005 and 2006 to supplement regular stipend. Salary competitive. Consideration of applications will begin December 3, 2003, and continue until available positions are filled. Send letter of application, current curriculum vitae, at least four letters of recommendation, one of which should address teaching ability, and description of research to:

Lawrence F. Gray, Head
School of Mathematics
University of Minnesota
127 Vincent Hall
206 Church Street S.E.
Minneapolis MN 55455

See also http://www.math.umn.edu.

The University of Minnesota is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, color, creed, national origin, sex, age, marital status, disability, public assistance status, veteran status, or sexual orientation.

UNIVERSITY OF MINNESOTA-MINNEAPOLIS
School of Mathematics

Tenured or Tenure-Track Positions

The School of Mathematics may have available several tenure-track assistant professor or tenured associate or full professor positions starting fall semester, 2004. Ph.D. or equivalent terminal degree in mathematics or closely related field by the beginning date of appointment, outstanding research and teaching abilities are required. Applications at all levels are invited; preference will be given to applicants whose research interests are compatible with those of the school. Salary competitive. Consideration of applications will begin December 3, 2003, and continue until available positions are filled. Send letter of application, current curriculum vitae, at least four letters of recommendation, one of which should address teaching ability, and description of research to:

Lawrence F. Gray, Head
School of Mathematics
University of Minnesota
127 Vincent Hall
206 Church Street S.E.
Minneapolis MN 55455

See also http://www.math.umn.edu.

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NEBRASKA

UNIVERSITY OF NEBRASKA-LINCOLN
Department of Mathematics

Applications are invited for two tenure-track positions and two postdoctoral positions in mathematics, starting in August, 2004, as follows: 1. One tenure-track assistant/associate professor position in algebra or discrete mathematics. Preference will be given to applicants who show strong research promise in areas of algebra or discrete mathematics that complement and extend the strengths of the department. An exceptionally qualified candidate may be appointed at the associate professor level. 2. One tenure-track assistant professor position in partial differential equations or a closely related field. Applicants must have a solid background in analysis: well-developed computational skills are highly desirable. 3. Two three-year postdoctoral (non-tenure-track) positions in mathematics. Preference will be given to applicants within three years of having received the Ph.D. who show strong research promise in one of the areas in which UNL's mathematics faculty is currently active. For all positions, use of the AMS application cover sheet is encouraged. Review of applications will begin December 15, 2003, and continue until suitable candidates are found. Successful candidates for all positions should have a Ph.D. in mathematics and outstanding potential for research and teaching in mathematics. Applicants should send a letter of application, a CV, statements addressing their research and teaching, and three or four letters of reference, at least one of which should address teaching, to:

Search Committee,
Department of Mathematics,
University of Nebraska-Lincoln,
Lincoln, NE 68588-0323

Applicants should state clearly in their cover letter which position(s) they are seeking. For more information see the department's website: http://www.math.unl.edu. The University of Nebraska is committed to a pluralistic campus community through Affirmative Action and Equal Opportunity and is responsive to the needs of dual career couples. We assure reasonable accommodation under the Americans with Disabilities Act; contact Marilyn Johnson at (402) 472-3731 for assistance.

DECEMBER 2003
NOTICES OF THE AMS 1463
NEW HAMPSHIRE

DARTMOUTH COLLEGE
John Wesley Young Research Instructorship

The John Wesley Young Instructorship is a postdoctoral two-year appointment intended for promising Ph.D. graduates with significant strengths in both research and teaching whose research interests overlap a department member’s. Recent research areas include algebra, analysis, combinatorics, geometry, logic, and set theory, number theory, probability, and topology. Instructors teach four ten-week courses distributed over three terms, though one of these terms in residence may be free of teaching. The assignments normally include introductory, advanced undergraduate, and graduate courses. Instructors usually teach at least one course in their own specialty. Nine-month salary of $44,676 supplemented each year by summer research stipends of $9,928 for instructors in residence for two months in summer. To be eligible for a 2004-06 instructorship, candidate must be able to complete all requirements for the Ph.D. degree before September 2004.

Applicants should get a copy of the application information and the required response form at http://www.math.dartmouth.edu/recruiting/. Or submit a letter of application; curriculum vitae; graduate school transcript; thesis abstract; statement of research plans and interests; and at least three, preferably four, letters of recommendation to: Donna Black, Department of Mathematics, Dartmouth College, 6188 Bradley Hall, Hanover, NH 03755-3551. At least one referee should write about applicant’s ability; at least two referees should write about applicant’s research ability. Applications received by January 5, 2004, receive first consideration; applications will be accepted until position is filled. Dartmouth College is committed to diversity and strongly encourages applications from women and minorities.

DARTMOUTH COLLEGE
Department of Mathematics

The Department of Mathematics anticipates a tenure-track opening with initial appointment in the 2004-05 academic year. The position is for an assistant professor in applied mathematics who has practical experience in statistical techniques and methods. Various applied projects in the department are currently funded by NSF, NIH, and DoD. Active collaborations with computer science, the medical and engineering schools, and programs in cognitive neuroscience exist. Collaborations and/or appointments in Dartmouth’s M.D./Ph.D. program, as well as Dartmouth’s Institute for Secure Technologies Studies, are also possible.

Candidates with several years of experience should be able to give evidence of a research program that has achieved peer-recognition and that promises future research leadership in the mathematical community. Candidates who do not have this level of experience must have demonstrated the potential for future mathematical research leadership in their Ph.D. work. In exceptional circumstances, an appointment to a higher level may be possible. Candidates for the position must be committed to outstanding teaching and interaction with students at all levels of undergraduate and graduate study and must demonstrate an exceptional potential for research. Candidates should have demonstrated practical experience in statistical techniques and methods and be eager to take responsibility for the department’s statistics offerings.

To create an atmosphere supportive of research, Dartmouth offers new faculty members grants for research-related expenses, a quarter of sabbatical leave for each three academic years in residence, and flexible scheduling of teaching responsibilities. The teaching responsibility in mathematics is two courses per quarter for two ten-week quarters or one course for each of two quarters and two courses for one quarter. The combination of committed colleagues and bright, responsive students encourages excellence in teaching at all levels.

To apply, get a copy of the application information and the required response form at http://www.math.dartmouth.edu/recruiting/. Or send a letter of application; curriculum vitae; a brief statement of research results and interests; and four letters of reference, at least one of which specifically addresses teaching, to: Donna Black, Recruiting Secretary, Department of Mathematics, Dartmouth College, 6188 Bradley Hall, Hanover, NH 03755-3551. Applications received by January 5, 2004, will receive first consideration. Dartmouth College is committed to diversity and strongly encourages applications from women and minorities. Inquiries about the progress of the selection process may be directed to Dan Rockmore, Recruiting Chair.

NEW YORK

COLGATE UNIVERSITY
Hamilton, NY

The Neil Grabois Chair in Mathematics

Colgate University announces the establishment of the Neil Grabois Chair in Mathematics. The chair will be filled at either the associate or full professor level. We are looking for someone with broad interests in the mathematical sciences, an established research reputation, and a record of excellence in teaching at the undergraduate level. The successful candidate will join a department with a strong commitment to meeting the diverse needs of its students and will have the opportunity to enrich its program in the mathematical sciences.

Candidates should submit a letter of application, a full curriculum vita with a list of publications, and three letters of reference to Professor Thomas Tucker, Chair, Department of Mathematics, Colgate University, 13 Oak Drive, Hamilton, NY 13346. Review of applications begins in December. Colgate University is an Equal Opportunity/Affirmative Action Employer. Women and minorities are strongly urged to apply. Nominations are also accepted and should be directed to Professor Tucker.

For further information about the Mathematics Department and Colgate University, see http://www.departments.colgate.edu/math.

THE COURANT INSTITUTE
AT NEW YORK UNIVERSITY
Department of Mathematics
Tenure-Track Position

The Courant Institute Department of Mathematics anticipates having a small number of faculty positions in mathematics to begin in September 2004. Appointments may be made at either a junior or senior level. These positions will be in a range of areas in computational, applied, and pure mathematics; some may be multidisciplinary appointments that are joint with a science department from the Faculty of Arts and Sciences. Applications should be addressed to: Appointments Committee, Courant Institute of Mathematical Sciences, 251 Mercer Street, New York, NY 10012.

The Courant Institute/New York University is an Equal Opportunity/Affirmative Action Employer.

OHIO

THE OHIO STATE UNIVERSITY
Department of Mathematics

The Department of Mathematics of the The Ohio State University expects to have tenure-track/tenured positions and several visiting positions available, effective autumn quarter 2004. Candidates in all areas of pure and applied mathematics are invited to apply. A Ph.D. in mathematics, significant mathematical research accomplishment, and evidence of excellent teaching ability are required.

The department will also have several Hans J. Zassenhaus Assistant Professorships and VIGRE Arnold Ross Assistant Professorships available. These term positions are renewable annually for up to
a total of three years. Candidates are expected to have a Ph.D. in mathematics and to present evidence of excellence in research and teaching.

Please send a CV and at least three letters of recommendation to: Advisory Committee Department of Mathematics The Ohio State University 231 W. 18th Avenue Columbus, OH 43210 Applications are considered on a continuing basis, but the review process begins November 17, 2003. Please direct inquiries to facultysearch@math.ohio-state.edu.

The Ohio State University is an Equal Opportunity/Affirmative Action Employer. Women, minority, veterans, and individuals with disabilities are encouraged to apply.

UNIVERSITY OF DAYTON Department of Mathematics

Applications are invited for a tenure-track position in the Department of Mathematics at the assistant professor level starting in August 2004. Candidates must have a Ph.D. in mathematics, financial mathematics, statistics, or some related field. Preference will be given to applicants with experience in stochastic or computational methods in financial mathematics. Applicants must have a strong commitment to research and the potential to become an effective teacher. Responsibilities include teaching, mentoring, and curriculum development in support of a newly developed M.S. program in financial mathematics. Further responsibilities include teaching in a strong undergraduate major in mathematics, research, and service.

The selection process begins December 15, 2003. To receive full consideration, all materials must be received by January 14, 2004. A complete application consists of a resume, three letters of recommendation, a statement of research and professional plans, and a statement of teaching philosophy. Both teaching abilities and research abilities should be addressed in the letters of recommendation. Please include an email address in your correspondence. Send applications to: Dr. Joe Mashburn, Chair of the Mathematics Search Committee, Department of Mathematics, University of Dayton, Dayton, OH 45469-2316. Contact the search committee at joe.mashburn@notes.udayton.edu. To obtain further information, see http://www.udayton.edu/mathdept.

The University of Dayton is a private, comprehensive, Catholic university founded by the Society of Mary in 1850. It has more than 6,000 undergraduate and 3,000 graduate students. The Department of Mathematics offers the B.A. and B.S. degrees in mathematics, the B.S. degree in applied mathematical economics, and the M.S. degree in applied mathematics. The University of Dayton is an Equal Opportunity/Affirmative Action Employer. Women, minorities, individuals with disabilities, and veterans are encouraged to apply. The University of Dayton is firmly committed to the principle of diversity.

OKLAHOMA

THE UNIVERSITY OF OKLAHOMA Department of Mathematics

Applications are invited for one or more full-time, tenure-track position(s) in mathematics beginning 16 August 2004. The position(s) is initially budgeted at the assistant professor level, but an appointment at the associate professor level may be possible for a strong candidate with qualifications and experience appropriate to that rank. Normal duties consist of teaching two courses per semester, conducting research, and rendering service to the department, university, and profession at a level appropriate to the faculty member's experience. The position(s) requires an earned doctorate and research interests that are compatible with those of the existing faculty; preference will be given to applicants with experience in stochastic or computational methods. Successful candidates are expected to have a strong commitment to research and teaching. Salary and benefits are competitive. For full consideration, applicants should send a completed AMS cover sheet, curriculum vitae, a description of current and planned research, and three letters of recommendation (at least one of which must address the applicant's teaching experience and proficiency) sent to:

Search Committee Department of Mathematics The University of Oklahoma 601 Elm, PHSC 423 Norman, OK 73019-0315 Phone: 405-325-6711 fax: 405-325-7484 email: search@math.ou.edu

Screening of applications will begin on December 15, 2003, and will continue until the position(s) is filled.

The University of Oklahoma is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

OREGON

UNIVERSITY OF OREGON Department of Mathematics

Applications are invited for tenure-track assistant or associate professor positions in all areas of pure and applied mathematics, statistics, and mathematics education. Qualifications are a Ph.D. in the mathematical sciences, an excellent record of research accomplishment, and evidence of teaching ability. See http://darkwing. uoregon.edu/math/employment.html.

Competitive salary with excellent fringe benefits. Mail complete vita and at least three letters of recommendation to: Search Committee, 1222 Department of Mathematics, University of Oregon, Eugene, OR 97403-1222. Application materials may NOT be submitted electronically.

Closing date is January 5, 2004. Women and minorities are encouraged to apply. The University of Oregon is an EO/AA/ADA Institution committed to diversity.

PENNSYLVANIA

CARNEGIE MELLON UNIVERSITY Center for Computational Finance

The Center for Computational Finance expects to appoint a postdoctoral fellow in mathematical finance, beginning in September 2004. This position will be funded by Morgan Stanley and the National Science Foundation, and is contingent upon approval of the National Science Foundation funding. Applicants should have a strong record of accomplishment in probability research and a serious interest in the applications of probability to finance. This will be a two-year appointment with no teaching duties. The recipient will be expected to make short visits to Morgan Stanley during the academic year, and Morgan Stanley is expected to offer an internship in the summer between the academic years. Applicants should send a vita, list of publications, a statement describing current and planned research, and arrange to have at least three letters of recommendation sent. For full consideration, applications should be received by January 12, 2004. All communications should be addressed to: Computational Finance Postdoctoral Committee, Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213. Carnegie Mellon University is an Affirmative Action/Equal Opportunity Employer.

GETTYSBURG COLLEGE Department of Mathematics Tenure-Track Assistant Professor Position in Mathematics

Gettysburg College invites applications for one (and perhaps two) tenure-track, assistant professor positions in mathematics beginning August 2004; in exceptional cases, applicants at the associate level may also be considered. Applicants must have a Ph.D. in mathematics, applied mathematics, or statistics or expect to complete all
requirements for this degree by September 2004. Promise of excellence in teaching and commitment to a vigorous research program are essential. A successful candidate will have the opportunity to teach a broad range of undergraduate mathematics courses and to involve undergraduate students in mathematical activity outside the classroom.

Gettysburg College is a highly selective liberal arts college located within 90 minutes of the Baltimore/Washington metropolitan area. Established in 1832, the college has a rich history and is situated on a 220-acre campus with an enrollment of 2,500 students. Gettysburg College celebrates diversity and invites applications from members of any group that has been historically underrepresented in the American academy. The college assures equal employment opportunity and prohibits discrimination on the basis of race, color, national origin, gender, religion, sexual orientation, age, and disability.

Please send a letter of application explaining your interest in our department, a curriculum vitae, a brief description of your teaching methods and objectives, and a summary of your research goals to:

Mathematics Search Committee
Department of Mathematics
Gettysburg College
Gettysburg, PA 17325

Also arrange for the committee to receive three letters of recommendation addressing teaching effectiveness and research potential. Completed applications received by December 15, 2003, will receive full consideration.

MILLERSVILLE UNIVERSITY
OF PENNSYLVANIA
Department of Mathematics

Full-time, tenure-track assistant professorship to begin August 2004. Area of expertise in MATHEMATICS EDUCATION. The department, consisting of twenty faculty members and approximately 180 undergraduate majors, offers B.A. and B.S. degrees in mathematics and B.S.Ed. and M.Ed. degrees in mathematics education. Duties include an annual 24-hour teaching load, including mathematics courses for preservice elementary and secondary teachers and a variety of undergraduate mathematics service courses. Scholarly activity, student advisement, curriculum development in mathematics education at both the undergraduate and graduate levels and committee work. Doctorate (or completion by second year of reappointment) in mathematics education or in mathematics with a specialization in mathematics education is required, including at least 30 hours of graduate level courses in pure or applied mathematics. Must exhibit evidence of strong commitment to excellence in teaching and continued scholarly activity, and have familiarity with current directions in mathematics education, including technology. Must complete a successful interview and teaching demonstration. Evidence of teaching effectiveness is a primary consideration. Preference will be given to candidates with experience teaching both K-12 and college-level mathematics. Candidates must be able to work effectively with professional groups and community groups. Salary/benefits are competitive. Completed application must be received by January 20, 2004, to assure full consideration. Email applications will not be accepted. Send application letter, vita, copies of undergraduate and graduate transcripts, and three letters of reference (at least two of which attest to recent teaching effectiveness) to Dr. Dorothee Blum, Search Committee/AMS1203, Department of Mathematics, Millersville University of Pennsylvania, P.O. Box 1002, Millersville, PA 17551-0302. An Equal Opportunity/Affirmative Action Institution.

UNIVERSITY OF PITTSBURGH
Mathematics Department

The mathematics department of the University of Pittsburgh invites applications for a tenure-track position in number theory/cryptography or algebraic geometry/representation theory to begin in the fall term 2004, pending budgetary approval. The appointment is at the assistant professor level. We seek excellence in teaching and research so applicants should demonstrate substantial research accomplishment and dedication to teaching. Send a vita, three letters of recommendation, a research statement, and evidence of teaching accomplishments by December 5, 2003, to: Search Committee in Biology, Department of Mathematics, University of Pittsburgh, Pittsburgh, PA 15260. The University of Pittsburgh is an Affirmative Action, Equal Opportunity Employer. Women and members of minority groups underrepresented in academia are especially encouraged to apply.

UNIVERSITY OF PITTSBURGH
Mathematics Department
Analysis

The Mathematics Department of the University of Pittsburgh invites applications for a tenure-track position in analysis to begin in the fall term 2004, pending budgetary approval. The appointment is at the assistant professor level. We seek excellence in teaching and research, so applicants should demonstrate substantial research accomplishment and dedication to teaching. Send a vita, three letters of recommendation, a research statement, and evidence of teaching accomplishments by December 5, 2003, to: Search Committee in Analysis, Department of Mathematics, University of Pittsburgh, Pittsburgh, PA 15260. The University of Pittsburgh is an Affirmative Action, Equal Opportunity Employer. Women and members of minority groups underrepresented in academia are especially encouraged to apply.

RHODE ISLAND
BROWN UNIVERSITY
Division of Applied Mathematics
Position in Statistics and Probability

The Division of Applied Mathematics seeks applicants for a position at the tenure-track (assistant professor) or tenured (associate or full professor) level in the general areas of statistics and probability. The starting date for the position is July 1, 2004. Applicants are expected to have demonstrated outstanding high-caliber research either in theory or in the combination of theory and novel applications to life or natural sciences. Tenure applicants should have achieved international recognition and should have made first-class contributions in their specialties. Additionally, applicants for full professor should be leading figures in their fields and should be prepared to assume a leadership role in statistics and/or probability at Brown. Good communication and teaching skills are expected of all the applicants. Applicants should submit curriculum vitae, representative preprints or reprints, and a concise description of research interests and goals to:

Attn: Professor Chi-Wang Shu, Chairman
Division of Applied Mathematics
Brown University
Providence, Rhode Island 02912

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Applications may be sent either in hard form or electronically. All applications must be submitted by December 15, 2003. Brown University is an Affirmative Action/Equal Opportunity Employer. Women and minorities are encouraged to apply.

SOUTH CAROLINA

UNIVERSITY OF SOUTH CAROLINA
Department of Mathematics

Palmetto Assistant Professor applications are invited for the new Palmetto Assistant Professorship in Mathematics. This is a tenure-track position open to mathematicians who have completed a doctorate with emphasis on mathematical research and teaching. The Palmetto Assistant Professor will be hired at a base salary, and during the initial three-year appointment be given a one course per semester teaching load, and provided with a $10,000 annual supplement, half of which will be used as a salary supplement to the base salary. Assistant/associate professor applications are invited for anticipated visiting or tenure-track positions, primarily at the assistant or beginning associate professor rank. Applicants must have the Ph.D. in mathematics or related area, outstanding research credentials, and demonstrated excellence in teaching. The department seeks accomplished individuals in any field of pure or applied mathematics, but candidates in computational or discrete mathematics are especially encouraged to apply. The beginning date for all positions is August 16, 2004. A complete application should include a detailed vita with a summary of research accomplishments and goals, a completed AMS Standard Cover Sheet, and four letters of recommendation. One letter should appraise the applicant's teaching abilities. Applications may be sent either in hard copy or by email in the form of .pdf or .ps files to: Hiring Committee, Department of Mathematics, University of South Carolina, Columbia, SC 29208, e-mail:hiring@math.sc.edu. Full consideration will be given to applications received by December 15, 2003. Further information about our department can be obtained on our website http://www.math.sc.edu. The University of South Carolina is an EOE/AA Employer, and the department encourages applications from women and minorities.

UNIVERSITY OF SOUTH CAROLINA
Department of Mathematics

The Wyman L. Williams and Ernest A. and Marguerite Zeigel Hedberg Chair in Mathematics.

The Department of Mathematics at the University of South Carolina invites applications or nominations for the Wyman L. Williams and Ernest Albert and Marguerite Zeigel Hedberg Chair in Mathematics. Candidates are expected to have demonstrated excellence in both teaching and research and have a substantial record of external funding. Candidates in all areas of mathematics or applied mathematics are encouraged to apply. The Williams-Hedberg-Hedberg Professor will have a permanent position as a tenured full professor in the mathematics department at a competitive salary. The initial appointment to the chair is for three years, and is renewable. Nominations or letters of application (with a curriculum vita) should be sent to: Hiring Committee, Department of Mathematics, University of South Carolina, Columbia, SC 29208. Electronic submissions in the form of .pdf or .ps files are welcome and should be sent to: hedberg@math.sc.edu. Applications will be accepted until the position is filled. Full consideration will be given to applications received by January 31, 2004.

Professor of Mathematics and Director of the Industrial Mathematics Institute.

Applications are invited for the position of Director of the Industrial Mathematics Institute (IMI) within the Department of Mathematics of the University of South Carolina. The appointee will possess a distinguished record of scholarship in the mathematical sciences, a strong record of external grant funding, and superior management skills. The successful candidate will hold the rank of full professor with tenure within the Department of Mathematics and in addition will assume the Directorship of the Industrial Mathematics Institute for an initial three-year term. Applicants should send a curriculum vitae with a cover letter and arrange to have at least four letters of recommendation sent to: IMI Director Search Committee, Department of Mathematics, University of South Carolina, Columbia, SC 29208. Electronic submissions in the form of .pdf or .ps files should be sent to: imi@math.sc.edu. Applications will be screened beginning January 31, 2004. Nominations for this position are also welcome. Further information about our department and the IMI can be obtained on our website http://www.math.sc.edu. The University of South Carolina is an EOE/AA Employer, and the department encourages applications from women and minorities.

TAMU UNIVERSITY
Department of Mathematics

Applications are invited for tenure-track assistant professor positions beginning in fall 2004. Higher level appointments are possible in exceptional cases. The Department encourages applications from women and members of underrepresented minority groups.

TEXAS UNIVERSITY
Mathematics Department

Applications are invited for a tenure-track position in the Department of Mathematics at the rank of assistant professor. Candidates should have extremely strong research potential and very good teaching skills.

Send a curriculum vitae to: Appointment Committee, Department of Mathematics, Rice University, P.O. Box 1892, Houston, TX 77251-1892. In addition, please solicit at least three letters of recommendation and ask that they be sent directly to the address above. Submission of the AMS Application Cover Sheet would be greatly appreciated.

RICE UNIVERSITY
Mathematics Department

Applications which are complete by December 1, 2003, will be assured full consideration.

Rice University is an Equal Opportunity/Affirmative Action Employer and strongly encourages applications from women and members of underrepresented minority groups.

TEXAS TECH UNIVERSITY
Department of Mathematics and Statistics

Applications are invited for up to three tenure-track assistant professor positions beginning fall 2004. Higher level appointments are possible in exceptional cases. For one position, priority will be given to candidates in the areas of applied mathematics and computation with research interests that complement existing departmental research areas.
For the other positions, all areas will be considered. Candidates whose mathematical or statistics background and scholarly activities have, or have shown, excellent potential for interdisciplinary collaboration are encouraged to apply.

Strong promise or accomplishment in teaching and scholarly activity and a Ph.D. degree at the time of appointment are required. Texas Tech University is committed to diversity among its faculty. Please send a resume, a completed AMS standard cover sheet and three letters of recommendation to: Professor Wayne Lewis, Hiring Committee Chair, Dept. of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409-1042.

Review of applications will begin immediately. Further information is available at http://www.math.ttu.edu/~plewis/hiring.html.

Texas Tech is an AA/EO Employer.

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Texas Christian University
Fort Worth, TX
Department of Mathematics

Applications are invited for a tenure-track assistant professor. All areas of pure mathematics will be considered, with preference for algebraic geometry, complex and harmonic analysis, global analysis, operator algebras, or number theory. Qualifications include a Ph.D. in mathematics, excellent research potential, and a record of outstanding teaching.

Candidates should submit: (a) An AMS cover sheet; (b) a complete vita, including a list of publications; (c) a research plan; (d) a teaching statement, and (e) at least five letters of recommendation, two of which address the candidate's teaching. Materials should be sent to: Bob Doran, Chair, Department of Mathematics, TCU Box 29999, Fort Worth, TX 76129.

A preliminary closing date is January 5, 2004. Interviews will be conducted at the AMS winter meeting in Phoenix. However, the position will remain open until filled.

Texas Christian University is a major teaching and research university of approximately 7000 students. The university is located in the Dallas-Fort Worth metroplex, a vibrant metropolitan area of five million people. TCU does not discriminate in admissions or hiring on the basis of religion. Women and minorities are encouraged to apply. TCU is an EO/AA/ADA institution committed to diversity.

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THE UNIVERSITY OF TEXAS AT AUSTIN
Austin, TX 78712
Department of Mathematics

Expected openings for fall 2004 include:
(a) Instructorships, some that have R.H. Bing Faculty Fellowships attached to them and others that are VIGRE Instructorships, and (b) four 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 25, 2005. Other factors being equal, preference will be given to those whose doctorates were conferred in 2003 or 2004. Candidates should show superior research ability and have a strong commitment to teaching.

(b) An applicant for a tenure-track 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 M.A. or 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 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 email (address: recruit@math.utexas.edu) is encouraged.

All applications must be supported by three or more letters of recommendation, at least one of which speaks to the applicant's teaching credentials. The screening of applications will begin on December 1, 2003. The University of Texas at Austin is an Equal Opportunity Employer.

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UNIVERSITY OF TEXAS-PAN AMERICAN
Department of Mathematics

The Department of Mathematics, chaired by Professor Lokenath Debnath, invites applications for at least one tenure-track assistant professor position, possibly three, pending approval. Particular attention will be given to the areas of Mathematics Education, probability and statistics, applied mathematics, and combinatorial mathematics, but all areas of mathematics and mathematical sciences will be considered. All positions are to be filled effective fall 2004. Successful candidates will develop a strong research program and have a strong commitment to excellence in teaching and professional service. A doctorate in mathematics education, statistics, mathematics or related area by the date of employment is required. Review of applications will begin December 15, 2003, and continue until the position(s) is/are filled. Salary is competitive and commensurate with qualifications. Additional information about the Department of Mathematics, UTPA, and these positions may be obtained from the website http://www.math.panam.edu. Women and minorities are encouraged to apply.

The University of Texas-Pan American is an Equal Opportunity/Affirmative Action Employer. Completed applications must include a vita, three letters of recommendation, all higher education transcripts, and summaries of research and teaching philosophies. Send to: Dr. John Emil Thomas, Bernard, Ph.D., Search Committee Chair, Department of Mathematics, University of Texas-Pan American, 1201 W. University Drive, Edinburg, Texas 78541-2999. Tel: (956) 381-3452, Fax: (956) 384-5001. Note: This position is security-sensitive and subject to Texas Education Code 51.215, which
The successful applicant will have an outstanding research record, will be expected to interact with related groups at UBC, and will have demonstrated interest and ability in teaching. Applicants should send a current CV including a list of publications and a statement of research and teaching interests, and arrange for three letters of recommendation to be sent to the following address:

Chair, departmental committee on appointments
Department of Mathematics
University of British Columbia
#121 - 1984 Mathematics Road
Vancouver, B.C. Canada V6T 1Z2

The deadline date for applications is Jan. 15, 2004.

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The Department of Applied Mathematics, University of Waterloo, invites applications for a tenure-track faculty position in the field of scientific computation and computational mathematics, to begin on or after July 1, 2004. The position is at the assistant professor level and salary will be commensurate with experience and research record (in exceptional cases, an appointment at a higher level may be possible). Applicants should have as their primary interest the development and analysis of algorithms for the effective computer solution of fundamental problems in science and engineering. We are particularly interested in applicants whose area of application is in biomechanics, control theory, mathematical imaging, mathematical biology or stochastic processes, although exceptionally qualified applicants in other areas may also be considered. Candidates should show evidence of outstanding potential in research and should have a strong mathematical background. We are looking for applicants with enthusiasm for the supervision of graduate students and for teaching at both the undergraduate and graduate levels. Applicants are asked to send a current curricular vitae (including a statement of research interests and teaching philosophy) and the names and addresses of at least three referees to: J. Wainwright, chairman, Department of Applied Mathematics, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1. The deadline for receiving applications is December 1, 2003. Applications received after this date will be considered only if the position has not been filled.
expansion will include the creation of a Centre for Computational Mathematics in Industry & Commerce, which will oversee the recently introduced program in Computational Mathematics at the undergraduate level, and a significant growth in graduate studies in the area.

The Department of Applied Mathematics, together with the Departments of Combinatorics & Optimization, Pure Mathematics, Statistics & Actuarial Science and the School of Computer Science, form the Faculty of Mathematics, which is a major centre for research in the mathematical sciences. There are also close collaborations with the Faculties of Engineering and Science in the University and with the nearby Perimeter Institute of Theoretical Physics. Further information about the department may be obtained from our webpage at http://www.math.uwaterloo.ca/Applied/Maths/dept/index.shtml.

The University of Waterloo encourages applications from all qualified individuals, including women, members of visible minorities, native peoples, and persons with disabilities. All qualified candidates are encouraged to apply; however, Canadian citizens and permanent residents will be given priority. This appointment is subject to the availability of funds.

**UNIVERSITY OF WATERLOO**
Department of Applied Mathematics
Tenure-Track Position in Mathematical Physics

Applications are invited for a tenure-track faculty position in the Department of Applied Mathematics at the University of Waterloo, in the field of Mathematical Physics, to begin on or after July 1, 2004. The position is at the assistant professor level and salary will be commensurate with experience and research record (in exceptional cases, an appointment at a higher level may be possible). We are particularly interested in applicants in the areas of quantum theory (preferably, but not limited to, quantum information theory) or statistical physics. Candidates should show evidence of outstanding potential in research and should have a strong background in both mathematics and physics. We are looking for applicants with enthusiasm for the supervision of graduate students and for teaching at both the undergraduate and graduate level. Waterloo is developing into a very active and large centre for research in mathematical physics. In particular, the successful applicant may be considered for an Associate Membership at the independent Perimeter Institute for Theoretical Physics (http://www.perimeterinstitute.ca). The successful applicant may also become a member of the Institute for Quantum Computation at the University of Waterloo. Applicants should send a curriculum vitae (including a statement of research interests and teaching philosophy) and the names and addresses of at least three referees to: J. Wainwright, chairman, Department of Applied Mathematics, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1. The deadline for receiving applications is January 15, 2004. Applications received after this date will be considered only if the position has not been filled.

The Department of Applied Mathematics is part of the Faculty of Mathematics, which is a major centre for research in the mathematical sciences. The Faculty also includes the Department of Pure Mathematics, the Department of Combinatorics and Optimization, the Department of Statistics and Actuarial Science, as well as the School of Computer Science. We maintain close ties with the faculties of science and engineering regarding both research and teaching, and we offer a joint undergraduate program in mathematical physics with the Department of Physics. Further information about the department may be obtained from our webpage at http://www.math.uwaterloo.ca/Applied/Maths/dept/index.shtml.

The University of Waterloo encourages applications from all qualified individuals, including women, members of visible minorities, native peoples, and persons with disabilities. All qualified candidates are encouraged to apply; however, Canadian citizens and permanent residents will be given priority. This appointment is subject to the availability of funds.

**PORTUGAL**

**INSTITUTO SUPERIOR TÉCNICO**
1049-001 Lisboa, Portugal
Departamento de Matemática Postdoctoral Positions

The Center for Mathematical Analysis, Geometry, and Dynamical Systems of the Department of Mathematics of Instituto Superior Técnico, Lisbon, Portugal, invites applications for postdoctoral positions for research in mathematics, subject to budgetary approval. Positions are for one year, with the possibility of extension for a second year upon mutual agreement. Selected candidates will be able to take up their positions between September 1, 2004, and January 1, 2005.

Applicants should have a Ph.D. in mathematics preferably obtained after December 31, 2001. They must show very strong research promise in one of the areas in which the mathematics faculty of the Center is currently active. There are no teaching duties associated with these positions.

Applicants should send a curriculum vitae; reprints, preprints and/or dissertation abstract; description of research project (of no more than 1,000 words); and three letters of reference to be sent directly to the director at the above address.

To ensure full consideration, complete application packages should be received by January 15, 2004. Additional information about the Center and the positions is available at: http://www.math.ist.utl.pt/cam/.

**SINGAPORE**

**NATIONAL UNIVERSITY OF SINGAPORE**
Department of Mathematics

The Department of Mathematics at NUS invites applications for tenure-track and visiting positions beginning August 2004. We seek promising young scholars as well as established researchers in all areas of pure and applied mathematics, but we are particularly interested in candidates for financial mathematics, computational biology, scientific computing, and operations research.

Application materials should be sent to:

Department of Mathematics
National University of Singapore
2 Science Drive 2, Singapore 117543
Republic of Singapore
Fax: +65 6779 5452

and should include: (1) an American Mathematical Society Standard Cover Sheet; (2) a detailed CV, including publications list; (3) a statement of research accomplishments and plans; (4) at least three letters of recommendation, including one which indicates the candidate’s effectiveness and commitment to teaching. Inquiries may be sent via email to search@math.nus.edu.sg. Review of applications will begin December 15, 2003, and will continue until positions are filled. For further information about the department, please see http://www.math.nus.edu.sg.

**TAIWAN**

**NATIONAL CHIAO TUNG UNIVERSITY**
Department of Applied Mathematics

Applications are invited for regular or visiting positions of all levels (assistant professors and above) beginning August 2004. All areas of pure and applied mathematics are considered. Applicants should hold Ph.D. (by August 2004) in mathematics or related field and demonstrate strong research potential. The usual language of instruction is Mandarin.

Send letter of application, curriculum vitae, research plans, three recommendation letters, transcripts of graduate work (for recent graduates), etc. to:

Hiring Committee
Department of Applied Mathematics
National Chiao Tung University
Hsinchu 300, Taiwan
Full consideration to applications received by February 15, 2004.

The department is one of the leading research centers in Taiwan, with 23 faculty members in combinatorics, differential equations, differential geometry, dynamical systems, financial mathematics, functional analysis, Lie theory, mathematical physics, number theory, operator theory, probability theory, and scientific computation. Visit the website http://www.math.nctu.edu.tw/ for more details.

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
DHAHRAN, SAUDI ARABIA
College of Sciences - Department of Mathematical Sciences

Senior Tutor for Mathematics Learning Center

The Mathematics Learning Center (MLC) invites applications for faculty positions of a Senior Tutor. The primary work is to assist the MLC Director in providing a wide range of support and enough learning resources to help students, especially at the orientation level, meet their mathematical challenges through self learning and good study habit that will help them overcome their mathematical difficulties. He will be expected to conduct Remedial Classes and Problem Solving for small group and on an individual basis.

A Ph.D. in Mathematics or Mathematics Education is required.

Candidates will be assessed on excellence in teaching, previous work in a similar Center, and fluency in English.

Salary/Benefits: Two-year renewable contract. Competitive salaries based on qualifications and experience. Free furnished air-conditioned on-campus housing unit with free essential utilities and maintenance. The appointment includes the following benefits according to the University’s policy: air ticket to Dammam on appointment; annual repatriation air tickets for up to four persons; assistance with local tuition fees for school-age dependent children; local transportation allowance; two months’ paid summer leave; end-of-service gratuity. KFUPM campus has a range of facilities including a medical and dental clinic, an extensive library, computing, research and teaching laboratory facilities and a recreation center.

To apply: Mail, fax or e-mail cover letter and detailed CV/Resume (including a list of research and teaching activities) and e-mail address of three professional references to:
Dean, Faculty & Personnel Affairs,
KFUPM Box 5005, Dhahran 31261, Saudi Arabia
DEPT.No.: MATH/MLC-2369 Fax: 966-3-860-2429
E-Mail: faculty@kfupm.edu.sa or mlc@kfupm.edu.sa

Please quote the above DEPT. REF No. in all correspondence. For additional information, please visit our website: http://www.kfupm.edu.sa/fpa/
International Mathematics Research Notices

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AIMS AND SCOPE

IMRN provides very fast publication of research articles of high current interest in all areas of mathematics. All articles are fully refereed and are judged by their contribution to advancing the state of the science of mathematics. Issues are published as frequently as necessary. IMRN will publish 80± issues in volume 2004. The articles of the IMRN are reviewed/indexed in COMPUMATH Citation Index, Current Contents, Mathematical Reviews, Science Citation Index, SciSearch, and Zentralblatt für Mathematik.

INSTRUCTIONS FOR AUTHORS

IMRN is devoted to advancing the state of the science of mathematics by publishing research articles of high current interest in all fields of mathematics. Articles of any length are welcome and all articles are refereed and judged for correctness, interest, originality, depth, and applicability. Illustrations can be in color. There are no page charges. Each author shall receive 50 complimentary reprints with covers. Submissions are made by email to submit@imrn.hindawi.com. An abstract for each article should be included. A copy may also be sent to an editor. Only an acknowledgment from the editorial office officially establishes the date of receipt. Submissions not prepared using LaTeX should be typed or printed on one side of the page, be double-spaced (including references), have ample margins, and be accompanied by a page that lists all potentially ambiguous notations. Check contact information for submission by fax or post. When articles are accepted, production begins immediately; authors should be available to assist the editorial staff.

FORTHCOMING ARTICLES

- A Differential Inequality for the Isoperimetric Profile, Vincent Bayle
- A Proof of the q,t-Schröder Conjecture, J. Haglund
- Diagonal Coinvariants and Double Affine Hecke Algebras, Ivan Cherednik
- Hyperbolic Volume of Representations of Fundamental Groups of Cusped 3-Manifolds, Stefano Francaviglia
- Mirković-Vilonen Cycles and Polytopes in Type A, Jared Anderson and Mikhail Kogan
- Monopole Classes and Einstein Metrics, D. Kotschick
- On the Distribution of Lattice Points in Thin Annuli, C. P. Hughes and Z. Rudnick
- On the Local Severi Problem, V. V. Shevchishin
- Path Model for Quantum Loop Modules of Fundamental Type, Jacob Greenstein and Polynoniu Lamprou
- Periodic Orbits for Exact Magnetic Flows on Surfaces, Gonzalo Contreras, Leonardo Macarini, and Gabriel P. Paternain
- Projective Complete Cohomological Dimension of a Group, Jang Hyun Jo
- Quasideterminants and Casimir Elements for the General Linear Lie Superalgebra, Alexander Molev and Vladimir Retakh
- Remarks on Zeta Regularized Products, Kazufumi Kimoto and Masato Wakayama
- Vanishing of Cohomology Associated to Quantized Drinfeld-Sokolov Reduction, Tomoyuki Arakawa

SUBSCRIPTION INFORMATION

Institutional subscription rates for volume 2004 (80± issues) are $2395 for print or online and $2874 for print and online. New print subscribers shall receive a free copy of all back volumes, i.e., volumes 1991–2003. New and current online subscribers shall receive “perpetual” online access to volumes 1991–2004. Please contact orders@hindawi.com for more information.
Topics include normal operators, analytic functions of operators, invariant subspace lattices, compact operators, invariant and hyperinvariant subspaces, von Neumann algebras, transitive operator algebras, and algebras associated with invariant subspaces. 1973 ed. New Appendix on Recent Developments. xii+292 pp. 5½ x 8½. 42998-7 $16.95

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   Ed. by Dept. of Math., Tokyo Inst. of Technology
   vol. 173-176 (4 issues) $242

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BOOLEAN REASONING: The Logic of Boolean Equations, Frank Markham Brown. Concise text consists of an overview of elementary mathematical concepts; outlines theory of Boolean algebras; defines operators for elimination, division, and expansion; covers syllogistic reasoning, solution of Boolean equations, and functional deduction. 1990 ed. 18 figures. 19 tables. xii-292pp. 5½ x 8½. 42785-4 $16.95

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Send to: Dover Publications, Dept. #SA03 56 31 E. 2nd St., Mineola, NY 11501.
Introduction to Vertex Operator Algebras and Their Representations

J. LEPOWSKY and H. LI, both, Rutgers University, Piscataway, NJ

This book introduces the reader to the theory of vertex operator algebras and covers the basic techniques and examples. Beginning with a detailed presentation of the theoretical foundations and preceding to a range of applications, the text features a number of original results and brings fresh perspective to the work of many researchers. The concept of a “representation” of a vertex (operator) algebra is treated in detail; this approach is used to construct important families of vertex (operator) algebras and their modules. Requiring only a familiarity with basic algebra, this book will be useful for graduate students and researchers in mathematics and physics.

2003/APPROX. 265 PP., 10 ILLUS./HARDCOVER/$74.95 (TENT.) ISBN 0-8176-3404-8

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This Sunyer Prize-winning monograph is the first self-contained treatment of the theory of Hamiltonian reduction in the presence of singularities. It features a comprehensive examination of the connection between symmetries and reduction, treating in full detail the singular case using conservation laws. The exposition reviews all the necessary prerequisites, followed by a discussion of momentum maps and the geometry of conservation laws. The Weil-Beukers-Steinberg normal form is then presented, and the last part of the book is devoted to advanced topics. Various research directions are noted throughout, and an extensive bibliography and index complete this work, which is suitable as a reference or text for graduate courses and seminars in Lie theory and mathematical physics.

2003/APPROX. 370 PP., 10 ILLUS./HARDCOVER/$59.95 (TENT.) ISBN 0-8176-4307-7

PROGRESS IN MATHEMATICS

Lie Theory

Lie Algebras and Representations

J-P. ANKER, Université d'Orléans, Orleans, France, and
B. ORSTED, University of Southern Denmark, Odense, Denmark (Eds.)

Three volumes, under the title Lie Theory, feature survey work and original results by well-established researchers in key areas of semisimple Lie theory. A wide spectrum of topics is treated, with emphasis on the interplay between representation theory and the geometry of adjoint orbits for Lie algebras over fields of possibly finite characteristic, as well as for infinite-dimensional Lie algebras. Also covered is unitary representation theory and branching laws for reductive subgroups, an active part of modern representation theory. Finally, there is a discussion of compactifications of symmetric spaces, number theory via Selberg's trace formula, and harmonic analysis through a far-reaching generalization of Harish-Chandra's Plancherel formula for semisimple Lie groups. Ideal for graduate students and researchers, Lie Theory provides a broad examination of semisimple Lie groups and their importance to many branches of mathematics.

2003/APPROX. 352 PP., 10 ILLUS./HARDCOVER/$89.95 (TENT.) ISBN 0-8176-3257-1

PROGRESS IN MATHEMATICS
Computational Science and Engineering

The conventional theory-experiment basis for scientific inquiry has expanded to include simulation, especially of complex phenomena, which is an increasingly important component of many pursuits. Every order-of-magnitude increase in computing power allows new science to be addressed by scientific simulation and expands the application of computation in the experimental arena. Adding to its strong foundations in experimental and theoretical science, the California Institute of Technology (Caltech) has long been engaged in the development and exploitation of computation as an indispensable adjunct. At present, a significant fraction of scientific research at Caltech relies on large-scale distributed computing, scalable algorithms and data structures, the recording, handling, processing, and visualization of large data sets, and the organization of, and access to, large data bases. These and related endeavors in applied mathematics and computer science are recognized as an area of research in its own right: Computational Science and Engineering (CSE).

Caltech is initiating an Institute-wide program in CSE, hosted by the Division of Engineering and Applied Science (E&AS), which will coordinate the academic and research activities in CSE that transcend disciplinary boundaries. A goal of this program is to advance the tools of CSE, and further integrate them into fundamental science across the Institute.

Applications are solicited for two professorial positions. The emphasis of this search is on applicants with a record in fundamental CSE research and its applications. While the preference at this time is to make junior tenure-track appointments, serious consideration will be also given to eminent scholars in CSE at the tenured level. The successful candidates will be expected to lead the establishment of a research and educational program in CSE fundamentals that has connections to applications and the broad research missions of the Institute. Areas of significant interest include (but are not limited to) development and analysis of scalable distributed algorithms, grid-based computing, large-scale visualization, and data mining.

Caltech’s research programs are organized along Divisional lines and faculty receive appointments in one or more of these divisions. The six Divisions are Biology, Chemistry and Chemical Engineering, Engineering and Applied Science, Geology and Planetary Science, Humanities and Social Sciences, and Physics, Mathematics and Astronomy. The Division of Engineering and Applied Science hosts active research groups in Applied and Computational Mathematics, Computer Science as well as significant research activities in areas closely allied with CSE, often across Divisional boundaries. It is anticipated that successful applicants will be appointed in the Division of Engineering and Applied Science but, if appropriate, may hold a joint appointment in another Caltech Division. They will also participate actively in the Institute-wide CSE program which is currently under development.

The term of the initial appointment is normally four years, and appointment is contingent upon completion of the Ph.D. degree. Applicants should include a statement of research accomplishments and objectives, their Curriculum Vitae, copies of three papers that best describe their research, as well as a list of suggested references and should have three letters of recommendation sent to the address below.

Applications must be initiated online at www.cse.caltech.edu/search. Hard copy materials associated with an application should be sent to:

CSE Search Committee
Caltech 08-31
Pasadena, CA 91125

Caltech is an Equal Opportunity/Affirmative Action Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.
Cosponsored Conferences

AAAS Meeting to Offer Strong Mathematics Program

The 2004 Annual Meeting of the American Association for the Advancement of Science, February 12–16, in Seattle, WA, will feature many outstanding expository talks by prominent mathematicians. These include the following three-hour symposia (and organizers) sponsored by Section A (Mathematics) of the AAAS:

• The Convergence of Computer Graphics and Computer Vision (P. Anandan and Jim Kajiya, Microsoft Research)
• Optimal Stent Design for Cardiovascular Intervention (Suncica Canic, University of Houston)
• Phase Transitions in Computer Science (Allon Percus, Institute for Pure and Applied Mathematics)
• The Changing Nature of Proof in Mathematics: Past, Present, Future (Warren Page, City University of New York)
• Community Structure of the Internet and WWW (Jennifer Tour Chayes, Microsoft Research)

Other symposia that will be of interest to the mathematical community include:

The Rise of Machine Learning
What Progress Have We Made in Integrating Technology into Teaching and Learning?
Wavelet-Based Statistical Analysis of Multiscale Geophysical Data
Forum for School Science: Preparation of Science and Mathematics Teachers
Bioterrorism Policy and Quantitative Methods
Modeling and Risk Assessment
21st Century Photonics
Intellectual Property and the Research Exemption: Its Impact on Science

The above symposia are only a few of the 150 or so AAAS program offerings in the physical, life, social, and biological sciences. For further details about the 2003 AAAS program, see the October 17, 2003, issue of Science.

AAAS annual meetings are the showcases of American science, and they encourage participation by mathematicians and mathematics educators. (AAAS acknowledges the generous contributions of AMS for travel support and SIAM for support of media awareness.) In presenting mathematics-related themes to the AAAS Program Committee, I have found the committee to be genuinely interested in offering symposia on mathematical topics of current interest. Thus, Section A's committee seeks organizers and speakers who can present substantial new material in an accessible manner to a large scientific audience. Toward this end, I invite you to attend our Section A Committee business meeting 7:45 p.m.–10:45 p.m. Friday, February 13, 2004, at the Sheraton Seattle Hotel (room to be determined). I invite you also to send me, and encourage your colleagues to send me, symposia proposals for future AAAS annual meetings.

—Warren Page, secretary of Section A of the AAAS
wxpny@aol.com
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/. Programs and abstracts will continue to be displayed on the AMS website in the Meetings and Conferences section until about three weeks after the meeting is over. Final programs for Sectional Meetings will be archived on the AMS website in an electronic issue of the Notices as noted below for each meeting.

Bangalore, India

India Institute of Science

December 17–20, 2003
Wednesday - Saturday

Meeting #992
First Joint AMS-India Mathematics Meeting
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: October 2003
Program first available on AMS website: Not applicable
Program issue of electronic Notices: Not applicable
Issue of Abstracts: Not applicable

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses

R. Balasubramanian, Institute for Mathematical Sciences, Title to be announced.
George C. Papanicolaou, Stanford University, Title to be announced.
M. S. Raghunathan, Tata Institute of Fundamental Research, Title to be announced.
Peter Sarnak, Princeton University and New York University-Courant Institute, Title to be announced.
K. B. Sinha, Indian Statistical Institute, Title to be announced.
Vladimir Voevodsky, Institute for Advanced Study, Title to be announced.

Special Sessions
Algebraic and Geometric Topology, Parameswaran Sankaran, Institute of Mathematical Sciences, and P. B. Shalen, University of Illinois.
Automorphic Forms and Functoriality, James Cogdell, Oklahoma State University, and T. N. Venkataramana, Tata Institute of Fundamental Research.
Cycles, K-Theory, and Motives, Eric M. Friedlander, Northwestern University, Steven Lichtenbaum, Brown University, Kapil Paranjape, Institute of Mathematical Sciences, and Vasudevan Srinivas, Tata Institute of Fundamental Research.
Differential Equations and Applications to Population Dynamics, Epidemiology, Genetics and Microbiology, Bindhyachal Rai, University of Allahabad, Sanjay Rai, Jacksonville University, Terrance Quinn, Ohio University Southern, and Sunil Tiwari, Sonoma State University.
L-Functions, Automorphic Forms and Cryptography, 
R. Balasubramanian, Institute of Mathematical Sciences, and 
K. Soundararajan, University of Michigan.

The Many Facets of Linear Algebra and Matrix Theory, 
Richard Brualdi, University of Wisconsin, and 
Rajendra Bhatia, Indian Statistical Institute.

PDE and Applications, Susan B. Friedlander, University of 
Illinois, and P. N. Srikanth, Tata Institute of Fundamental 
Research.

Probability Theory, Rajeeva Karandikar, Indian Statistical 
Institute, and 
Srinivasa R. S. Varadhan, New York University-Courant Institute.

Quantum Dynamics, William Arveson, University of California 
Berkeley, and B. V. Rajarama Bhat, Indian Statistical 
Institute.

Reductive Groups: Arithmetic, Geometry and Representation 
Theory, Vikram Mehta and R. Parimala, Tata Institute of Fundamental 
Research, and 
Gopal Prasad, University of Michigan, Ann Arbor.

Spectral and Inverse Spectral Theories of Schrödinger 
Operators, Peter David Hislop, University of Kentucky, and 
Krishna Maddaly, Institute of Mathematical Sciences.

Phoenix, Arizona
Phoenix Civic Plaza

January 7–10, 2004
Wednesday – Saturday

Meeting #993
Joint Mathematics Meetings, including the 110th Annual 
Meeting of the AMS, 87th Annual Meeting of the Mathem­
atical Association of America (MAA), annual meetings of 
the Association for Women in Mathematics (AWM) and the 
National Association of Mathematicians (NAM), 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 2003
Program first available on AMS website: November 1, 2003
Program issue of electronic Notices: January 2004
Issue of Abstracts: Volume 25, Issue 1

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: 
Expired
For abstracts: Expired
For summaries of papers to MAA organizers: Expired

AMS Program Updates
The Gibbs Lecture on Wednesday evening, given by Eric 
Lander, will be on Biology as information.

The Retiring Presidential Address on Thursday after­
noon, given by Hyman Bass, will be on Mathematics, math­
ematicians, and mathematics education.

MAA Program Updates
NCATE and the Mathematics Community, Wednesday, 
3:45 p.m. to 5:15 p.m., organized by Judith L. Covington, 
Louisiana State University-Shreveport and Marilyn L. Hala, 
National Council of Teachers of Mathematics (NCTM). 
The purpose of this session is to get feedback from the 
mathematics community on the proposed new mathematics 
guidelines for NCATE (National Council for Accreditation 
of Teacher Education) accreditation. Someone will be pre­
tend to discuss the new changes and to get feedback from 
the audience. The panel is sponsored by the MAA Com­
mittee on the Mathematics Education of Teachers (COMET) 
and NCTM.

A Fresh Start for Collegiate Mathematics, Wednesday, 
4:30 p.m. to 6:00 p.m., organized by Nancy Baxter Hast­
ings, Dickinson College and Sheldon P. Gordon, Farm­
ingdale State University of New York. The MAA has 
launched a new initiative, in cooperation with NCTM and 
AMATYC, to refocus the courses below calculus to provide 
the meaning and experiences to all students. This in­
volves a greater emphasis on conceptual understanding 
and realistic applications via mathematical modeling. As part 
of this movement, the MAA is publishing a collection of 
some fifty articles on different aspects of the issues 
related to courses such as college algebra and precalculus. 
Some of the major themes include reforming college 
algbera, precalculus and related courses, research on stu­
dent learning, the transition from high school, the needs 
of other disciplines, implications of technology, imple­
mentation issues, and projects that work. In this presen­
tation, the four editors of the volume will present overviews 
of the issues and the points made by the authors. Panelists 
include Nancy Baxter Hastings, Dickinson College; Shel­
don P. Gordon, Farmingdale State University of New York; 
Florence S. Gordon, New York Institute of Technology; and 
Jack Y. Narayan, SUNY at Oswego, who will act as mod­
erator.

Environmental Mathematics SIGMAA Business Meet­
ing and Invited Address, Thursday, 5:45 p.m. to 6:45 
p.m., organized by Ben Fusaro, Florida State University. 
Marcia Sward, former executive director of the MAA, will 
speak on Assessing America’s Energy IQ. Findings from 
a recent survey conducted by the National Environmental 
Education and Training Foundation will be presented.

Presentations by Teaching Award Recipients, Friday, 
2:30 p.m. to 4:00 p.m. Presenters and their talks include 
Thomas A. Garrity, Williams College, Functions for the 
world; Andrew C.-F. Liu, University of Alberta, A S.N.A. 
Math Fair; and Olympia Nicodemi, SUNY at Geneseo, 
Clueless.

Environmental Mathematics, Friday, 5:45 pm to 7:00 
pm, organized by Patricia Clark Kenschaft, Montclair 
State University. Three authors from the book Environ­
mental Mathematics, published by the MAA in 2003, will 
share some ideas about using environmental issues to 
teach mathematics. All have written a chapter about a
unit that does so without using calculus. The topics and type of mathematics will vary, but will be useful to those teaching the first two years of college mathematics, either to majors or to nonmajors, both to those especially interested in environmental issues and to those who simply want to increase their quantitative literacy. Panelists include Mohammed Moazzam, Salisbury State University; Barry Schiller, Rhode Island College; and William Stone, New Mexico Institute of Mining and Technology.

Other Organizations

London Mathematical Society, Friday, 3:30 p.m. to 5:00 p.m. An invited address will be given by Gerard van der Geer, Universiteit van Amsterdam, on Curves over finite fields and congruences between modular forms.

Other Events

Mathematical Art Exhibit, various hours, Wednesday—Saturday. A new feature at this year’s meeting provides a break in your day. On display are paintings, prints, and sculpture by artists whose work is inspired by mathematics and by mathematicians who use visual art to express their findings. Fractals, symmetry and tiling, topology, polyhedra, optical illusions, and unusual perspective systems are some of the ideas at play here. Don’t miss this unique opportunity!

Social Events

Elsevier Science 5K Fun Run/Walk and Breakfast, Thursday, 7:00 a.m. to 8:00 a.m. Join your colleagues for this healthy eye-opener!

MAA Two-Year College Reception, Thursday, 5:45 p.m. to 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. Sponsored by Addison Wesley Longman.

University of Wisconsin-Madison Reunion Reception, Friday, 5:30 p.m. to 7:00 p.m.

Tallahassee, Florida

Florida State University

March 12–13, 2004

Friday – Saturday

Meeting #994

Southeastern Section

Associate secretary: John L. Bryant

Announcement issue of Notices: January 2004

Program first available on AMS website: January 29, 2004

Program issue of electronic Notices: March 2004

Issue of Abstracts: Volume 02, Issue 04

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions:

November 25, 2003

For abstracts: January 20, 2004

Invited Addresses

Fern Y. Hunt, National Institute of Standards, Title to be announced.

William H. Jaco, Oklahoma State University, Title to be announced.

Yair Minsky, Yale University, Title to be announced.

Glenn F. Webb, Vanderbilt University, Title to be announced.

Special Sessions

Algebraic Geometry and Topology (Code: SS 5A), Eriko Hironaka, Paolo Aluffi, and Ettore Aldrovandi, Florida State University.

Applications of Mathematics to Problems in Biology (Code: SS 1A), Richard Bertram and Jack Quine, Florida State University.


Geometric Topology in Honor of John Bryant (Code: SS 6A), Washington Mio, Florida State University, and Erik K. Pedersen, Binghamton University (SUNY).

Harmonic Analysis (Code: SS 7A), Daniel M. Oberlin, Florida State University, and Laura de Carli, Florida International University.

Knot Theory and Applications (Code: SS 2A), Yuanan Diao, University of North Carolina at Charlotte.

Modeling and Simulation of Complex Fluid Systems (Code: SS 8A), Qi Wang and Mark Sussman, Florida State University, and Xiaoming Wang, Iowa State University.

PDE’s and Turbulence (Code: SS 9A), Xiaoming Wang, Iowa State University.

Results in 3-Manifolds and Related Topics (Code: SS 3A), Wolfgang H. Heil and Sergio R. Fenley, Florida State University.

Robert Gilmer and Joe Mott: Forty Years of Commutative Ring Theory at Florida State University (Code: SS 4A), William J. Heinzer, Purdue University, and James W. Brewer, Florida Atlantic University.

Szygies and Hilbert Functions (Code: SS 10A), Irena Peeva and Christopher A. Francisco, Cornell University.

Athens, Ohio

Ohio University

March 26–27, 2004

Friday – Saturday

Meeting #995

Central Section

Associate secretary: Susan J. Friedlander

Announcement issue of Notices: January 2004

Program first available on AMS website: February 12, 2004
Los Angeles,
California
University of Southern California
April 3–4, 2004
Saturday - Sunday
Meeting #996
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of Notices: February 2004
Program first available on AMS website: February 19, 2004
Program issue of electronic Notices: April 2004
Issue of Abstracts: Volume 02, Issue 04

Invited Addresses
Dan Boneh, Stanford University, Title to be announced.
Maria E. Schonbek, University of California Santa Cruz, Title to be announced.
Paul Smith, University of Washington, Noncommutative algebraic geometry.
Christopher Martin Thiele, University of California Los Angeles, Title to be announced.

Special Sessions
Arithmetic Geometry and K-Theory (Code: SS 7A), Thomas Geisser and Wayne Raskind, University of Southern California.
Complex and Hyperbolic Geometry (Code: SS 6A), Francis Bonahon and Dragomir Saric, University of Southern California.
Contact and Symplectic Geometry (Code: SS 1A), Dragomir Dragnev, Ko Honda, and Sang Seon Kim, University of Southern California.
Dynamic Equations on Time Scales: Theory and Applications (Code: SS 5A), John M. Davis and Johnny Henderson, Baylor University, and Qin Sheng, University of Dayton.
Financial Mathematics (Code: SS 3A), Jaksa Cvitanic and Jianfeng Zhang, University of Southern California.
Fluid Problems and Related Questions (Code: SS 2A), Maria Schonbek, University of California Santa Cruz, and Yuxi Zheng, Pennsylvania State University.
Nonlinear and Harmonic Analysis (Code: SS 10A), Rowan Killip and Christopher Thiele, University of California Los Angeles.

Partial Differential Equations (Code: SS 9A), Igor Kukavica, University of Southern California, and Qi S. Zhang, University of California Riverside.

Recent Advances in the Mathematical Analysis of Geophysical and Hydrodynamical Models (Code: SS 8A), Mohammed Ziane, University of Southern California.

Smooth Ergodic Theory and Related Topics (Code: SS 4A), Nicolai Haydn, University of Southern California, and Huyi Hu, Michigan State University.

Lawrenceville, New Jersey
Rider University
April 17–18, 2004
Saturday – Sunday

Meeting #997
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: February 2004
Program first available on AMS website: March 4, 2004
Program issue of electronic Notices: April 2004
Issue of Abstracts: Volume 03, Issue 04

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: December 30, 2003
For abstracts: February 24, 2004

Invited Addresses
Sylvia Serfaty, New York University-Courant Institute, Title to be announced.
Dennis P. Sullivan, City College (CUNY), Title to be announced.
Wim F. Sweldens, Bell Laboratories, Title to be announced.
Gaoyong Zhang, Polytechnic University, Title to be announced.

Special Sessions
Algebraic Geometry and Mirror Symmetry (Code: SS 4A), Ciprian Borcea, Rider University.
Analytic Convex Geometry (Code: SS 15A), Alina Stancu, Polytechnic University, and Elisabeth Werner, Case Western Reserve University.
Automorphic Forms and Analytic Number Theory (Code: SS 1A), Stephen Miller, Rutgers University, and Ramin Takloo-Bighash, Princeton University.
Commutative Algebra and Algebraic Geometry (Code: SS 14A), Alberto Corso, University of Kentucky, Claudia Polini, University of Notre Dame, and Wolmer V. Vasconcelos, Rutgers University.

Convergence of Riemannian Manifolds (Code: SS 12A), Christina Sormani, Herbert H. Lehman College (CUNY), Xiaochun Rong, Rutgers State University, and Guofang Wei, University of California Santa Barbara.

CR Geometry and Singularities (Code: SS 10A), Joseph J. Kohn, Princeton University, John P. D’Angelo, University of Illinois, Xiaojun Huang, Rutgers University, and Andreia Nicoara, Harvard University.


Geometry and Arithmetic of Lattices (Code: SS 13A), John H. Conway, Princeton University, and Derek A. Smith, Lafayette College.

Geometry of Protein Modelling (Code: SS 5A), Ileana Streinu, Smith College, and Jack Snoeyink, University of North Carolina at Chapel Hill.

Group Cohomology and Related Topics (in Honor of William Browder’s 70th Birthday) (Code: SS 16A), Alejandro Adem, University of Wisconsin, and Jonathan Pakianathan, University of Rochester.

Homotopical Physics (Code: SS 7A), James Stasheff, University of North Carolina, and Thomas J. Lada, North Carolina State University.

Homotopy Theory, a Special Session in Honor of William Browder’s 70th Birthday (Code: SS 3A), Martin Bendersky, Hunter College, and Donald Davis, Lehigh University.

Strings and Branes (Code: SS 6A), Thomas P. Branson, University of Iowa, and S. James Gates, University of Maryland.

Surgery, a Special Session in Honor of William Browder’s 70th Birthday (Code: SS 8A), Frank S. Quinn, Virginia Polytechnic Institute & State University.

Tomography and Integral Geometry (Code: SS 2A), Andrew Markoe, Rider University, and Eric Todd Quinto, Tufts University.


Houston, Texas
Hyatt Regency Houston
May 13–15, 2004
Thursday – Saturday

Meeting #998
Sixth International Joint Meeting of the AMS and the Sociedad Matemática Mexicana (SMM).
Associate secretary: John L. Bryant
Announcement issue of Notices: February 2004
Program first available on AMS website: March 11, 2004
Program issue of electronic Notices: April 2004
Meetings & Conferences

Issue of Abstracts: Volume 03, Issue 04

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions:
  January 6, 2004
For abstracts: March 2, 2004

Invited Addresses
Luchezar Avramov, University of Nebraska, Title to be announced.
Persi W. Diaconis, Stanford University, Title to be announced.
Samuel Gitler, CINVESTAV, Title to be announced.
Adolfo Sanchez-Valenzuela, Centro de Investigacion en Matematicas, Title to be announced.
Jose Seade-Kuri, UNAM, Title to be announced.
Bernd Sturmfels, University of California Berkeley, Title to be announced (Erdos Memorial Lecture).

Special Sessions
Algebraic Geometry (Code: SS 19A), Pedro Luis Del Angel R., CIMAT.
Algebraic Topology (Code: SS 11A), Miguel A. Xicotencatl, CINVESTAV, and Frederick R. Cohen, University of Rochester.
Associative Rings (Code: SS 5A), Jose Rios Montes, UNAM, Maria-Jose Arroyo, UAM-Iztapalapa, and Sergio R. Lopez-Permouth, Ohio University.
Coding Theory and Cryptography (Code: SS 17A), Horacio Tapia-Recillas, UAM-Iztapalapa, and Neal I. Koblitz, University of Washington.
Complex Analysis and Operator Theory (Code: SS 10A), Enrique Ramirez de Arellano, CINVESTAV, John F. Dorness, University of Michigan, Ann Arbor, and Norberto Salinas, University of Kansas.
Continua Theory and General Topology (Code: SS 6A), Janusz J. Charatonik, UNAM, Charles L. Hagopian, California State University, Sacramento, and Sergio Macias, UNAM.
Continuous Distributed Parameters Models in Mathematical Biology (Code: SS 13A), William E. Fitzgibbon, University of Houston, and Jorge X. Velasco Hernandez, Instituto Mexicano del Petroleo.
Designing Frames and Wavelets: From Theory to Digitalization (Code: SS 18A), Peter R. Massopust, Tuboscope Pipeline Services, and Manos I. Papadakis, University of Houston.
Differential Geometry (Code: SS 20A), Raul Quiroga Barranco, CINVESTAV, and Alberto Candel, California State University, Northridge.
Dynamical Systems (Code: SS 8A), Renato Iturriaga, CIMAT, and Rafael de la Llave, University of Texas at Austin.
Graph Theory and Combinatorics (Code: SS 1A), Gelacio Salazar, IICO, UASLP, Isidoro Gitler, CINVESTAV, and Nathaniel Dean, Texas Southern University.
Harmonic and Functional Analysis (Code: SS 3A), Salvador Perez-Esteva, UNAM-Cuernavaca, Carlos Bosh-Giral, ITAM, and Josefina Alvarez, University of New Mexico.
Homological Algebra of Commutative Rings (Code: SS 21A), Srikanth Iyengar, University of Nebraska, and Graham J. Leuschke, University of Toronto.
Low Dimensional Topology (Code: SS 7A), Victor Nuñez, CIMAT, and Luis G. Valdez, University of Texas, El Paso.
Mathematical Physics (Code: SS 16A), Carlos Villegas-Blas, UNAM, and Alejandro Uribe, University of Michigan, Ann Arbor.
Mathematical Problems in the Analysis of Synchronous States in Networks (Code: SS 22A), Kresimir Josic, University of Houston, and Valentin Afraimovich, IICO-UASLP.
Nonlinear Analysis (Code: SS 4A), Monica Clapp, UNAM, and Alfonso Castro, University of Texas at San Antonio.
Problems and Issues in Electronic Publishing (Code: SS 12A), Klaus Kaiser, University of Houston, and Bernd Wegner, Technische Universität Berlin.
Representations of Algebras (Code: SS 2A), Rita Zuazua, UNAM, and Gordana G. Todorov, Northeastern University.
Stochastical Processes and Probability (Code: SS 9A), Daniel Hernandez, CIMAT, Paul G. Dupuis, Brown University, and Daniel L. Ocone, Rutgers University.

Nashville, Tennessee
Vanderbilt University

October 16-17, 2004
Saturday - Sunday

Meeting #999
Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of Notices: August 2004
Program first available on AMS website: September 2, 2004
Program issue of electronic Notices: October 2004
Issue of Abstracts: Volume 04, Issue 04

Deadlines
For organizers: March 16, 2004
For consideration of contributed papers in Special Sessions:
  June 29, 2004
For abstracts: August 24, 2004
Albuquerque, New Mexico
University of New Mexico

October 16-17, 2004
Saturday - Sunday

Meeting #1000
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of Notices: August 2004
Program first available on AMS website: September 3, 2004
Program issue of electronic Notices: October 2004
Issue of Abstracts: Volume 04, Issue 04

Deadlines
For organizers: March 16, 2004
For consideration of contributed papers in Special Sessions: June 29, 2004
For abstracts: August 24, 2004

Invited Addresses
Sara C. Billey, University of Washington, Seattle, Title to be announced.
Peter Ebenfelt, University of California San Diego, Title to be announced.
Theodore Stanford, New Mexico State University, Title to be announced.
Craig A. Tracy, University of California Davis, Title to be announced.

Special Sessions
Random Matrix Theory and Growth Processes (Code: SS 1A), Craig A. Tracy, University of California Davis.

Evanston, Illinois
Northwestern University

October 23-24, 2004
Saturday - Sunday

Meeting #1001
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: August 2004
Program first available on AMS website: September 9, 2004
Program issue of electronic Notices: October 2004
Issue of Abstracts: Volume 04, Issue 04

Deadlines
For organizers: March 23, 2004
For consideration of contributed papers in Special Sessions: July 7, 2004
For abstracts: August 31, 2004

Invited Addresses
Ian Agol, University of Illinois at Chicago, Title to be announced.
Robert W. Ghrist, University of Illinois, Title to be announced.
Yuri Manin, Northwestern University, Title to be announced.
Paul Seidel, Imperial College-London and University of Chicago, Title to be announced.

Special Sessions
Extremal Combinatorics (Code: SS 2A), Dhruv Mubayi and Yi Zhao, University of Illinois at Chicago.
Index Theory, Morse Theory, and the Witten Deformation Method (Code: SS 3A), Igor Prokhorov and Ken Richardson, Texas Christian University.
Modern Schubert Calculus (Code: SS 1A), Ezra Miller, University of Minnesota, and Frank Sottile, University of Massachusetts.

Pittsburgh, Pennsylvania
University of Pittsburgh

November 6-7, 2004
Saturday - Sunday

Meeting #1002
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: September 2004
Program first available on AMS website: September 23, 2004
Program issue of electronic Notices: November 2004
Issue of Abstracts: Volume 04, Issue 04

Deadlines
For organizers: April 7, 2004
For consideration of contributed papers in Special Sessions: July 20, 2004
For abstracts: September 14, 2004

Special Sessions
Convexity and Combinatorics (Code: SS 2A), James F. Lawrence and Valeriu Soltan, George Mason University.
Invariants of Knots and 3-Manifolds (Code: SS 1A), Marta M. Asaeda, University of Maryland, Jozef H. Przytycki, George Washington University, and Adam S. Sikora, SUNY at Buffalo.
Meetings & Conferences

Atlanta, Georgia
Atlanta Marriott Marquis and Hyatt Regency Atlanta
January 5–8, 2005
Wednesday – Saturday
Joint Mathematics Meetings, including the 111th Annual Meeting of the AMS, 88th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association of Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL).
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: October 2004
Program first available on AMS website: To be announced
Program issue of electronic Notices: January 2005
Issue of Abstracts: To be announced
Deadlines
For organizers: April 5, 2004
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Bowling Green, Kentucky
Western Kentucky University
March 18–19, 2005
Friday – Saturday
Southeastern Section
Associate secretary: John L. Bryant
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: July 19, 2004
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Newark, Delaware
University of Delaware
April 2–3, 2005
Saturday – Sunday
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced

Mainz, Germany
June 16–19, 2005
Thursday – Sunday
Second Joint International Meeting with the Deutsche Mathematiker-Vereinigung (DMV) and the Oesterreichische Mathematische Gesellschaft (OMG)

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Lubbock, Texas
Texas Tech University
April 8–10, 2005
Friday – Sunday
Southeastern Section
Associate secretary: Susan J. Friedlander
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

Santa Barbara, California
University of California Santa Barbara
April 16–17, 2005
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: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
Meetings & Conferences

Associate secretary: Susan J. Friedlander
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

Invited Addresses
Helene Esnault, University of Essen, Title to be announced.
Richard Hamilton, Columbia University, Title to be announced.
Michael J. Hopkins, Massachusetts Institute of Technology, Title to be announced.
Frank Natterer, University of Muenster, Title to be announced.
Horng-Tzer Yau, New York University and Stanford University, Title to be announced.

Johnson City, Tennessee
East Tennessee State University

October 15-16, 2005
Saturday - Sunday
Southeastern Section
Associate secretary: John L. Bryant
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 15, 2005
For consideration of contributed papers in Special Sessions:
    To be announced
For abstracts: To be announced

Lincoln, Nebraska
University of Nebraska in Lincoln

October 21-22, 2005
Friday - Saturday
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: August 2005
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 4, 2006
For consideration of contributed papers in Special Sessions:
    To be announced

San Antonio, Texas
Henry B. Gonzalez Convention Center

January 12-15, 2006
Thursday - Sunday
Joint Mathematics Meetings, including the 112th Annual Meeting
    of the AMS, 89th 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).
Associate secretary: John L. Bryant
Announcement issue of Notices: October 2005
Program first available on AMS website: To be announced
Program issue of electronic Notices: January 2006
Issue of Abstracts: To be announced

Deadlines
For organizers: April 12, 2005
For consideration of contributed papers in Special Sessions:
    To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

New Orleans, Louisiana
New Orleans Marriott and Sheraton
New Orleans Hotel

January 4-7, 2007
Thursday - Sunday
Joint Mathematics Meetings, including the 113th Annual Meeting
    of the AMS, 90th Annual Meeting of the Mathematical
    Association of America (MAA), annual meetings of the Association
    for Women in Mathematics (AWM) and the National Association
    of Mathematicians (NAM), and the winter meeting of
    the Association for Symbolic Logic (ASL).
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: October 2006
Program first available on AMS website: To be announced
Program issue of electronic Notices: January 2007
Issue of Abstracts: To be announced

Deadlines
For organizers: April 4, 2006
For consideration of contributed papers in Special Sessions:
    To be announced

DECEMBER 2003
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**Tutor for Mathematics Learning Center**

The Mathematics Learning Center (MLC) invites applications for faculty positions of a Tutor. The primary work is to assist the MLC Director in providing a wide range of support and enough learning resources to help students, especially at the orientation level, meet their mathematical challenges through self learning and good study habit that will help them overcome their mathematical difficulties. He will be expected to conduct Remedial Classes and Problem Solving for small group and on an individual basis.

A MA, M.Sc. or M.Ed. in Mathematics or Mathematics Education is required.

Candidates will be assessed on excellence in teaching, previous work in a similar Center, and fluency in English.

**Salary/Benefits:** Two-year renewable contract. Competitive salaries based on qualifications and experience. Free furnished air-conditioned on-campus housing unit with free essential utilities and maintenance. The appointment includes the following benefits according to the University's policy: air ticket to Dammam on appointment; annual repatriation air tickets for up to four persons; assistance with local tuition fees for school-age dependent children; local transportation allowance; two months' paid summer leave; end-of-service gratuity. KFUPM campus has a range of facilities including a medical and dental clinic, an extensive library, computing, research and teaching laboratory facilities and a recreation center.

**To apply:** Mail, fax or e-mail cover letter and detailed CV/Resume (including a list of research and teaching activities) and e-mail address of three professional references to:

Dean, Faculty & Personnel Affairs,
KFUPM Box 5005, Dhafran 31261, Saudi Arabia
DEPT.No.: MATH/MLC-2399 Fax: 966-3-860-2429
E-Mail: faculty@kfupm.edu.sa or mlc@kfupm.edu.sa

Please quote the above DEPT. REF No. in all correspondence. For additional information, please visit our website: [http://www.kfupm.edu.sa/pa/](http://www.kfupm.edu.sa/pa/)

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**Meetings & Conferences**

For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

**San Diego, California**

*San Diego Convention Center*

**January 6-9, 2008**

*Sunday - Wednesday*

Joint Mathematics Meetings, including the 114th Annual Meeting of the AMS, 91st Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).

Associate secretary: Michel L. Lapidus

Announcement issue of Notices: October 2007

Program first available on AMS website: November 1, 2007

Program issue of electronic Notices: January 2008

Issue of Abstracts: Volume 29, Issue 1

**Deadlines**

For organizers: April 6, 2007
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

**Washington, District of Columbia**

*Marriott Wardman Park Hotel and Omni Shoreham Hotel*

**January 7-10, 2009**

*Wednesday - Saturday*

Joint Mathematics Meetings, including the 115th Annual Meeting of the AMS, 92nd Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).

Associate secretary: Lesley M. Sibner

Announcement issue of Notices: October 2008

Program first available on AMS website: November 1, 2008

Program issue of electronic Notices: January 2009

Issue of Abstracts: Volume 30, Issue 1

**Deadlines**

For organizers: April 7, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced
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The Meetings and Conferences section of the Notices gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Information in this issue may be dated. Up-to-date meeting and conference information can be found at www.ams.org/meetings/.

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Important Information regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 108 in the January 2003 issue of the Notices for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of \LaTeX is necessary to submit an electronic form, although those who use \LaTeX may submit abstracts with such coding, and all math displays and similarly coded material (such as accent marks in text) must be typeset in \LaTeX.

To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html, or send mail to abs-submit@ams.org, typing help as the subject line; descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. There is a $20 processing fee for each paper abstract. There is no charge for electronic abstracts. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

June 5-July 24, 2004: Joint Summer Research Conferences in the Mathematical Sciences, Snowbird, Utah. (See November 2003 Notices, page 1363.)
Phoenix Joint Meetings Advance Registration/Housing Form

Name __________________________________________________________

Mailing Address __________________________________________________

Telephone __________________________________ Fax __________________________

Email Address ______________________________________________________

Badge Information: Affiliation for badge ____________________________

Nonmathematician guest badge name ____________________________ (please note charge below)

<table>
<thead>
<tr>
<th>Joint Meetings</th>
<th>by Dec 12</th>
<th>at mtg</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member AMS, ASL, CMS, MAA, SIAM</td>
<td>$193</td>
<td>$251</td>
<td></td>
</tr>
<tr>
<td>Nonmember</td>
<td>$299</td>
<td>$369</td>
<td></td>
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<tr>
<td>Graduate Student</td>
<td>$38</td>
<td>$48</td>
<td></td>
</tr>
<tr>
<td>Undergraduate Student</td>
<td>$20</td>
<td>$26</td>
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<tr>
<td>High School Student</td>
<td>$2</td>
<td>$5</td>
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</tr>
<tr>
<td>Unemployed</td>
<td>$38</td>
<td>$48</td>
<td></td>
</tr>
<tr>
<td>Temporarily Employed</td>
<td>$153</td>
<td>$176</td>
<td></td>
</tr>
<tr>
<td>Developing Countries Special Rate</td>
<td>$38</td>
<td>$48</td>
<td></td>
</tr>
<tr>
<td>Emeritus Member of AMS or MAA</td>
<td>$38</td>
<td>$48</td>
<td></td>
</tr>
<tr>
<td>High School Teacher</td>
<td>$38</td>
<td>$48</td>
<td></td>
</tr>
<tr>
<td>Librarian</td>
<td>$38</td>
<td>$48</td>
<td></td>
</tr>
<tr>
<td>Nonmathematician Guest</td>
<td>$10</td>
<td>$10</td>
<td></td>
</tr>
</tbody>
</table>

AMS Short Course: Trends in Optimization (1/5-1/6)
| Member of AMS or MAA | $80 | $100 |          |
| Nonmember | $110 | $130 |          |
| Student, Unemployed, Emeritus | $35 | $50 |          |

MAA Short Course:
The History of Mathematical Technologies (1/5-1/6)
| Member of MAA or AMS | $125 | $140 |          |
| Nonmember | $175 | $190 |          |
| Student, Unemployed, Emeritus | $50 | $60 |          |

MAA Minicourses (see listing in text)
I would like to attend: ☐ One Minicourse ☐ Two Minicourses
Please enroll me in MAA Minicourse(s) ________________________________

In order of preference, my alternatives are: __________________________

Note: $30 for Minicourses #1-6, $70 for #7, and $60 for #8-16

Employment Center
Applicant résumé forms and employer job listing forms will be on the AMS website and in Notices in September and October:

Employer—First Table | $220 | $300 |
| Regular | ☐ | ☐ |
| Self-scheduled | ☐ | ☐ |
| Employer—Each Additional Table | $65 | $100 |
| Regular | ☐ | ☐ |
| Self-scheduled | ☐ | ☐ |
| Employer—Posting Only | $50 | N/A |
| ☐ | ☐ |
| Applicant (all services) | $40 | $75 |
| ☐ | ☐ |
| Applicant (Winter List & Message Ctr only) | $20 | $20 |

Events with Tickets
| MER Banquet (1/8) | $45 | #Regular | #Veg |
| NAM Banquet (1/9) | $46 | #Regular | #Veg |
| AMS Banquet (1/10) | $44 | #Regular | #Veg |

Other Events (no charge)
| ☐ | ☐ |
| ☐ | ☐ |

Total for Registrations and Events $____________

<table>
<thead>
<tr>
<th>Membership</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑ all that apply</td>
</tr>
</tbody>
</table>

AMS ☐ | ASA ☐ | ASL ☐ | AWM ☐ |
| CMS ☐ | MAA ☐ | NAM ☐ | SIAM ☐ |
| YMN ☐ |

| I DO NOT want my program and badge to be mailed to me on 12/12/03. |

Registration & Event Total (total from column on left) $____________

Hotel Deposit (only if paying by check) $____________

Total Amount To Be Paid $____________

(Not: A $5 processing fee will be charged for each returned check or invalid credit card. Debit cards are not 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.

☐ Credit Card: VISA, MasterCard, AMEX, Discover (no others accepted)

Card number: ____________________ CVV# ________

Exp. date: __________ Zipcode of credit card billing address: __________

Signature: ____________________

Name on card: ____________________

☐ Purchase order __________ (please enclose copy)

Registration for the Joint Meetings is not required for the Short Courses, but it is required for the Minicourses and the Employment Center.

Other Information

Mathematical Reviews: field of interest #

How did you hear about this meeting? Check one: ☐ Colleague(s) ☐ Notices ☐ Focus ☐ Internet

☐ 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.

☐ Please do not include my name on any promotional mailing list.

☐ Please ☐ check this box if you have a disability requiring special services.

Mail to:
Mathematics Meetings Service Bureau (MMSB)
P.O. Box 6887 Providence, RI 02940-6887 Fax: 401-455-4004

Questions/changes call: 401-455-4143 or 1-800-321-4267 x 4143; mmsb@ams.org

Deadlines
For résumé/job descriptions printed in the Winter Lists, return this form by:

To be eligible for the room lottery:

For housing reservations, badges/programs mailed:

For housing changes/cancellations through MMSB:

For advance registration for the Joint Meetings, Employment Center, Short Courses, MAA Minicourses, & Tickets:

For 50% refund on banquets, cancel by:

For 50% refund on advance registration, Minicourses & Short Courses, cancel by:

*no refunds after this date

Oct. 24, 2003
Oct. 31, 2003
Nov. 7, 2003
Dec. 1, 2003
Dec. 12, 2003
Dec. 30, 2003*
Jan. 2, 2004*
# Phoenix Joint Meetings Hotel Reservations

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 a ranked or unranked hotel at a comparable rate. Participants are urged to call the hotels directly for details on suite configurations, sizes, and availability; however, suite reservations can be made only through the MMSB to receive the convention rates listed. Reservations made directly with the hotels may be charged to a higher rate. All rates are subject to a 12.07% sales tax. 

Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee. The Wyndham will charge one night's deposit at the time of booking.

- **Deposit enclosed**
- **Hand with my credit card**
- **Card Number**
- **Exp. Date**
- **Signature**

**Date and Time of Arrival**

**Date and Time of Departure**

**Name of Other Room Occupant**

**Arrival Date**

**Departure Date**

**Child (give age(s))**

---

<table>
<thead>
<tr>
<th>Order of choice</th>
<th>Hotel</th>
<th>Single</th>
<th>Double 1 bed</th>
<th>Double 2 beds</th>
<th>Triple 2 beds</th>
<th>Triple 2 beds w/cot</th>
<th>Triple King w/cot</th>
<th>Quad 2 beds</th>
<th>Quad 2 beds w/cot</th>
<th>Suites Starting rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hyatt Regency Phoenix at Civic Plaza (hqtrs)</td>
<td>$152</td>
<td>$152</td>
<td>$152</td>
<td>$152</td>
<td>N/A</td>
<td>$177</td>
<td>$152</td>
<td>N/A</td>
<td>$450</td>
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<tr>
<td></td>
<td>Wyndham Phoenix</td>
<td>$130</td>
<td>$130</td>
<td>$130</td>
<td>$130</td>
<td>N/A</td>
<td>$155</td>
<td>$130</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td></td>
<td>Ramada Inn-Downtown Phoenix</td>
<td>$129</td>
<td>$129</td>
<td>$129</td>
<td>$139</td>
<td>$149</td>
<td>$149</td>
<td>$149</td>
<td>$159</td>
<td>$399</td>
</tr>
<tr>
<td></td>
<td>SpringHill Suites (all studio suites)</td>
<td>$129</td>
<td>$129</td>
<td>$129</td>
<td>$139</td>
<td>$139</td>
<td>$139</td>
<td>$139</td>
<td>$149</td>
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<tr>
<td></td>
<td>Hotel San Carlos</td>
<td>$129</td>
<td>$129</td>
<td>$129</td>
<td>$139</td>
<td>N/A</td>
<td>$149</td>
<td>N/A</td>
<td>N/A</td>
<td>$220</td>
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<tr>
<td></td>
<td>Hampton Inn-Phoenix Midtown</td>
<td>$109</td>
<td>$119</td>
<td>$119</td>
<td>$129</td>
<td>$139</td>
<td>$139</td>
<td>$139</td>
<td>$149</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Hilton Garden Inn Phoenix/Midtown</td>
<td>$99</td>
<td>$99</td>
<td>$99</td>
<td>$109</td>
<td>$124</td>
<td>$124</td>
<td>$119</td>
<td>$134</td>
<td>$149</td>
</tr>
<tr>
<td></td>
<td>Holiday Inn Phoenix Midtown</td>
<td>$95</td>
<td>$95</td>
<td>$95</td>
<td>$105</td>
<td>$115</td>
<td>$115</td>
<td>$115</td>
<td>$125</td>
<td>N/A</td>
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<tr>
<td></td>
<td>Wellesley Inn and Suites Midtown</td>
<td>$99</td>
<td>$99</td>
<td>$99</td>
<td>$99</td>
<td>N/A</td>
<td>N/A</td>
<td>$99</td>
<td>N/A</td>
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<tr>
<td></td>
<td>Sunshine Hotel and Suites</td>
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<td>$99.95</td>
<td>$99.95</td>
<td>$99.95</td>
<td>$109.95</td>
</tr>
</tbody>
</table>

**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:**

---

If you are not making a reservation, please check off 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.**
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