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Notices

of the American Mathematical Society

December 2013 **Volume 60, Number 11**

125th Anniversary
AMS
American Mathematical Society

About the cover: Binomial coefficients in Al Bāhir fī al-Jabr
(see page 1498)

American Mathematical Society

Who Wants to Be a Mathematician

$x^2 + x + 1 = 0$

High School Students Compete for $10,000

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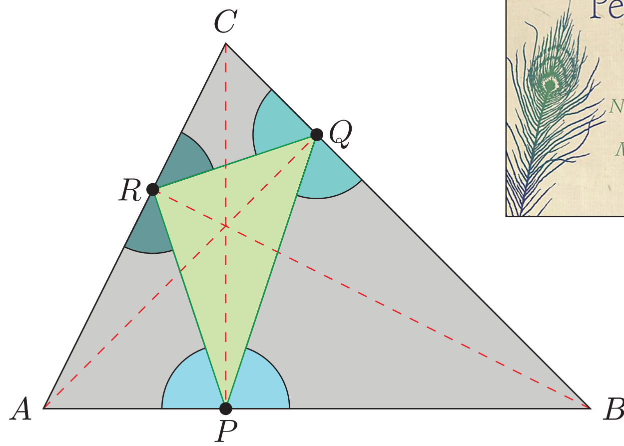
Communications

Commentary

Altmetric **1479**



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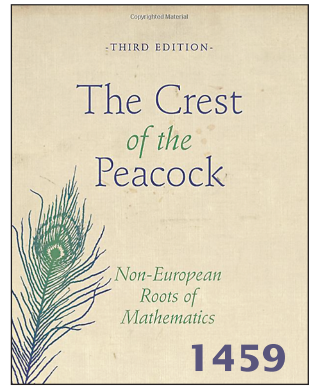

We close the year with a variety of articles on diverse mathematical subjects. These include (i) hearing the shape of a triangle, (ii) the role of Soviet ideology in mathematics, (iii) the universality of teaching techniques in school mathematics, (iv) numerical experimentation on a quantum computer, and (v) the CBMS mathematics survey. Our goal is to treat all aspects of mathematics that may affect or interest the *Notices* readership.

—Steven G. Krantz, Editor

Features

Notices

of the American Mathematical Society

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Departments

[Contemporary Pure] Math Is Far Less Than the Sum of Its [Too Numerous] Parts

In a newspaper article entitled "Math is more than the sum of its parts" (*New York Daily News*, July 8, 2012), the great pure mathematician Edward Frenkel, along with mathematics educator Ronald Ross, preached the importance of math, apropos of the announcement of the discovery of the Higgs boson.

What Frenkel and Ross did not tell us is that the "math" that led to the discovery of the Higgs boson is not their kind of (pure-and-rigorous) math, but the much more effective, and efficient, nonrigorous mathematics practiced by theoretical physicists called quantum field theory. This highly successful (and precise!) mathematical theory would not be considered mathematics by most members of the American Mathematical Society, since it is completely nonrigorous.

The detection of the Higgs boson probably also involved many hours of heavy-duty computer calculations, very far afield from esoterica most pure mathematicians hold dear, such as Frenkel's own research in the Langlands program. Ironically, (pure) mathematicians are much more indebted to theoretical physicists than vice versa (e.g., Seiberg-Witten and quantum groups). From physics, mathematicians have absorbed fresh ideas with which to pursue their often very beautiful, but completely useless, game.

It is common for pure mathematicians to praise the RSA algorithm. Let me remind you that the "safety" of RSA is only conjectural (from the pedantic standpoint of pure mathematicians). It is possible (but very unlikely!) that tomorrow an assistant professor of computer science (not math!), together with two undergrads, will find a fast algorithm for integer factorization. The rest of the math behind the clever RSA algorithm goes back to Euler. Establishing RSA does not require mathematical arcana such as the Langlands program. And the RSA algorithm would be *just as useful* if it had only an "empirical" proof.

The reason so many mathematically talented students are so turned off from math is that once they go to university, even the science and engineering students are taught by professional mathematicians, whose rigid, pedantic, "rigor-or-nothing" philosophy is imposed on the courses, at least in part.

Communication in mathematics is, even at the "highest" level of conference talks, highly dysfunctional. Highly specialized specialists who attempt to communicate their subject to a "general mathematical audience", just read their highly technical, usually very dry, preprepared laptop presentations, and (almost) no one has any clue. Indeed, pure math has gotten so splintered that very few people see the mathematical forest. Most can barely understand their own trees.

One example is the AMS Colloquium Lecture series at the Joint Mathematics Meetings. No doubt some of these three-hour lecture series have been very good. But too often they are delivered by talented mathematicians who do not even attempt to make the lectures accessible to a general mathematical audience. Rather, they give highly technical talks with completely unrealistic expectations about the background of the audience.

Mathematics is so useful because physical scientists and engineers have the good sense to largely ignore the "religious" fanaticism of professional mathematicians and their insistence on so-called rigor, which in many cases is misplaced and hypocritical, since it is based on "axioms" that are completely fictional, i.e., those that involve the so-called infinity.

The purpose of mathematical research should be the increase of mathematical knowledge, broadly defined. We should not be tied up with the antiquated notions of alleged "rigor". A new philosophy of and attitude toward mathematics is developing, called "experimental math" (though it is derided by most of my colleagues; I often hear the phrase, "It's only experimental math"). Experimental math should trickle down to all levels of education, from professional math meetings, via grad school, all the way to kindergarten. Should that happen, Wigner's "unreasonable effectiveness of math in science" would be all the more effective!

Let's start right now! A modest beginning would be to have every math major undergrad take a course in experimental mathematics.

Please don't misunderstand me. Personally, I love (quite a few) rigorous proofs, and it's okay for anyone who loves them to look for them in his or her spare time. However, for the research and teaching that we get paid for, we should adopt a much more open-minded attitude to mathematical truth similar to the standards of the "hard" physical sciences. We need to abandon our fanatical insistence on "rigorous" proofs.

—Doron Zeilberger
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Letters to the Editor

Regarding "Mathematics and Historical Chronology"

Letters in the August 2013 issue of *Notices* regarding Florin Diacu's article ["Mathematical methods in the study of historical chronology", April 2013] dealt mostly with the opinions of Fomenko and his coworkers. But there are grave problems with the content of the article itself. "Mathematical methods" are emphasized in the title of the article, but Diacu's account of them resists my attempt to understand it.

Consider the account, beginning on page 443, of the moon's elongation and its acceleration. What is meant by "acceleration"? It is clear, even to a reader who has not specialized in astronomy, that a detailed account of the moon's elongation must be complex. One might start from a naive model of the solar system, in which the earth moves uniformly in a circle around the sun, and the moon likewise around the earth, and moreover these circles are coplanar. In this model, the elongation increases at a uniform rate, and its acceleration is 0. To a better, Keplerian, approximation, the orbits are ellipses, the motions of the sun, earth, and moon are nonuniform, and the moon's orbit is inclined relative to the earth's. All of these considerations impose periodic variations on the observed elongation. A yet better model must include changes in the orbital elements caused by gravitational interactions.

In this complicated context, what is the meaning of the expression D'' in Diacu's article? I can only conjecture that after all the accountable variations are accounted for, there are long-term changes (on a scale of several hundred years) that remain. But I cannot decipher what they are or what they might mean for chronology.

Another difficulty appears on page 445: "... the 532-year periodicity of the Easter dates. The last cycle started in 1941." What can this mean? Surely we may mark a beginning point of any recurring cycle anywhere we like. We may begin our calendar year at January 1 or (like many businesses) at July 1 or (like the ancient Romans) at March 25; it makes no difference at all to the motion of the earth.

It would be tedious to go on describing my frustration. In my opinion, the article does not succeed in communicating what the author intended.

—Christopher Henrich
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(Received September 4, 2013)

Response to Henrich

Christopher Henrich first complains that I do not explain what the acceleration of the moon's elongation means. I did not provide more details because introducing the model would have taken a lot of space without adding much insight into the chronology point I was making. Henrich can learn all the details about this standard model of celestial mechanics from the works of Robert Newton and Anatoli Fomenko mentioned in the references.

Henrich also writes that cycles can be started any time, so why did I mention that the last 532-year cycle of the Easter dates began in 1941? I am afraid that he did not read my text carefully. The point I made in my article is why did the Council of Nicaea meet in AD 325 but start counting the first 532-year cycle in AD 345? In other words, it would have been more natural to start the count when the Easter book was canonized, AD 325. The 1941 start of the latest cycle is a consequence of this unnatural choice.

—Florin Diacu
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(Received September 10, 2013)

AMS Should Sever Ties to NSA

I am writing this Letter to the Editor to suggest the AMS sever all ties with the NSA (National Security Agency):

With the revelations of Edward Snowden the public received, and continues to receive, specific and reliable information about the vast secret spying programs of the NSA that wildly exceed anything conspiracy theorists could imagine.

What should be done is a question not only for U.S. citizens but also for people all over the world: the NSA destroyed the security of the Internet and privacy of communications for the whole planet. But if any healing is possible, it would probably start with making the NSA and its ilk *socially unacceptable*—just as, in the days of my youth, working for the KGB was socially unacceptable for many in the Soviet Union.

The AMS regularly publishes advertisements for positions at the NSA and manages reviews for the NSA Mathematical Sciences Grants Program. The relationship between the NSA and the AMS seems to be a symbiotic one: The NSA needs mathematicians for its tasks, and the AMS has an interest in increasing research funding. But any relationship with an organization whose activity is so harmful for the fabric of human society is unhealthy. For the sake of integrity, the AMS should shun all contacts with the NSA.

—Alexander Beilinson
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(Received September 12, 2013)

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Numeric Experiments on the Commercial Quantum Computer

Richard H. Warren

This paper describes the creativity that is needed to solve an optimization problem on an adiabatic quantum computer. Current features of adiabatic quantum computing are discussed. Research questions are posed. Quantum complexity is briefly addressed.

We will also discuss the mathematics at the forefront of this new era in computing, describe some of the initial work done at Lockheed Martin on an adiabatic quantum computer, and indicate the distinct mindset that is used when programming this type of machine. The paper begins with a description of the commercial, adiabatic quantum computer and concludes with a discussion of current limitations that point to future research.

Quantum computing is motivated by an expected speedup for solving large problems. In 2010 experimenters estimated the time for adiabatic quantum optimization would be about 4 to 6 orders of magnitude faster than for classical solvers of large problems [8]. New results show a variation of speedup. The largest reported is a speedup of about 3600 times for two types of problems on specific software packages [10]. The adiabatic quantum computing model is polynomially equivalent to the quantum circuit model [1], which is the standard quantum computation method. This means that Shor's factoring algorithm can be implemented on an adiabatic quantum machine, but to our knowledge no one has done this.

Richard H. Warren is retired after thirty years with Lockheed Martin as an applied mathematician. He learned his applied skills at Wright-Patterson Air Force Base, Ohio, as a new Ph.D. His email address is `rwarre01@villanova.edu`.

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Background Information

Commercial quantum computers are constructed only by D-Wave Systems, a Canadian technology firm. Lockheed Martin Corporation purchased the first one in 2011 for a reported 10 million dollars. The machine was moved from Canada to the University of Southern California's School of Engineering [15]. A large percentage of the operating time is devoted to academic computing, with the rest reserved for Lockheed Martin applications.

This computer is an adiabatic quantum computer, not the popularized gate array type. Essentially, it does one thing: it solves discrete minimization problems extremely fast. In order to do this, it needs an objective function and constraints, both expressed in binary variables. This requires declaring the variables, their types, and their coefficients. There are no procedural instructions, such as "if X, then do Y".

In 2013 it was announced that a consortium of Google, NASA AMES, and the nonprofit Universities Space Research Association had purchased an adiabatic quantum computer from D-Wave [7].

Adiabatic Quantum Computing

In the commercial adiabatic quantum computer, the quantum bits (qubits) are loops of superconducting wire, the coupling between qubits is magnetic wiring, and the machine is supercooled. Reference [8] describes this superconducting adiabatic quantum processor. Fabrication limits the number of pairwise-coupled qubits, which in turn limits the number of variables for problems that are implemented on the computer.

Quantum annealing is a process where the qubits achieve an optimal state of low energy when supercooled. The Ising objective function for this

Photo courtesy University of Southern California.
Photographer: Steve Cohn.

On the left: Professor Daniel Lidar, scientific director of the Quantum Computing Center, with USC engineering dean Yannis Yortsos in front of an adiabatic quantum computer.

optimal state is

$$\text{(1)} \qquad \min \left(\sum_{(i,j)} s_i J_{ij} s_j + \sum_i h_i s_i \right),$$

where i and j are qubits, s_i is the input state of qubit i (either 0 or 1), h_i is the energy bias for qubit i, and J_{ij} is the coupling energy between qubits i and j. Quantum annealing can be thought of as a path from an initial state to a final state according to the weights h_i and J_{ij} which minimizes energy. There are difficulties achieving the theoretical features of quantum annealing, but there are techniques to mitigate the obstacles [10].

Also, there are questions whether D-Wave machines are true quantum systems. Boixo and his colleagues report some evidence that they are [3], [4]. The discussion is ongoing [16], [17].

Next we will describe how to transform optimization problems into the form of the Ising function (1) and solve them on an adiabatic quantum computer. This means the optimization problem needs to be expressed in binary variables corresponding to s in the Ising function and is limited to linear and quadratic terms corresponding to $h_i s_i$ and $s_i J_{ij} s_j$ in the Ising function. This requires creativity to exploit a problem's structure, often in new ways, in order to adapt it to an adiabatic quantum computer. Thus, a unique mindset is used to program this machine.

Reference [9] indicates that many NP-complete problems have been transformed into quadratic binary problems that the Ising model (1) requires. In addition, the work at Lockheed Martin has transformed the traveling salesman problem [13], the job shop problem for one machine, and a logistics problem into the form of the Ising model (1). The first two problems were implemented on the Lockheed Martin adiabatic quantum machine. Numeric results showed that the probability of finding an optimal solution increases as the quantum annealing process is done more frequently. This correlates with the theory in [12].

Other problems that have been implemented on an adiabatic quantum computer include machine learning and anomaly detection [11], quadratic unconstrained binary optimization, weighted maximum 2-satisfiability, and the quadratic assignment problem [10]. Also, [10] cites finding Ramsey numbers, binary classification in image matching, and 3D protein folding on earlier D-Wave machines with fewer qubits.

Adapting an Optimization Problem to an Adiabatic Quantum Computer

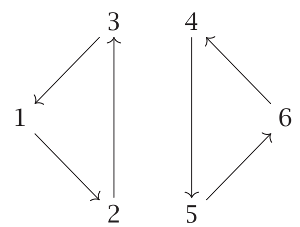
As in 0-1 integer programming, an initial step identifies binary variables for the problem, i.e., variables that are restricted to 0 or 1 and represent the problem. The goal is to use the binary variables (with real coefficients) to write an objective function that represents a solution to the optimization problem. It is important to describe the condition that the binary variables represent when they are 1 and when they are 0. Next we suggest describing the (real) coefficients of the variables and what they represent. Using the binary variables and their coefficients, we write an objective function that has the pattern of (1); i.e., the degree of each term is at most 2. Since $x^2 = x$ when x is binary, this reduction may be useful for obtaining a quadratic objective function.

For example, in the traveling salesman problem [13], the distance d_{ij} to proceed directly from city i to city j is known for all cities i and j. The objective is to find a route through all the cities that returns to the starting city and is minimum in length. Our binary variables are x_{ij} for the path directly from city i to city j. Our variable x_{ij} is 1 if the salesman proceeds directly from city i to city j; otherwise the value of x_{ij} is 0. The coefficients of the variables are the d_{ij}. Assuming the number of cities is n, our objective function is

$$\text{(2)} \qquad \sum_{i,j=1}^{n} d_{ij} x_{ij}$$

such that $i \neq j$. We want the adiabatic quantum computer to assign 0, 1 to the variables x_{ij} so that the objective function (2) is a minimum over all n-cycles representing routes for the salesman.

The next step is to identify constraints that need to be satisfied to prevent minimum solutions that are not feasible. What are the boundaries for the optimization problem? What type of minimizations might occur that should be excluded? For example, in the traveling salesman problem, we need to ensure that the route for a solution enters each city once and departs from each city once. Also, we need to prevent subtours, which are cycles using fewer than all of the cities. In the case for 6 cities, this includes preventing a solution that has a 3-cycle through cities 1, 2, and 3 and another 3-cycle through cities 4, 5, and 6.



Usually the constraints are equations or inequalities with real coefficients and the previously identified variables. The degree of a constraint is restricted by (1) to be at most quadratic. For a 6-city traveling salesman problem, the constraint $x_{21} + x_{31} + \cdots + x_{61} = 1$ ensures that the salesman uses exactly one route into city 1. The inequality $x_{12} + x_{23} + x_{31} \leq 2$ will prevent a 3-cycle through cities 1, 2, and 3 in a solution for a 6-city problem.

The final step in the binary characterization is verification that the objective function and constraints represent the optimization function.

Forming the Hamiltonian

The Hamiltonian is a square, symmetric matrix with a row and column for each variable. The diagonal entries of the Hamiltonian are the values assigned to qubits. The off-diagonal entries in the Hamiltonian are the values assigned to the connections between qubits. The entries in the Hamiltonian are the coefficients of the terms from the sum of the objective function and the penalty functions (to be described in the next paragraphs).

Since equations and inequalities cannot be combined with a function, the usual technique is to reformulate the constraints as penalty functions. The constraints that are equations can be changed to penalty functions by reversing the algebraic sign of all terms on one side of the equation and deleting the equality sign. Most likely, the minimum for the result is not the same as the solution for the constraint equation. Thus we square the result, simplify it with the property $x^2 = x$ for binary variables, and delete the constant term.

In summary, we have shown a method to convert a constraint equation to a penalty function. The purpose is to add the objective function and the penalty functions to obtain an expression for an optimization problem that corresponds to (1). The coefficients in this sum are the entries in the Hamiltonian.

Exercise 1. Let x and z be binary variables. Find a penalty function for the constraint $z = \neg x$.[1]

Exercise 2. Let x, y, and z be binary variables. Find a penalty function for the constraint $z = x \vee y$.[2]

Next we describe a technique to convert a constraint inequality to a penalty function. We insert slack variables to change the inequality to an equation, as is done in the simplex algorithm for linear programming. We require the slack variables to be binary 0, 1. Then the above method can be used to change the equation to a penalty function. For example, consider the constraint $x + y + z \leq 2$ where x, y, and z are binary variables. We insert slack, binary variables s and t to obtain $x + y + z + s + t = 2$. Exercises 3 and 4 verify correctness.

Exercise 3. Let x, y, and z be binary variables such that $x + y + z \leq 2$. Show that there are binary values for s and t such that $x + y + z + s + t = 2$.

Exercise 4. Let x, y, z, s, and t be binary variables such that $x + y + z + s + t = 2$. Show that the variables x, y, and z satisfy $x + y + z \leq 2$.

If the weight of the objective function greatly exceeds the weight of the constraints, then the quantum solution is likely to be tilted toward a solution that satisfies the objective function but violates a constraint. On the other hand, if the weight favors the constraints, then the quantum solution is apt to find a suboptimal solution that satisfies the constraints. As in the simplex algorithm for linear programming, a lambda factor is used to balance the coefficients in the objective function and the coefficients in the penalty functions. See the discussion in [9, pp. 239–40] about the scalar P in Transformation 1. Lockheed Martin experiments on the quantum machine showed that the lambda factor has a narrow range that is dependent on the coefficients.

Complexity Considerations

After creating the objective function and constraints, the major steps to solve a minimization problem on an adiabatic quantum computer are:

- Form the Hamiltonian.
- Input the Hamiltonian and computing parameters to the machine.
- Wait while the Hamiltonian transitions to a final state on the machine.
- Read the final Hamiltonian on the machine.
- Interpret the final Hamiltonian to the variables.

---

[1] *A solution for Exercise 1:* $2xz - x - z$.

[2] *A solution for Exercise 2:* $xy + (x + y)(1 - 2z) + z$.

- Verify that the result is optimal.

A critical input parameter is the number of times to iterate a problem on the quantum machine. This is due to errors [18] and the analog nature of the machine when it treats input parameters [5].

The Hamiltonian is usually formed by a preprocessor. This is not considered part of quantum complexity [5]. Input and output steps are treated as instantaneous in [5]. A postprocessor may interpret the final Hamiltonian and prove the result is optimal. Thus, in both theory and practice, adiabatic quantum complexity is viewed as a function of the time to evolve the initial Hamiltonian to the final Hamiltonian. The (scaled) Schrödinger equation [5, equation (2)] contains a term τ representing the time for a quantum system to evolve from an initial state to a final state. The adiabatic theorem [2], [14] in quantum mechanics ensures that under certain conditions the evolution is close to the ground state of the final Hamiltonian, i.e., evolves to an optimal solution.

Cao and Elgart [5] cite the literature trail for theoretic bounds on τ for variations of the quantum database search algorithm of Grover. This work assumes conditions on a final Hamiltonian and asks what initial Hamiltonians and input parameters minimize τ and what the optimal value of τ is. Partial answers are cited. Cao and Elgart [5] extend the results.

Turning to the experimental side of quantum complexity, the current adiabatic quantum computer is too small to verify the theory. It has 512 qubits. If all qubits are operational, the largest complete graph that can be embedded in it has 33 vertices (qubits).[3] This limits the traveling salesman problem (TSP) to 6 cities on the current adiabatic quantum machine, since the TSP requires a complete graph and an n-city problem has $n(n-1)$ variables x_{ij} for the objective function (2).

In summary, Cao and Elgart [6] point out that quantitative characterization of the speedup of adiabatic quantum computing is largely unknown.

Quantum Hardware Effects on Computation

There is an accuracy difficulty, since for a single program loaded into the adiabatic quantum computer and iterated 100 times, about 1 percent of the time none of the 100 solutions are optimal. The theoretic work in [5] acknowledges the accuracy problem by indicating "the AQC algorithm is probabilistic in the sense that it gives a correct answer with the probability γ^2. The probability of failure can be decreased to the desired value (namely $O(1/N)$) by repeating the algorithm $(\ln N)/\gamma^2$ times. We set $\gamma = 1/5$ throughout this paper." Here AQC = adiabatic quantum computation, $N = 2^n$, and n is the dimension of the input space.

There is another hardware difficulty. The number of fully connected qubits limits the number of variables. This is significant, because the number of variables may grow rapidly as the size of the problem increases. Variables in the Ising model (1) equate to qubits that need to be connected, physically or logically, in order to represent their relationships. Current development methods are impractical for fabricating connectivity between qubits as the number of qubits increases [8]. This leads to the following open problems.

Find a decomposition algorithm that breaks a large optimization problem into small problems that an adiabatic quantum computer can solve. Find a reassembly algorithm that combines the solutions into a global optimal solution. Early work indicates that the algorithms may depend on properties of the Hamiltonian.

Summary and Research Areas

An adiabatic quantum machine provides a remarkable setting for computing some discrete optimization problems. The machine needs a quadratic objective function, binary variables, and quadratic penalty functions that are balanced with the objective function. Then quantum annealing can be expected to produce a near optimal solution extremely fast.

Theory and experimental verification are needed to refine the quantum annealing process so that an optimal solution is obtained in one iteration. A dual problem technique has been recommended so there is a simple, uniform method to verify that the result is optimal. Much work is needed to achieve a quantified method to express complexity for adiabatic quantum computing. Lastly, compilers are needed to simplify the pre- and postprocesses.

Acknowledgments

Daniel M. Davenport, Maxwell D. Henderson, and Joseph A. Angelozzi, who were my colleagues at Lockheed Martin, are thanked for discussions and ideas that improved the foundations for this report.

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Hearing the Shape of a Triangle

Daniel Grieser and Svenja Maronna

Introduction

The question, "Can one hear the shape of a drum?" has attracted and inspired many mathematicians since it was asked by Mark Kac in 1966 [16]. The methods used to understand this problem draw on diverse areas: for example, partial differential equations, dynamical systems, group theory, number theory, and probability. In this article we will review some of the history and state of the art of the problem and add a new twist to the story that leads to a curious elementary geometric problem about triangles, which we then solve.

Let us state the problem precisely. For a domain (bounded open set) $\Omega \subset \mathbb{R}^2$ consider the problem of finding a function u on the closure of Ω, vanishing at the boundary $\partial\Omega$, and a number $\lambda \in \mathbb{R}$ satisfying

$$-\Delta u = \lambda u$$

in Ω, where $\Delta := \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$ is the Laplace operator. We call λ a *Dirichlet eigenvalue* of Ω if there is a solution $u \not\equiv 0$. Multiplying the equation by u and integrating by parts (i.e., using Green's identity), one sees that any eigenvalue must be positive; and using basic techniques from PDEs and functional analysis, one can show (see [6]) that the set of eigenvalues is an infinite discrete subset of $\mathbb{R}$ and that the eigenspace, i.e., the set of solutions u, corresponding to each eigenvalue is finite dimensional. Hence one may write the eigenvalues as a sequence $0 < \lambda_1 \leq \lambda_2 \leq \lambda_3 \cdots \to \infty$, where each eigenvalue is repeated according to the dimension of its eigenspace.

In this way a sequence of numbers $\lambda_1, \lambda_2, \ldots$ is associated with each domain Ω. This begs for mathematical investigation. Can we calculate the λ_k? No, except in a very few cases, for example, rectangles, the disk,[1] and certain triangles. Can we say anything interesting about how the eigenvalues depend on the shape of Ω? Yes. This is the subject of the mathematical discipline called spectral geometry (see [2] for a short introduction and more references, and also [6] and [17]). We can also pose the *inverse problem*: Is the domain Ω determined uniquely by its eigenvalue sequence? Of course, two congruent domains have the same eigenvalue sequence (we say they are *isospectral*), but do any two isospectral domains have to be congruent? This is Kac's question, mentioned earlier, for the following reason: Think of Ω as a drum, i.e., a membrane that is stretched over a wire frame in the shape of $\partial\Omega$. The membrane can vibrate freely, except that it is fixed at the boundary. When the drum vibrates you will hear a sound, which is composed of tones of various frequencies. These frequencies are the numbers $\gamma\sqrt{\lambda_k}$, where γ is a constant depending on the material and tension of the drum.[2] So if you know γ, then in this sense you can "hear" the eigenvalues λ_k. Without that knowledge you can still hear the quotients $\sqrt{\lambda_k/\lambda_1}$, which correspond to the musical intervals between the overtones and the fundamental tone of the drum's sound.

The problem may be easily generalized to higher dimensions and to compact Riemannian manifolds (with or without boundary). Already in Kac's time it was known that the answer is "no" in the realm of Riemannian manifolds: Milnor had constructed two flat tori of dimension 16 which are isospectral but not isometric (the appropriate notion of congruence for Riemannian manifolds).

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[1] *Here "calculate" is not to be taken literally: the eigenvalues are the squares of the zeroes of the Bessel functions.*

[2] *This is an idealized physical model; for real drums the frequencies are slightly different due to nonlinear effects and the influence of the resonance chamber.*

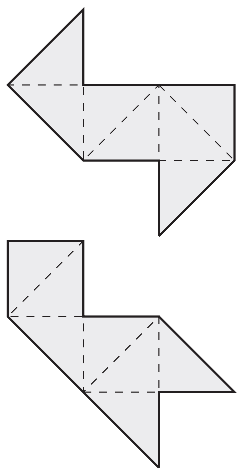

Figure 1. Two drums with the same overtones; see [13]. Isospectrality may be proved by transplantation; see [3], [5], and `http://www.geom.uiuc.edu/docs/research/drums/planar/planar.html`, and `http://www.math.udel.edu/~driscoll/research/drums.html` for pictures of eigenfunctions: For each triangle of the top drum one prescribes Euclidean motions to three triangles of the bottom drum. Then given any eigenfunction on the top drum, one transplants it to the bottom drum by moving the part of the eigenfunction on each top triangle to the bottom according to the given motions and adding (inserting suitable ± signs) the functions obtained on each bottom triangle. The motions and signs can be chosen in such a way that the resulting function on the bottom drum is smooth across the dashed lines and hence an eigenfunction with the same eigenvalue.

So the question was whether there could also be a counterexample among domains in the plane.

It took twenty-six years to reduce the dimension of counterexamples and make them fit into the plane. The first planar counterexamples were given in 1992 by C. Gordon, D. Webb, and S. Wolpert [13]. Figure 1 shows one of the first examples that was found. Since then many more examples of isospectral Riemannian manifolds, among them continuous families, have been found. Recent surveys on these constructions are [11] and [12].

What Can You Hear?

Rather than focus on counterexamples to Kac's question, let's be positive and ask which geometric properties of a domain or Riemannian manifold *can* be determined from its eigenvalue sequence. The indirect way in which the eigenvalues arise makes this seem a tough question to attack. However, there is a wonderful idea that helps us. It is the idea of transforms and traces. The two most important instances of this idea are the *heat trace* and the *wave trace*, corresponding to a sort of Laplace and Fourier transform of the eigenvalue sequence. More precisely, the heat trace is the function

$$h(t) = \sum_{k=1}^{\infty} e^{-\lambda_k t}, \quad t > 0, \tag{1}$$

and the wave trace is

$$w(t) = \sum_{k=1}^{\infty} \cos\sqrt{\lambda_k}t, \quad t \in \mathbb{R}. \tag{2}$$

The sum defining $h(t)$ converges for every $t > 0$, and h is a smooth function. The sum defining $w(t)$ never converges, but one can make sense of it in the sense of distributions, so w is a distribution on $\mathbb{R}$. For example, if $\lambda_k = k^2$ and we sum over $k \in \mathbb{Z}$, then the Poisson summation formula gives

$$w(t) = \sum_{k\in\mathbb{Z}} \cos kt = 2\pi \sum_{l\in\mathbb{Z}} \delta_{2\pi l}(t), \tag{3}$$

where $\delta_{2\pi l}$ is the delta distribution sitting at the point $2\pi l$ (to check this formally, simply calculate the Fourier series of the right-hand side). For this article we will be sloppy about the distinction between functions and distributions.

So why are the functions h, w useful for our problem? The reason is that there is a different way of understanding them, and this yields the desired link to the geometry of Ω. For h this involves the heat equation

$$(\partial_t - \Delta)v(t,x) = 0, \quad t > 0,\ x \in \Omega,$$

where $\partial_t := \frac{\partial}{\partial t}$. This equation has a unique solution for any initial data $v(0,x) = f(x)$ if we impose the boundary condition that $v(t,x) = 0$ for all $t > 0$ and $x \in \partial\Omega$. By separation of variables we obtain $v(t,x) = \sum_{k=1}^{\infty} a_k e^{-\lambda_k t} u_k(x)$, where the u_k form an orthonormal basis of $L^2(\Omega)$ of real-valued eigenfunctions corresponding to the λ_k and $a_k = \int_\Omega f(y)u_k(y)\,dy$. In other words,

$$v(t,x) = \int_\Omega H(t,x,y)f(y)\,dy,$$

where $H(t,x,y) = \sum_{k=1}^{\infty} e^{-\lambda_k t}u_k(x)u_k(y)$. The function $H : (0,\infty)\times\Omega\times\Omega \to \mathbb{R}$ is called the heat kernel of Ω, and since the u_k are normalized in L^2, one sees that

$$h(t) = \int_\Omega H(t,y,y)\,dy. \tag{4}$$

This is the trace of the operator $e^{t\Delta} : f \mapsto v(t,\cdot)$; hence the name heat trace for h. Now we observe that for any fixed $y \in \Omega$, the function $(t,x) \mapsto H(t,x,y)$ is the solution of the heat equation with initial data $f(x) = \delta_y(x)$; that is, it describes the distribution of heat after time t, when initially there is a single hot spot at y. Although heat spreads at infinite velocity (that is, $H(t,x,y) > 0$ for all x no matter how small $t > 0$), the value of

$H(t,x,y)$ at $x = y$ for t close to zero will be mostly influenced by the geometry of Ω near the point y. A precise analysis of the heat equation shows that for a Riemannian surface Ω without boundary we have the asymptotic behavior

$$H(t,y,y) \sim t^{-1} \sum_{j=0}^{\infty} a_j(y) t^j \quad \text{as } t \to 0,$$

where each $a_j(y)$ is a universal polynomial in derivatives of the Gauss curvature $K(y)$ of Ω at y. For example, $a_0(y) = \frac{1}{4\pi}$, $a_1(y) = \frac{1}{12\pi}K(y)$. If Ω has a boundary, then its influence is felt only when the distance of y to the boundary is of order at most $\sqrt{t}$, and in the integral (4) this contributes extra terms involving the curvature of the boundary and terms involving the powers $t^{-1/2+j}$. In the case of planar domains with polygonal boundary there is no curvature, but the corners give a contribution, and this leads to the formula

$$h(t) = a_0 t^{-1} + a_{1/2} t^{-\frac{1}{2}} + a_1 + O(e^{-\frac{c}{t}}) \quad \text{as } t \to 0$$

for some constant $c > 0$ where

$$a_0 = \frac{A}{4\pi},\ a_{1/2} = -\frac{P}{8\sqrt{\pi}},\ a_1 = \frac{1}{24}\sum_i \left(\frac{\pi}{\alpha_i} - \frac{\alpha_i}{\pi}\right),$$

where A is the area, P is the perimeter, and the α_i are the interior angles of the polygon. This formula was first mentioned in [18]; the first published proof was given in [20]. In the case of the triangle we have $\sum_i \alpha_i = \pi$, so $a_1 = \frac{\pi}{24}\sum_{i=1}^{3}\frac{1}{\alpha_i} - \frac{1}{24}$. Therefore, if we know all the λ_k, then we know the function $h(t)$ and hence the coefficients $a_0, a_{1/2}, a_1$, hence the area, the perimeter, and the sum of the reciprocals of the angles of the triangle. So we can hear these quantities. This motivates the following theorem:

Theorem 1. *A triangle is determined uniquely up to congruence by its area A, its perimeter P, and the sum R of the reciprocals of its angles.*

Corollary 1. *One can hear the shape of a triangle among all triangles.*

That is, if we know that Ω is a triangle, then the spectrum of Ω determines which triangle it is.

Corollary 1 was first proved by C. Durso; see [10]. Durso used in her proof the *wave kernel*, which is a much more powerful tool in spectral geometry than the heat kernel—at the cost of harder technical issues in its analysis. The main idea, however, is beautiful and easy to understand. After telling this remarkable story we will return to the proof of Theorem 1. This yields a new proof of Corollary 1, which avoids the use of the wave kernel.

The Wave Kernel

The wave trace $w(t)$ can be obtained in the same way as the heat trace but starting with the wave equation

$$(\partial_t^2 - \Delta)u(t,x) = 0, \quad t \in \mathbb{R},\ x \in \Omega$$

with initial data $u(0,x) = f(x)$, $(\partial_t u)(0,x) = 0$ and boundary values $u(t,x) = 0$ for all $t \in \mathbb{R}$, $x \in \partial\Omega$. This equation has a unique solution for each f, and it describes vibrations of Ω, or propagation of waves on Ω, with initial shape f. Again the solution can be written in the form $u(t,x) = \int_\Omega W(t,x,y) f(y)\,dy$, where W is now a distribution, and

(5) $$w(t) = \int_\Omega W(t,y,y)\,dy,$$

the trace of the operator $\cos t\sqrt{-\Delta} : f \mapsto u(t,\cdot)$.

How can we learn anything about the function $W(t,x,y)$? It may help to think of Ω as a lake. At time $t = 0$ we drop a stone into the lake at the place y—this corresponds to the initial condition $f(x) = \delta_y(x)$—and observe the resulting waves. In a linear water wave model, $x \mapsto W(t,x,y)$ is the lake's surface at time t. Everyone knows what happens: A circular wave front centered at y will form, its radius increasing linearly with t. When it reaches the boundary of the lake, it will be reflected. In our simple model there is no loss of energy, and the wave will move on forever. The precise shape of the wave front can be described as follows: Starting at y walk in any direction at speed 1. Always walk straight, except when you hit the boundary. In this case reflect off the boundary according to the law "angle of reflection = angle of incidence". The wave front at time t is the set of points that you can reach in this way when walking for time t.

This helps us understand the integrand $W(t,y,y)$ in (5): It will be large only for those times t for which the wave front returns to y after time t, i.e., for which there is a path[3] from y to y of length t. A more careful analysis then shows that when integrated over y, many of these "large" contributions cancel with neighboring paths due to oscillation. Only contributions from *closed paths*—that is, those which return to y in the same direction in which they started—are not cancelled in this way. To summarize, we arrive at the conclusion that $w(t)$ is large only for $|t| \in T$, where

(6) $$T = \{\text{lengths of closed paths in } \Omega\} \cup \{0\}.$$

[3] *Here a "path" is a succession of straight lines, or geodesics, obeying the law of reflection when hitting the boundary of Ω. If Ω has corners, as for a triangle, then a path running into a corner can leave the corner in any direction.*

Here we also need to count the "instant" path of length zero.

The precise mathematical statement of this involves the notion of singular support of a distribution, i.e., the set where the distribution is not given by a smooth function. The wave front at time t is precisely the singular support of the distribution $x \mapsto W(t,x,y)$. The result above translates into the statement

$$\operatorname{singsupp} w \subset \operatorname{clos}(T)$$

(see [14] for the rather technical proof and [7] for a survey of the history of this theorem). If there is precisely one path for each $t \in T$ (up to reversal of direction), then the singular support is equal to $\operatorname{clos}(T)$. It is conjectured that this equality is always true, but this is an open problem. In the example where Ω is a circle of length 2π (or alternatively, the interval $[0, 2\pi]$ where we impose periodic boundary conditions), this can be seen explicitly: The eigenvalues are k^2, $k \in \mathbb{Z}$, and the wave trace is (3); the numbers $2\pi l$ are precisely the lengths of closed paths in Ω.

So we see that essentially we can hear the set T of lengths of closed paths on Ω. This analysis can be refined substantially by analyzing the *kind* of singularities that the wave trace w has at points of T. It turns out that the singularity at $t = 0$ carries the same information as the full asymptotic expansion of the heat kernel at $t = 0$. The other singularities yield additional information, and using this, one can prove that one can hear generic convex domains with analytic boundary and certain symmetries; see [21], [15]. As a final remark on this, we would like to mention the remarkable recent work [8], in which for the first time the behavior of w at cluster points of T was analyzed in the special case of a disk. A recent survey on inverse spectral results obtained using trace formulae and related methods is [9].

To end this section, let us explain Durso's proof that one can hear the shape of a triangle.

It is classical that in an acute triangle Ω there is a unique shortest closed path, and it is given by the triangle formed by the base points of the three altitudes of Ω; see Figure 2. Therefore, one can hear the length of this path. Durso shows that in the case of an obtuse or right-angled triangle, the shortest closed path is the shortest altitude, traversed up and down, and that the wave trace w is singular at l_0, the length of this path (this is the hard analytical part of the proof). So one can hear l_0. Then she shows by an elementary geometric argument that any triangle is determined uniquely by area, perimeter, and the length of its shortest closed path.

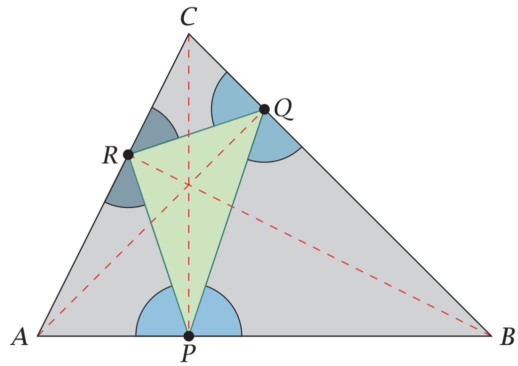

Figure 2. In an acute triangle $\triangle ABC$, how should one choose points P, Q, R on each side so that the triangle $\triangle PQR$ has minimal perimeter? The answer: Choose the base points of the altitudes of $\triangle ABC$. The resulting triangle is called the *Fagnano triangle*. There is a clever proof of this fact using reflections of the side AB across the sides AC and BC. Also, by a standard variational argument it follows that the circumference of the Fagnano triangle obeys the law of reflection at each of the points P, Q, R, so an ideal billiard ball on the billiard table $\triangle ABC$ will run forever along this line.

A Theorem about Triangles

We now return to the proof of Theorem 1. This is a rather peculiar statement: Have you ever heard of *reciprocals of angles*? There does not seem to be any geometric meaning to this, and our proof draws on classical analysis rather than geometry. Note that in contrast to Durso's proof, our proof uses only tools known in the 1960s.

First, let us remark that it is quite clear that the three quantities A, P, R determine a triangle *up to finitely many choices*. This follows easily from the fact that the space of triangles $\mathcal{T}$ is three dimensional (for example, it may be parameterized by the side lengths), that the functions A, P, R on $\mathcal{T}$ are analytic and independent (in the sense that none of them can be expressed as a function of the other two; independence in a stronger sense will follow from Lemma 1 below), and that R is a proper function on $\mathcal{T}/\mathbb{R}_{>0}$, the quotient of $\mathcal{T}$ by scalings: R tends to infinity when one of the angles tends to zero, which is the only way to leave all compact subsets of $\mathcal{T}/\mathbb{R}_{>0}$. However, just as prescribing the lengths of two sides and an angle not enclosed by them determines a triangle only up to two choices, it is not obvious why there should be only one triangle with any given A, P, R. Of course it is not hard to check this numerically, but it is far from obvious how to give a rigorous proof.

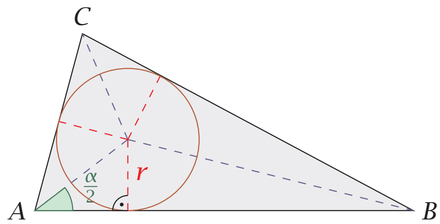

Figure 3. Proof of (7): $A = r\frac{P}{2}$ and $\cot\frac{\alpha}{2} + \cot\frac{\beta}{2} + \cot\frac{\gamma}{2} = \frac{1}{r}\frac{P}{2}$.

We denote the angles of the triangle by α, β, γ. We use the following formula from triangle geometry;[4] see Figure 3:

$$\frac{P^2}{4A} = \cot\frac{\alpha}{2} + \cot\frac{\beta}{2} + \cot\frac{\gamma}{2}. \tag{7}$$

This allows us to work exclusively with angles. We will prove:

Proposition 1. *A triple (α, β, γ) of positive real numbers satisfying $\alpha + \beta + \gamma = \pi$ is uniquely determined, up to ordering, by the values of*

$$f(\alpha, \beta, \gamma) = \cot\frac{\alpha}{2} + \cot\frac{\beta}{2} + \cot\frac{\gamma}{2}, \tag{8}$$

$$g(\alpha, \beta, \gamma) = \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}. \tag{9}$$

Theorem (1) follows directly from this: If area A, perimeter P and $R = g$ are given, then the angles are determined by equation (7) and the proposition, so the triangle is determined up to dilation. Then the given area fixes the dilation factor.

So it remains to prove the proposition. One way to proceed would be to eliminate one of the variables, say α, using the relation $\alpha = \pi - \beta - \gamma$; then eliminate another variable, say β, from the given value of g by solving a quadratic equation; then plug the expressions for α and β into f and investigate the resulting equation for γ. But this is horrible! Even if it works, it is ugly mathematics. If nothing else, the beautiful symmetry present in the statement of the proposition is lost.

Symmetry is a treasure. One should keep it and use it as long as possible. This is what we shall do.

Proof of Proposition 1. Let

$$D = \{(\alpha, \beta, \gamma) : \alpha, \beta, \gamma > 0, \\ \alpha + \beta + \gamma = \pi\} \subset \mathbb{R}^3_{>0},$$

where $\mathbb{R}_{>0} = (0, \infty)$. We think of points of D as "marked triangles up to dilation", where "marked" means that we have named the angles in a certain order. The set D is (the interior of) a triangle itself—the triangle cut out of the plane $\alpha+\beta+\gamma = \pi$ by the positive octant; see Figure 4. Points on the dashed lines correspond to isosceles triangles; the center e corresponds to the equilateral triangle. Let us call a point that does not lie on a dashed line a *nonisosceles point*. The nonisosceles points form six connected subsets, which we call *chambers*. The dashed lines are also lines of symmetry: If we pick a nonisosceles point and reflect it step by step across all dashed lines, we obtain six points, one in each chamber. These six points correspond to the same triangle, with angles named in different orders. Each chamber corresponds to one ordering of the angles, for example, the lower left chamber to the ordering $\alpha > \beta > \gamma$ or $\alpha \geq \beta \geq \gamma$ when we include its dashed boundary parts.

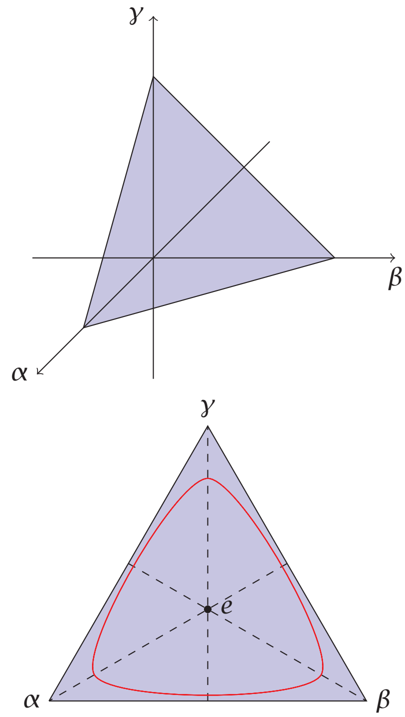

Figure 4. The space of angles of a triangle, and a level line of *g*.

The idea of the proof is to show that the level sets of the function g are convex curves (see Figure 4) and that f is strictly monotone along the part of any one of these curves lying in one chamber.

Lemma 1. *Consider the functions f,g and $h(\alpha,\beta,\gamma) = \alpha+\beta+\gamma$ on the positive octant $\mathbb{R}^3_{>0}$.*

a) *The function g is strictly convex on $\mathbb{R}^3_{>0}$.*
b) *The gradients $\nabla f, \nabla g, \nabla h$ are linearly independent at all nonisosceles points of D.*

Let us finish the proof of Proposition 1 and then return to prove Lemma 1. The strict convexity of

[4] *We are grateful to Richard Laugesen for pointing out this identity. Amazingly, both sides are also equal to the product $\cot\frac{\alpha}{2}\cot\frac{\beta}{2}\cot\frac{\gamma}{2}$. It's a nice little exercise in addition theorems to prove this.*

g implies that the sublevel set $G_{\leq s} = \{p \in \mathbb{R}^3_{>0} : g(p) \leq s\}$ is strictly convex for any $s > 0$, with boundary the level surface $G_s = \{p \in \mathbb{R}^3_{>0} : g(p) = s\}$. Furthermore, these sets are symmetric under all permutations of the coordinates. These properties then also hold for the intersections of the sublevel and level sets with the plane $\alpha + \beta + \gamma = \pi$. Since $g(p) \to \infty$ when p approaches the boundary of D (i.e., when at least one of the angles tends to zero), it follows that the sets $G_s \cap D$ are either closed curves in the interior of D which encircle the point e or are the point e or are empty. Since the equilateral triangle has $g(e) = \frac{9}{\pi}$, the first case corresponds to $s > \frac{9}{\pi}$.

In particular, we see that the point e is already determined by the value of g alone.[5]

Now consider any level curve $G_s \cap D$ with $s > \frac{9}{\pi}$. Consider the arc of the curve running inside one chamber, with endpoints p, q corresponding to isosceles triangles. Our proof will be complete if we can show that f is strictly monotone along this part of the curve.

Suppose f is not strictly monotone. Then there would be a point r on this arc, different from p and q, where f is stationary; that is, the derivative of f along the arc vanishes at r. By the Lagrange multiplier theorem this would mean that $\nabla f(r)$ is a linear combination of $\nabla g(r)$ and $\nabla h(r)$. But this would be a contradiction to part b of Lemma 1. This completes the proof of the proposition. □

Proof of Lemma 1. a) The Hessian (matrix of second derivatives) of g is the diagonal matrix with entries $\frac{2}{\alpha^3}, \frac{2}{\beta^3}, \frac{2}{\gamma^3}$ on the diagonal. This is clearly positive definite for all $(\alpha, \beta, \gamma) \in \mathbb{R}^3_{>0}$, and this implies that g is strictly convex.

b) We have

$$\nabla f = -\frac{1}{2}\begin{pmatrix} \frac{1}{\sin^2 \frac{\alpha}{2}} \\ \frac{1}{\sin^2 \frac{\beta}{2}} \\ \frac{1}{\sin^2 \frac{\gamma}{2}} \end{pmatrix}, \ \nabla g = -\begin{pmatrix} \frac{1}{\alpha^2} \\ \frac{1}{\beta^2} \\ \frac{1}{\gamma^2} \end{pmatrix}, \ \nabla h = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}.$$

Suppose there was a nonisosceles point (α, β, γ) (i.e., the numbers α, β, γ are pairwise different) and numbers R, S, T, not all zero, with $R\nabla f + S\nabla g + T\nabla h = 0$. Note that R, S cannot both be zero. Then the non-constant function

$$F(y) = -\frac{R}{2}\frac{1}{\sin^2 \frac{y}{2}} - S\frac{1}{y^2} + T$$

would have three different zeroes in the interval $(0, \pi)$, namely, $y = \alpha$, $y = \beta$ and $y = \gamma$. In order to show that this cannot happen, we prove that the function F is strictly monotone or strictly concave or convex on this interval, depending on the values R, S, T. We use the following fact, proved below:

Lemma 2. *The function* $G(x) = \frac{1}{\sin^2 x} - \frac{1}{x^2}$ *is strictly increasing and strictly convex on the interval* $(0, \pi)$.

This lemma implies that the function $G_C(x) = \frac{1}{\sin^2 x} - \frac{C}{x^2}$ is, on the interval $(0, \pi)$, strictly increasing for $C \geq 1$ and strictly convex for $C \leq 1$, since $G_C(x) = G(x) + \frac{1-C}{x^2}$ and the function $\frac{1-C}{x^2}$ is increasing for $C > 1$ and convex for $C < 1$. Now clearly we can write $F(y)$ as a non-zero constant multiple of $G_C(\frac{y}{2})$, for some C, plus a constant. Therefore, F cannot have three different zeroes on the interval $(0, 2\pi)$, and Lemma 1b) follows. □

Proof of Lemma 2. First note that this is nontrivial: It is easy to check that both $\frac{1}{\sin^2 x}$ and $\frac{1}{x^2}$ have positive second derivative whenever they are defined, hence are convex, but it is not clear why their difference should be convex. However, things become very transparent when we use the series representation (partial fraction expansion)

$$\frac{1}{\sin^2 x} = \sum_{k=-\infty}^{\infty} \frac{1}{(x - k\pi)^2},$$

which follows from the well-known partial fraction expansion of the cotangent by differentiation. This yields $G(x) = \sum_{k \neq 0} \frac{1}{(x-k\pi)^2}$. Now every summand $\frac{1}{(x-k\pi)^2}$ is strictly convex on $(0, \pi)$ since the function $\frac{1}{x^2}$ is strictly convex on both half lines $x < 0$ and $x > 0$, so G is strictly convex. Furthermore, the series shows that G is regular at $x = 0$, and it is also even, so $G'(0) = 0$. Combined with strict convexity, this implies that G is strictly increasing on the interval $(0, \pi)$, which was to be shown. □

Further Remarks

Let us take another look at the proof of Theorem 1 from a slightly different perspective. Proposition 1, which implies Theorem 1 by elementary triangle formulas, may be restated as saying that the map $\Phi = (f, g) : D \to \mathbb{R}^2$ is injective on the closure in D of each chamber. The proof of injectivity has two ingredients: First, Lemma 1b), which may be restated as saying that the differential of the map Φ is invertible in the chamber and hence, by the inverse mapping theorem, that Φ is locally injective everywhere; that is, every point of the chamber has a neighborhood on which Φ is injective. Second, the convexity of Lemma 1a) allows us to infer global injectivity from this local statement. Finally, the analytic core of the whole argument is Lemma 2, which is used in the proof of Lemma 1b). We now take another look at this.

[5] *This can also be seen from the arithmetic-harmonic mean inequality* $3\left(\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}\right)^{-1} \leq \frac{\alpha+\beta+\gamma}{3}$ *with equality iff* $\alpha = \beta = \gamma$.

A Different Proof of Lemma 2

While the given proof using the partial fraction representation is very elegant, you might wonder if there is a more pedestrian way to prove convexity of G. Indeed there is. Here is a sketch. It was our first proof of this result, and it is the result of the bachelor's thesis of the second author. A short calculation gives $\frac{1}{2}G''(x) = \frac{3}{\sin^4 x} - \frac{2}{\sin^2 x} - \frac{3}{x^4}$. We need to show that this is positive (here and in the sequel we always assume $x > 0$). This is equivalent to the inequality

$$(10) \qquad 3\sin^4 x + 2x^4 \sin^2 x \overset{!}{<} 3x^4.$$

How can one prove an inequality involving trigonometric functions and polynomials? Maybe your first idea is to use the well-known inequality $\sin x < x$ to get rid of the sines. But clearly this does not help, since $3x^4 + 2x^4 \cdot x^2 > 3x^4$. How can we do better?

Recall where the inequality $\sin x < x$ comes from: x is the first term in the Taylor series of $\sin x$; the next term is negative. Of course this is not a proof, but it is the core idea, which can be turned into a proof as follows: The function $f(x) = x - \sin x$ vanishes at $x = 0$ and has derivative $f'(x) = 1 - \cos x$, which is always nonnegative, and is positive for small positive x. Thus, $x - \sin x > 0$ for all positive x follows by integration: $f(x) = \int_0^x f'(t)\,dt > 0$.

So in order to prove (10) we can try to use a better estimate for $\sin x$ by using more terms from its Taylor series. We have the estimate

$$(11) \qquad associatedwith \sin x < x - \frac{x^3}{6} + \frac{x^5}{120}.$$

This can be proved in the same way as $\sin x < x$: The function $f(x) = x - \frac{x^3}{6} + \frac{x^5}{120} - \sin x$ satisfies $f(0) = f'(0) = f''(0) = f'''(0) = f^{(4)}(0) = 0$ and $f^{(5)}(x) = 1 - \cos x \geq 0$, and > 0 for small positive x. Integrating, we obtain $f^{(4)}(x) = \int_0^x f^{(5)}(t)\,dt > 0$; then integrating again we get $f'''(x) > 0$, and so forth until we obtain $f(x) > 0$ for all $x > 0$.[6]

We now plug (11) into the left-hand side of (10). A rather tedious calculation shows that the result, which starts as $3x^4 - \frac{1}{15}x^8 + \cdots$, is less than $3x^4$ for $x < 4$. The main point is that the second term is negative. Among the higher terms some are positive, but they can easily be estimated against the negative ones.

A Few Open Problems

The way in which the Dirichlet eigenvalues determine the triangle is somewhat indirect: First one constructs the heat kernel h (see (1)), and then one considers the coefficients in its asymptotic expansion to prove the result. In particular, one needs to know (asymptotic information on) *all* the eigenvalues for this. It is natural to ask whether a finite number of eigenvalues, ideally only three, suffice to determine the triangle.

Problem. Do the first three Dirichlet eigenvalues, $\lambda_1, \lambda_2, \lambda_3$, determine a triangle?

Numerical evidence was provided in [1] that this is true—but that the corresponding statement for $\lambda_1, \lambda_2, \lambda_4$ is false. However, no proof of this is known. As a partial result in this direction, it is proved in [4] that for each $\varepsilon > 0$ there is a number N so that $\lambda_1, \dots, \lambda_N$ determine a triangle uniquely among all triangles whose angles are all greater than or equal to ε.

Problem. Is there a closed path (not hitting a corner) on every triangle?

For acute triangles the answer is "yes"; see Figure 2. The problem is open for general obtuse triangles.

Problem. Does the second Neumann eigenfunction on an obtuse triangle have its extrema on the boundary?

This is conjectured to be true and is a special case of the *hot spots conjecture*. See the recent discussion on polymath [19].

Let us mention two other open questions on the inverse spectral problem.

Problems. Can one hear the shape of a convex polygon? Can one hear the shape of a domain $\Omega \subset \mathbb{R}^2$ with smooth boundary?

We emphasize that the answer is "no" when convexity or smoothness is not required: All known counterexamples to "Can one hear the shape of drum?" are nonconvex polygons; cf. Figure 1.

[6] *Instead we could have used Taylor's formula with remainder for the function* $g(x) = \sin x$*:*

$$g(x) = \sum_{k=0}^{4} \frac{x^k}{k!} + \frac{1}{4!}\int_0^t (x-t)^4 g^{(5)}(t)\,dt,$$

which using $g^{(5)}(t) = \cos t \leq 1$ *(and* < 1 *for small positive t) and* $\int_0^t (x-t)^4\,dt = \frac{1}{5}x^5$ *yields the same result. Yet another proof uses Leibniz's criterion for the Taylor series* $x - \frac{x^3}{3!} + \frac{x^5}{5!} + \cdots$ *of* $\sin x$*, which is alternating. The terms after the fifth power are monotonically decreasing in absolute value if* $\frac{x^{2n+1}}{(2n+1)!} < \frac{x^{2n-1}}{(2n-1)!}$ *for* $n \geq 4$*, which is equivalent to* $x^2 < 2n(2n+1)$*, hence true for* $x < \sqrt{72}$*. Since the first omitted term after* $\frac{x^5}{5!}$ *is negative, we get that the sum of the series, which is* $\sin x$*, is less than* $x - \frac{x^3}{3!} + \frac{x^5}{5!}$*, at least for* $x < \sqrt{72}$*. Since* $\sqrt{72} > \pi$*, this is enough for our purpose.*

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The Struggle against Idealism: Soviet Ideology and Mathematics

Christopher Hollings

For several years now I have been studying the development of semigroup theory (see, for example, [21]). This is a relatively new area within mathematics, most of the major developments having taken place after the Second World War. The fact that there was a particularly strong Soviet school of semigroup theory has meant that I have been drawn into the study of Soviet mathematics more generally. Naturally it is not possible to investigate the latter area without having some awareness of ideological issues within the Soviet Union. The criticism by Soviet ideologues of the theory of relativity, for example, is reasonably well known (see [43]), as is the infamously detrimental effect that the pronouncements of Trofim Lysenko had on Soviet genetics (see [25]). The case of mathematics is, however, perhaps not so familiar in spite of a great deal of scholarship having been carried out in this area and it being a subject of continuing and current interest, as shown, for example, by recent books such as [20]. The present article (which I compiled originally simply as a document for my own reference) is intended as a concise introductory account of Soviet ideology of mathematics through which I hope to bring this fascinating subject to wider attention. In the words of one of the anonymous referees, this article is a "teaser". I must stress at this point that it is merely a survey and does not represent original scholarship.

Although I have drawn upon a range of sources in the compilation of this article, my account is based very heavily upon three excellent articles by Alexander Vucinich on the subject of Soviet ideology and mathematics [45], [46], [47]. These articles no longer represent the most up-to-date material in this area and might indeed be criticized for their slightly old-fashioned viewpoint (in a sense to be described below), but they nevertheless provide a useful framework for a first account of this subject. My purpose in writing a new article on this topic is to provide a shorter, punchier exposition of the material, which I hope will serve as a useful starting point for any reader who wishes to go on to read the greater detail available in the work of Vucinich and other authors. A wide range of references to other published materials on this theme is provided throughout. I have deliberately kept this article somewhat superficial—the study of Soviet ideology of mathematics is far more complicated than could ever be conveyed fully in a short article such as this. Instead, I hope that this article will inspire readers to follow up the references given. I have purposely cited mostly English secondary sources through which the interested reader will gain easy access to the Russian primary sources, particularly the archival material that is increasingly becoming available. The focus here is very much upon ideology rather than the personal stories of mathematicians, to which references will be given throughout. Although there are many fascinating such stories, I have chosen to omit them in order to keep the length of the article down and also because they

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are well recorded elsewhere—what is presented here is the technical framework against which the personal stories are to be understood.

For reasons that will be outlined in due course, the Soviet ideology of mathematics was in fact rather superficial and, ultimately, fairly ineffective: to a large extent, mathematicians continued with their work with little interference from the ideologues. This was in spite of the vast volume of ink that was expended in connection with the construction of a Marxist philosophy of mathematics. The promises that were made for this philosophy, and all that it might do for mathematics, were never realized. Many of the works that were written on this subject are distinctly unsatisfactory to the mathematician's brain: they tend to be somewhat vague, and, where an assertion is to be proved, this is often done as a "proof by examples". It may seem unreasonable to expect a mathematical level of rigor in the discussion of philosophical ideas, but it was the Marxist thinkers themselves who claimed that such precision was possible; however, they were never able adequately to demonstrate this assertion.

A curious effect of the superficiality of the Soviet ideology of mathematics is that it is possible to grasp a great deal of this subject, supposedly a topic within the philosophy of mathematics, with little knowledge either of philosophy or indeed of mathematics—although, naturally, a deeper understanding may be achieved if one knows a little of the underlying philosophy and mathematics. In writing this article, I have assumed that the reader will have a mathematical background but that they may not be well versed in Soviet philosophy. The article proper therefore begins with a very brief sketch of the philosophy which underpinned the ideology of the Soviet state: dialectical materialism. The official Soviet view was that all things (mathematics included) should be explicable in terms of dialectical materialism. Thus, the "Great Soviet Conceit" emerged: the idea that, in light of their conversance with state ideology, it was the Communist Party bosses rather than the appropriate specialists who were best placed to guide the development of any discipline. In the course of this article, we will see their ineffective attempts to do this in mathematics.

To pick up on the comments made above concerning Vucinich's "old-fashioned" perspective, it should be noted that his point of view was rooted firmly in cold war attitudes towards Soviet science, which regarded the ideological question in rather black-and-white terms as a struggle between "good" scientists and "bad" ideologues. Ideological "interference" in science was generally painted as a negative influence and a hindrance to progress: Lysenkoism was held up as the typical example. However, the reality appears to have been considerably more complicated, as many authors have argued in the post-Soviet period. For example, Alexei B. Kojevnikov has noted the use of ideology in clashes, not just between scientists and ideologues but between scientists from rival camps within the Soviet physics community [27]. Slava Gerovitch has written about the ways in which Soviet mathematicians used carefully phrased philosophical language to strengthen their own positions [15]. However, in light of the fact that the primary purpose of this article is to provide a short introduction to Soviet ideology of mathematics, in which I hope to interest the reader who has no previous knowledge of this subject, I prefer to present a simpler narrative even if it appears a little simplistic in places. Nevertheless, the reader should be aware of the above-mentioned issues, and further references will be given in the hope that the reader will then be interested enough to follow the references and fill in the further complications in the picture for themselves.

In his treatment of this subject, Vucinich identified three distinct phases in the development of the Soviet ideology of mathematics: before, during, and after Stalin's period in power. In the present article, I have retained Vucinich's division; the three phases are dealt with in turn. Roughly speaking, the pre-Stalin period was the phase in which mathematicians could safely ignore ideological issues, whereas the Stalinist period was characterized by greater state control of mathematics and mathematicians. In the post-Stalin phase, a certain harmony was reached in which the mathematicians had learned at least to pay lip service to ideology and the ideologues were much less fanatical. The article concludes with some suggestions for further reading.

Dialectical Materialism

Given that it was one of the twentieth century's most touted philosophies, it is perhaps not surprising that there are many books available on the subject of dialectical materialism, some easier to digest than others. One of the easiest that I have found is a rather old, but nevertheless very concise and readable, treatment in Edward Conze's *An Introduction to Dialectical Materialism* [6], where the philosophy is described "in a language that the ordinary worker-student can understand" [6, pp. 5–6]. The account which is perhaps most appropriate in the present context, however, is that to be found in Loren Graham's *Science in Russia and the Soviet Union: A Short History* [18, Chapter 5]. A similar account may also be found in Graham's earlier book, *Science and Philosophy in the Soviet Union* [17, Chapter II]. The present section is a condensed synthesis of the versions of Conze and

Graham, incorporating a few comments made by G. G. Lorentz [34, pp. 183–4]. This section will be kept brief, since, as has already been noted, a detailed knowledge of dialectical materialism is not in fact required for an understanding of the subsequent material.

In describing dialectical materialism, there are clearly two aspects that need to be dealt with: first, the concept of "materialism" and then the function of the adjective "dialectical". *Materialism* refers simply to a philosophical view that is based upon the real world. It asserts that the world is made up of matter and energy and that all of nature may be explained in terms of our understanding of these without recourse to a divine explanation. An objective reality exists outside the human mind, and this reality is subject to natural laws that the human mind is capable of discovering. No aspect of nature is inaccessible to rational explanation. Our knowledge of the world derives ultimately from our experience of it. Materialism sits in contrast to *idealism*, idealistic notions being those which are conjured up entirely from the human mind and have no basis in physical reality.

In some versions of materialism, the universe is regarded as a system that is not subject to overall change with the passage of time, but dialectical materialism is a form of *historical materialism*: a materialist philosophy that not only acknowledges the process of change within a system but also looks to the past development of that system as a means of anticipating its future tendencies. If the process of change is to be incorporated into a philosophical view, then the mechanism by which this change takes place must be identified. In the case of dialectical materialism, this mechanism is provided by the notion of the *dialectic*: essentially, a contrast between opposing notions. Dialectical materialism asserts that, within any given system (be it the universe, society, or any other system of our choosing), there will coexist certain pairs of contradictory ideas: *theses* and *antitheses*. It is the "tension" between a thesis and its corresponding antithesis that drives the process of change, leading ultimately to some sort of reconciliatory outcome (the *synthesis*). We may apply these ideas to society in order to see a very simplistic example of this process: a dialectic exists between the thesis "there are rich people" and the antithesis "there are poor people". The dialectic drives change in society, whereby the rich get richer by exploiting the poor, leading to the (in the Marxist view, inevitable) synthesis that is revolution and the establishment of a socialist state. The application of dialectical materialist ideas to society to develop a theory of social development, in companionship with dialectical materialism as a philosophy of science, forms the basis of Marxism. Marxist thinkers used the close connections between dialectical materialism and (exact) science to imbue their philosophy with what they saw as a greater precision than that present in any other philosophical scheme. This led them to the view that dialectical materialism was the only valid philosophy for the construction of socialism. Indeed, as G. G. Lorentz observes,

> Lenin, Stalin, and the Party had great respect for the exact sciences and mathematics based on the naive belief that the future of communism was ensured by following Marx's prescriptions and having science as an ally. They considered Marxism itself an exact science. [34, p. 198]

With its exalted status as the "one true philosophy", dialectical materialism became an overarching scheme into which all other disciplines needed to be integrated. This view had a highly destructive effect on Soviet genetics, for example, but as we have already noted, its effects on mathematics were much less severe.

Before Stalin

It was only several years after the October Revolution that Marxist thinkers began to turn their attention seriously to the development of a Soviet philosophy of mathematics. As Vucinich explains [45, p. 107], the reasons for this were twofold. First of all, the so-called "Marxist classics" (namely, the writings of Marx, Engels, and Lenin) provided little guidance on how to proceed. Second, the Marxist writers of the 1920s had little mathematical background, particularly when it came to the more recently developed branches of mathematics, such as set theory.[1] For these reasons, the Communist Academy, the Soviet body tasked with "perfecting" Marxism (that is, turning it into a unified and consistent theory) and integrating it with all other disciplines, had made little progress in connection with mathematics.

In the absence of any ability to make detailed dialectical analyses of mathematics, the Marxist theorists of the early days of the Soviet Union occupied themselves instead with the wholesale criticism of the perceived idealism of Western mathematics and its possible unwholesome influence on its Soviet counterpart. Set theory, logic, and the foundations of mathematics came under particular fire. However, as we will see in this section, any action taken against these areas in the 1920s was disorganized, inconsistent, and

[1] *In fact, such ignorance extended beyond mathematics, as Kojevnikov* [27, p. 280] *has commented: "... despite their professed respect towards science, Bolsheviks with very few exceptions did not possess even basic scientific literacy and could be highly suspicious of scientists in real life."*

thus ultimately ineffective. Although the Marxist philosophy of mathematics of the 1920s lacked much cohesion, it was, nevertheless, in Vucinich's view [45, pp. 108–10], based upon certain basic suppositions, which included the following:

(1) *The highly abstract nature of mathematics puts it at risk of developing idealistic leanings; these must be resisted. The following three idealistic tendencies must all be rejected:*
   (a) *Logicism: the reduction of mathematics to a branch of formal logic, detached from reality.*
   (b) *Formalism: the "axiomatic" attitude whereby mathematics is treated as a collection of formulae which have no specific interpretation and are merely manipulated according to certain rules.*
   (c) *Intuitionism: the idea that mathematics may be built upon human intuition rather than pure reason.*

   The Marxist position was that although each of these three approaches had had its own small-scale successes, none of them was strong enough to support an overarching philosophy of modern mathematics. Although logicism and formalism were universally condemned by Marxist thinkers, there was room for debate where intuitionism was concerned: some Marxists were prepared to accept intuitionism, since they felt that this was the mechanism through which cultural and social influences entered mathematics.
(2) *The degree of "mathematization" of a given science gives an indication of the state of development of that science. However, we must also take account of the "qualitative" aspect of science, the extent of which varies from discipline to discipline. This is particularly prominent, for example, in the social sciences.*
(3) *Mathematics should not be deprived of a practical basis: all mathematical notions should be separated from reality only by a well-defined sequence of necessary abstractions. Marxist theorists are to be the judges of the utility of a given branch of mathematics and are to ensure that mathematics addresses both the needs of science and of society.*
(4) *Mathematics consists of theoretical constructions which arise from hypotheses put in place by mathematicians. It is through the choice of these hypotheses that social and cultural influences penetrate mathematics. Conversely, mathematics gives dialectical materialism an exactness not present in other philosophies. Dialectical materialism is therefore the only philosophy that is suited to the needs of society.*

Even with these precepts laid down, Marxist scholarship had little impact on mathematics. As already commented, most Marxist thinkers had little mathematical background and were therefore unable to take on mathematics as a whole simply because there was much in it that they did not understand. They directed some criticism towards the perceived idealism of Cantor's theory of transfinite numbers, for example, but ultimately failed in their attack because they did not have the detailed mathematical knowledge to attempt to offer up a materialistic alternative. Non-Euclidean geometry also caused particular problems for Marxist thinkers. The fact that it had no experimental basis clearly left it open to accusations of idealism, and yet nationalist sentiments begged for the acceptance of such a prominent Russian contribution to modern mathematics. It took many years and much mental gymnastics for Marxist writers finally to integrate non-Euclidean geometry into dialectical materialism. This must have been particularly traumatic for them, since geometry was traditionally regarded as a very practical (and thus philosophically straightforward) branch of mathematics; the comment of one Marxist pundit was that

> [g]eometrical methods and problems have had a wholesome effect upon mathematics by drawing it back to "sinful mother earth". [5, p. 12]

In Vucinich's opinion, two major sources may be identified for the fragmentation of the Marxist analysis of mathematics: "an ideological compulsion to exaggerate the 'idealistic' leanings of many modern mathematicians and a doctrinaire rigidity in identifying the branches of mathematics characterized as impractical and as targets of direct attack" [45, p. 110]. Further division may be found in the Marxist commentators' approaches to Marxism as a whole. Most of those at the Communist Academy, for example, viewed Marxism as "an open theory demanding constant work on improvement and modernization" [45, p. 110]—this was, after all, the reason that the academy had been formed in the first place. The point of view at the academy was that, if Marxist philosophy was to survive, then it must take into account new developments in science. Other thinkers, however, took the opposite line concerning Marxism: that it was essentially a complete, closed theory in which no further improvement was possible. This dogmatic view insisted that science could be on the right track only if it supported the basic tenets of Marxism.

Mathematicians themselves generally, and perhaps wisely, steered clear of the Marxist interpretation of their discipline during this period, though the occasional objection was raised against the peremptory rejection of those areas of mathematics within which hints of an idealistic leaning had been detected [45, p. 111]. V. A. Steklov [41, pp. 37–8], for example, argued against an official ideological line in science: he felt that such would hinder scientific advancement. Steklov was careful not to name the Soviet authorities directly (he expressed these views in an essay about Galileo's clash with the church) [45, p. 111]. Nevertheless, before Stalin came to power it was reasonably safe for leading academics to be critical of the relations between science and Marxist philosophy. S. N. Bernstein [41, pp. 83–4], for example, repeatedly cast doubt upon the possibility of integrating mathematics fully with dialectical materialism. As Vucinich notes, it was probably Bernstein's international standing that saved him from any Party reprisals [45, p. 112]. On the whole, Soviet mathematicians presented a united front against the move towards "practicalism" in mathematics that was advocated by the dogmatic (and often unrealistic) pronouncements of dialectical materialism. A. Ya. Khinchin [41, pp. 267–8] even went so far as to accuse the ideologues of taking too narrow a view of mathematics: they had no appreciation of mathematics as a whole and thus no sense of the future benefits that it might bring [45, p. 117].

Soviet mathematics retained a significant degree of autonomy owing to the lack of any coordinated assault from Marxist theorists. Solidarity amongst mathematicians against interference from the ideologues was particularly conspicuous at the famous Moscow function theory school (see, for example, [9, 37]), which defended its individual members regardless of their philosophical leanings. This unity, coupled with the school's research excellence, gave it a strength with which it was able to resist the efforts to bring it under the control of the ideologues. Despite an encroaching state jingoism, Moscow mathematicians continued to publish in French and German journals. Such foreign publication would become a serious issue for Moscow mathematicians in particular—and for Soviet mathematicians more generally—in the 1930s.

By the end of the 1920s, Stalin was in power, and plans were afoot to bring science under strict state control in parallel with the kind of control exerted within the ongoing five-year plans. Ernst Kolman, a particularly rabid exponent of Stalinist Marxism who came to prominence in the 1930s, asserted that

> [f]or mathematics there is only one way out: conscious, planned reconstruction on the basis of materialist dialectics. [5, p. 11]

At this stage, however, there was still a lack of mathematicians who were well versed in Marxist theory. The authorities therefore took a more militant approach: for example, supposedly "idealistic" journals were banned, and, following a hasty mathematical education, "socialist vigilantes" were sent out to infiltrate scientific organizations, with a view to gathering information on and ultimately exposing those scientists who deviated from the Party line [45, p. 121]. At this point, we enter the Stalinist phase of ideological interference in mathematics.

The Stalinist Period

The beginning of Stalin's period of total authority in the USSR was marked by sweeping societal and economic changes (namely, the collectivization of agriculture and the five-year plans for the development of industry) and also by the beginning of the crackdown on all independent thought. If mathematics had been left largely unaffected by state ideology in the pre-Stalin period, it was beginning to feel the effects a little more from the early 1930s. As John Barber notes,

> [i]ntellectual neutrality and academic autonomy soon ceased to be options. Tolerance of non-Marxist intellectuals who co-operated with the regime was replaced by the demand for unequivocal commitment to the official worldview. [3, p. 141]

There is in fact some evidence to suggest that Stalin himself did not truly believe that mathematics could be integrated into Soviet philosophy (see [15, pp. 33–4]). Needless to say, this opinion was never stated publicly. Under Stalinism the development of a consistent Marxist philosophy of mathematics was more about state control of the scientist than philosophy for its own sake. Gerovitch notes that

> [d]ialectical materialism, once a thriving and productive field of philosophical scholarship, under Stalin gradually "calcified" and was used as a philosophical cudgel. [14, p. 552]

Calls were made for mathematicians finally to conform; Vucinich notes that the Communist Academy criticized the "ideological lethargy and philosophical aloofness of leading mathematicians" when it came to the development of a mathematics that was consistent with Marxist precepts [46, p. 54]. Ernst Kolman, who is described elsewhere by Vucinich as being one of "the most ubiquitous and ardent Stalinist philosophers during the 1930s" [44, p. 251], noted that "under the dictatorship of the proletariat…no discipline can exist in isolation from politics and Party leadership" [46, p. 54]. In his view, the independence thus far enjoyed by the mathematical community was entirely at odds with the needs of socialist construction. As a self-proclaimed mathematician (though a very superficial one, more interested in the Marxist interpretation of mathematics than mathematics itself),[2] Kolman was especially keen to see mathematics become a "Party science", closely linked to dialectical materialism and Party policy.

During this period, the notion of *partiinost* (партийность = "party-ness") became all important. This is a word that had an innocent day-to-day usage on official Soviet forms, where it indicated a person's Communist Party membership status: their partiinost would either be "партийный" (a Party member) or "беспартийный" (not a Party member). However, during the 1930s, the word took on a slightly different meaning: it came to refer to the adherence to the official Party line, as derived from the principles of dialectical materialism, and the extent to which Party objectives were put before all other considerations [30, p. 296]. Thus the degree of partiinost became a measure of the "soundness" of an individual or of a discipline in the eyes of the state. Bound up with the notion of partiinost was also the idea that there was no such thing as a neutral discipline: if a given subject was not fully behind Soviet ideology, then ipso facto it was against it (see [42, p. 39]). The task of the socialist vigilantes (see the end of "Before Stalin") was to expose those academics whose partiinost was questionable.

Marxists commentators despaired at the mathematicians (particularly those in the Moscow school) who took pride in the purity of their work and its isolation from other branches of science. Such mathematicians were also guilty of the cardinal sin of "philosophical neutrality": it was noted that the word "dialectics" was never used in the meetings of the Moscow and Leningrad Mathematical Societies [46, p. 55]. It was felt that only unity amongst Marxist philosophers of mathematics could rectify this situation and that this could only be achieved through a relentless attack on any perceived idealistic leanings within mathematics. Indeed, a sense of urgency emerged surrounding this issue when Marxist thinkers began to fear that idealism in mathematics could start to infect other areas, such as physics. For example, in an article on the perceived "crisis" in the mathematical sciences, Kolman noted that this concern

> …applies with particular force to present-day physics, with its remarkably abundant mathematical apparatus, with its efforts to formalise physics, to geometricise it, its aim of allowing matter to disappear and of retaining equations only…[5, pp. 1–2]

In 1931 the Communist Academy published the proceedings of a symposium on mathematics and dialectical materialism [28] in which the anonymously authored introduction attacked the Moscow mathematical school (in particular, its leading member, N. N. Luzin) for its avoidance of philosophical issues—this was said to be a mask for the school's idealistic leanings. The Leningrad mathematical school also came under fire, but no single individual was criticized in this instance.[3]

In his article for the proceedings, Kolman advocated the state planning of mathematical research and, in doing so, repeated much of the rhetoric that we have seen already: that mathematics must be integrated into dialectical materialism in order to be acceptable for socialist construction. He warned against the evils of idealism and noted that mathematics could never be incorporated fully into Soviet ideology so long as idealist tendencies were allowed to remain. However, in this and later writings, he gave no indication of how a specifically Marxist mathematics might be achieved; like previous authors, he spent more time criticizing the mathematics of the West.

During the 1920s the attacks of Marxist thinkers were directed almost entirely at mathematics rather than at mathematicians. However, in the 1930s attacks on mathematicians became rather more common, as Stalin sought to weaken the hitherto strongly independent intelligentsia. Amongst the first victims was the Moscow mathematician D. F. Egorov [41, pp. 61–2], who had not only made statements in favor of academic independence but also publicly refused to renounce his Orthodox faith in the face of state atheism. He was fired from his position as director of the Institute of Mathematics and Mechanics of Moscow University and, after a spell in prison, died in hospital. Other prominent mathematicians who found themselves under fire (though not as seriously so as in the case of Egorov) were V. F. Kagan and A. Ya. Khinchin. Even the loyally communist O. Yu. Schmidt came under attack: his article on algebra for the *Great Soviet Encyclopedia* (which he edited) was deemed to be insufficiently Marxist in tenor [46, p. 58]. The criticism of Schmidt, however, may have had less to do with ideology and more to do with a growing trend in Soviet academia that employed ideology, often somewhat cynically, as its weapon: the

[2] *For further details on Kolman, see* [29] *and* [38, Appendix A].

[3] *A more focussed ideological attack was launched against Leningrad mathematicians in 1949; see* [22].

attacks of younger academics, vying for advancement, on their older colleagues. Indeed, ideology was also used as ammunition in struggles between rival academics more generally: some of the most critical ideological attacks on mathematicians, for example, often came from other mathematicians [18, Appendix A].

The most infamous attack on a Soviet mathematician was that launched against N. N. Luzin [41, pp. 17–8] in the mid-1930s; amongst those who spoke against Luzin were a number of his former students.[4] Luzin, a one-time close associate of Egorov, was accused of being anti-Soviet on various grounds, including the accusation that he published his best work in foreign journals. The wider result of this imputation was the fact that Soviet mathematicians began to publish less work abroad.[5] Moreover, as Luzin was also criticized for his strong ties to the Paris set theory school, foreign contacts came to be discouraged more generally, resulting in a certain isolation of Soviet mathematics. The Academy of Sciences found Luzin guilty of all charges, but little punishment was meted out for reasons that remain obscure, although a number of plausible explanations have been given; see, for example, [20, p. 160] and [16, p. 6]. The judgement against Luzin was overturned in January 2012 [32].

Many leading mathematicians tried to adapt themselves to the needs of dialectical materialism without actually participating in the activities of Marxist organizations. P. S. Aleksandrov [41, pp. 223–5] and A. N. Kolmogorov [41, pp. 323–4], for example, contributed articles on mathematics to the publications of the Communist Academy. However, in these articles they simply made positive comments on dialectical materialism without dealing in specifics. Such articles did little to bridge mathematics and Soviet ideology. Nevertheless, the lip service paid to the official line seems to have placated many of the Marxist commentators on mathematics. Indeed, Kolmogorov's article on mathematics for the *Great Soviet Encyclopedia* (1938) was regarded for many years as being the most comprehensive account of the Marxist interpretation of mathematics despite the fact that it spoke of connections with dialectical materialism only in very vague, general terms. As with many mathematicians, Kolmogorov's apparent support of Soviet ideology of mathematics stemmed from pragmatism: Vucinich describes it as "fortuitous and superficial" [46, p. 61]. Nevertheless, Soviet mathematicians had Kolmogorov to thank for a certain reconciliation between abstract mathematics and Marxist thought. In an article of 1936, he argued that, far from being removed from real-world applications, greater abstraction in mathematics enabled one to encompass a wider range of applications in a single theory. Algebra and set theory were thus made more palatable to the Soviet ideologues, though not all of them were convinced [46, pp. 61–2]. For more on Kolmogorov's views, see, for example, [18, p. 118].

Aside from the disunity of Marxist commentators and their lack of deep understanding of mathematics, the international reputation of Soviet mathematics also helped to shield it from ideological interference, since it became a source of national pride and therefore worthy of being "protected... from reckless attacks by zealous ideologues" [46, p. 62]. So long as Soviet mathematicians maintained their established standards, their lip service to philosophical issues remained sufficient to appease the authorities. Pride in Soviet mathematics increased during the Second World War as part of the intensified nationalist feeling. The study of the history of Russian mathematics received greater attention, and it was at this point that Marxist thinkers strove to incorporate Lobachevskii's non-Euclidean geometry into their general scheme, even going so far as to claim to have identified embryonic dialectics in Lobacheskii's work [46, p. 69].

Many mathematicians were sympathetic towards Marxist principles but were of the opinion that it was Marxist theory that needed to be adapted to the needs of modern science rather than conversely. As Vucinich comments:

> Mathematics did not produce a Lysenko, that is, a dominant figure in the field who sacrificed the interests of science to the interests of dialectical materialism [46, p. 62].

Instead, Soviet mathematicians based their philosophy of their discipline upon the following four principles, as identified by Vucinich [46, p. 63]:

(1) All mathematical ideas have an empirical basis, but the further removed they are from this basis (the more abstract they are), the wider their scope of applicability.
(2) Western philosophies of mathematics are inherently idealistic and must therefore be criticized, but not all equally so: ideas with intuitionist leanings, for example, may admit a careful integration into the Marxist foundations of mathematics.
(3) Although the demands of science and technology lead to the wider development of "applied" mathematics, this must

[4] *There are many books and articles on the infamous "Case of Academician N. N. Luzin"; see, for example,* [11], [12], [31], [32], [33], [34, §6], [39], *and* [48].

[5] *For more on this point, including comments on nationalistic issues, see* [1].

never replace "pure" mathematics as the mathematician's primary concern.

(4) Mathematics develops both through its own internal logic and in response to technological requirements. However, Soviet mathematics has traditionally been slow in responding to the needs of technology, so more extensive involvement in industrialization is needed. Nevertheless, the growth of practical applications should not hinder work in abstract areas of mathematics.

It seems that most Soviet mathematicians subscribed to these general principles, which allowed them to be seen to be supporting Marxist views, but with the luxury of their own interpretation. The fact that they were permitted this luxury speaks to the continuing lack of a fully comprehensive, state-sanctioned philosophy of mathematics. In another numbered list, Vucinich [46, pp. 70–1] identifies the following three major difficulties experienced by Soviet thinkers in trying to turn mathematics into a Marxist discipline:

(1) The study of the social roots of mathematics never progressed beyond a preliminary stage. No comprehensive Marxist explanation was developed for the evolution of mathematical ideas. Articles were published which trumpeted what Marxism might do for mathematics, but it was never done.

(2) Just as no theory was devised to take care of the external, social development of mathematics, so too was the internal development of mathematics through dialectical processes neglected. Marxist writers identified several pairs of contrasting ideas within mathematics (for example, infinity/finiteness, continuity/discreteness, differentiation/integration, Euclidean geometry/non-Euclidean geometry) but did not attempt to explain how any of these could be viewed as a dialectic, driving mathematical change.

(3) The mathematically untrained Marxist commentators simply put "more emphasis on the foundations of mathematics than they could handle" [46, p. 70]. This resulted in their consistently negative approach: they criticized perceived idealism but never suggested alternative, dialectical approaches.

We have seen in this section that, by the end of Stalin's life, Soviet Marxist thinkers had progressed little from their position at the beginning of Stalin's time in power: they still had no consistent Marxist interpretation of mathematics. In contrast, Soviet mathematicians had become rather adept at either avoiding philosophical issues or reshaping them to suit their own requirements. Abstract mathematics continued to be developed, though with caution: by way of defense, the wider applicability of more abstract theories was often reemphasized. Of Soviet mathematicians, Vucinich notes that "their recognition of dialectical materialism was a tactical concession rather than a substantive accommodation" [46, p. 71].

After Stalin

No less than in any other aspect of Soviet life, Stalin's death in 1953 heralded the arrival of a more liberal period in Soviet mathematics. Mathematicians continued in their presentation of mathematics as a "universal science", in which greater abstraction would lead to wider applications, but they became even bolder in this view: they no longer felt the need to pay lip service to dialectical materialism and explicitly demoted considerations of physical reality to a secondary position. It became possible for areas of mathematics to develop according to their own internal logic rather than merely in response to the often ill-defined "needs of science and society". In this way, for example, non-Euclidean geometry finally became entirely acceptable.

The point of view that many Soviet mathematicians had (cautiously) advocated all along now came to the fore: that Marxist philosophy should be adapted to the needs of modern mathematics specifically and to those of modern science more generally, rather than the other way around. This new, liberal view even allowed for a more rational appraisal of Western mathematics. By the 1960s many Soviet thinkers felt that a Marxist philosophy of mathematics needed to incorporate the more acceptable aspects of Western thought. Fanatical criticism of perceived Western idealism and the view that a Soviet philosophy of mathematics could only be built only upon the ruins of Western thought gave way to a more balanced, case-by-case judgement of Western mathematics. It was now felt that Soviet and Western philosophies could be reconciled. Some Soviet thinkers even believed that Western thought was drifting slowly towards materialism [47, p. 30].

The shift towards a mathematical science that was more open to ideas from the West was largely unhindered by Marxist thinkers, though some, such as Ernst Kolman, persisted in their objections, criticizing the idealism of Western mathematics and lauding the practical grounding of Soviet science. However, such isolated criticism did not deter Soviet mathematicians from seeking to reintegrate their discipline with the international mathematical community. Questions of mathematics and ideology were now the preserve of moderate thinkers such as the mathematical physicist and loyal Communist, A. D. Aleksandrov [15, pp. 34–6].

Interest in the history of mathematics also grew, and the historical topics studied became broader in scope: rather than concentrating solely on Russian mathematics, more attention was paid to the development of mathematics in the wider world. The nationalist tendency to play up the independence and originality of Russian mathematics gave way to an interest in its place within international science.

This enthusiastic freeing of mathematical thought in the USSR was driven, at least in part, by the view that mathematics had just entered a new, third phase of historical development [47, p. 15]. It was felt that the first phase of the development of mathematics had lasted from ancient times until the seventeenth century and had been based upon the ideas and constructions of ancient Greek geometry and medieval Arabic algebra. The second phase saw the emergence of the notion of a function as being fundamental to mathematics. Finally, the third phase, beginning in the mid-twentieth century, was characterized by the growth of mathematics as a universal science: an abstract discipline in which it was increasingly possible to take in a range of applications with a single theory. It was noted that such a view of mathematics had first emerged in the nineteenth century (indeed, Soviet scholars credited Lobachevskii with its inception) but that it had become a central theme of mathematics only in the twentieth. An important part of "universal mathematics" was the search for "structural unity", where the term "structure" was used in the sense of Bourbaki [7]. It was felt that such an approach enabled mathematics to make qualitative statements about the world rather than merely quantitative ones. The scope of mathematics was thus broadened [47, p. 15].

The acceptance of a structural approach to mathematics, in which such notions as groups, vector spaces, and universal algebras become key, implicitly signalled the acceptance of the axiomatic method, which had been under fire from Marxist philosophers for so long. In the end, it was the success of the method that assured its place within Soviet mathematics and that fended off any residual criticism from the ideologues. A similar development took place in connection with cybernetics. From having been a discipline that was regarded with suspicion in the late 1940s and early 1950s owing to its close links with mathematical logic, which was itself deemed to be too far removed from reality to be acceptable, cybernetics caught the imagination of Soviet scientists from the mid-1950s onwards. Research in this area accelerated where it had been impeded before, and it gained the support of many prominent Soviet scientists—not just mathematicians, but also people in other disciplines, such as biology. Some criticism continued, but it had little impact; as Vucinich puts it, "Philosophical skepticism quickly retreated before the grand promises of cybernetics" [47, p. 17]. Indeed, cybernetics came to be seen as lending support to dialectical materialism, given its ability to provide scientific descriptions of information processes. Cybernetics thus became a heavily state-sponsored science; party leaders looked forward to the benefits to society that increased automation would bring. Some were keen on the idea that what had once been a "bourgeois science" was now being used to achieve communist goals [47, p. 20]. However, as a "party science", Soviet cybernetics eventually became intellectually rather shallow; see [15].

The growth not only of the theoretical side of cybernetics but also of the practical development of electronic computers meant that mathematical logic in turn became a respectable subject. More than this, its admittance to the Soviet mathematical canon was seen as crucial by some thinkers: as set theory became more acceptable, Marxist philosophers began to worry about various set-theoretic paradoxes, which it was felt only mathematical logic could resolve.

As Vucinich comments, in the decade following Stalin's death, "[Marxist] philosophers lost their right to criticize Soviet scientists either on scientific or on philosophical grounds" [47, p. 32]. Instead, they addressed their writings to a more general audience and did their best to adapt dialectical materialism to modern mathematics. Where criticism of Western mathematics did occur, it now tended to be more restrained and also more specific: by this stage, Marxist philosophers seem to have been more conversant with modern mathematics [47, p. 32]. The harassment of scientists (at least on scientific grounds) came to a halt, and by the 1980s, for example, the previously maligned work of N. N. Luzin had been reevaluated and was recognized as an important Russian contribution to mathematics. Nevertheless, scientific freedom did not mean social freedom. The young dissident scientists who, beginning in the 1960s, called for constitutional free thought in the USSR would not be satisfied until the era of *perestroika* in the 1980s.

Concluding Remarks and Suggestions for Further Reading

We have seen how the attempts of Soviet ideologues to construct and enforce a consistent Marxist philosophy of mathematics were ultimately unsuccessful. When approaching this area for the first time, it is difficult to understand how a subject about which so much was written and to which a great deal of thought was evidently given could apparently end in failure. In fact, in some ways, it did not. Ideology never went away, but instead became less dogmatic and was increasingly adapted by both mathematicians and philosophers to the needs of modern mathematics. Ideological debate existed between mathematicians, and, as noted in the introduction, mathematicians were even able to make careful use of philosophical language to advance their agenda for the "cybernetization" of science. Since this is far too intricate a topic to tackle here, I refer the reader instead to [15].

As noted at the beginning of this article, there are many sources available on Soviet ideology of mathematics and of science more generally. Besides those cited throughout the text, some useful general references are: [19], [26], [4], [24]. For a critique of Soviet science from the inside, see [35]. See also [10] for a guide to further sources on the development of mathematics in the USSR. For other ideological issues, see [13], [14], [15] on Soviet cybernetics; [36] on cosmology; [40] on probability; and [8], [23], [27] on physics. At the time of this writing, one of the most up-to-date sources on Soviet ideology of mathematics is [20], which tells the personal stories of D. F. Egorov, N. N. Luzin, and P. A. Florenskii. The situations of individual scientists are also related in [27] and [2], for example. Life for mathematicians under the later Soviet regime is described in [16].

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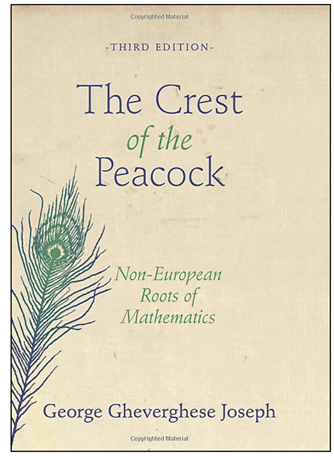
The Crest of the Peacock: Non-European Roots of Mathematics

Reviewed by Clemency Montelle



The Crest of the Peacock: Non-European Roots of Mathematics
George Gheverghese Joseph
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For many *Notices* readers, *The Crest of the Peacock* needs no introduction. Now in its third edition, the book has enjoyed widespread popularity for providing an accessible account of the mathematical culture of non-European peoples. Responding to earlier critiques, Joseph's revised edition has some notable changes. For one, the subtitle has been modified. In a small but significant alteration, *Non-Western Roots of Mathematics* has been changed to *Non-European Roots of Mathematics*. Sections have been added and several removed, a reorganization that addresses various scholarly objections stemming from historical and authenticity concerns. Endnotes have been expanded so as to reflect some current research, and an enlarged bibliographic section that is now grouped primarily according to geographical region provides references for further reading. In the third edition it is stated that this book is intended to be "an effective resource for students and teachers of mathematics while remaining accessible to general readers." Indeed, Joseph's original intention was to appeal to the general public and teachers and students of mathematics, and in that aim he has enjoyed success. The book has been popular. It covers an assortment of interesting aspects of the mathematical activity of selected early cultures with a minimum of technical details in a humanistic, undemanding way. Joseph aims to summarize the essence of technical scholarship that would otherwise be out of reach of this audience.

The third edition opens with a lengthy preface in which Joseph discusses the underlying rationale for the book: a response to a field that he believes is overly dominated by the hegemony of a "Western version" of mathematics, or Eurocentrism. Such attitudes, Joseph points out, are epitomized by Morris Kline's statement that "the mathematics of Egyptians and Mesopotamians is the scrawling of children just learning to write, as opposed to great literature" (p. 175). While the majority of scholars would have no objection to Joseph's observation, it is well accepted nowadays that Kline's attitude, as well as others that Joseph invokes to support his argument,[1] is outdated. Historiography has altered a lot in the last quarter century. Scholarship in the history of mathematics has made an undeniable change of direction since the time in which these attitudes were prevalent. Since then research culture has moved increasingly away from a narrow monolithic portrayal of mathematics to a more inclusive picture that sees as valid and important a broad range of mathematical activity and is increasingly sensitive to wider contextual issues.

To be sure, *The Crest of the Peacock* deserves a share of credit for injecting momentum into these growing new attitudes, though in fact, these attitudes had been present for decades in the work of many devoted scholars. Otto Neugebauer brought serious historical treatment of non-western mathematics to the forefront beginning in the late 1930s and, along with numerous others, published

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[1] *Some of the opinions Joseph refers to were made over a century ago, such as Rouse Ball's book published in 1908.*

extensively throughout subsequent decades on various cultures of inquiry. Concurrently with the appearance of the first edition of *The Crest of the Peacock*, Ubiratan D'Ambrosio published a seminal work on ethnomathematics, a term he had coined in the late 1970s. This was followed closely by Marcia Ascher writing on the same topic. The mid-1990s saw the rise of books dedicated to bringing non-European mathematical traditions into mainstream scholarship. One example from the many instances will suffice: the work *Mathematics across Cultures* (2001), edited by Helaine Selin, presented historiographical reflections as well as expository articles on various mathematical traditions, including Mesopotamian, Egyptian, Islamic, Hebrew, Incan, Mesoamerican, Sioux Tipi and Cone, the Pacific Cultures, Aboriginal, Central and Southern African, West African, and Yoruba, Chinese, Indian, Japanese, and Korean! Indeed, nowadays a significant number of scholars are actively seeking to be less binary in their approach, and the most current research in these fields focuses on the interplay of ideas and trends and eschews a divisive attitude. Scholars are now reaping the benefits of a measured consideration of the many different cultures of inquiry in the history of mathematics; the associated themes of transmission, comparison, social context, situated cognition, and the flourishing of mathematical inquiry in cultures with contrasting epistemic priorities are proving fruitful, not only for history of mathematics but for the history and philosophy of science more broadly.

While Joseph passionately denounces the Eurocentric approach throughout his book, at times his authorial stance seems to perpetuate the divisions caused by these attitudes in the first place. For instance, his lack of a dedicated section on Greece (despite his frequent reference to Greek achievements and their transmission) is restrictive, particularly given the importance of this culture of inquiry for many others in the book, first and foremost the Islamic Near East. Indeed, his arguments in favor of historical inclusiveness would be better supported by discussing the relevance of the Greek mathematical culture as well. The polarity between "European" and "non-European" is not mitigated either by Joseph's dismissive references to (mostly unspecified) "western philosophers" (p. 35 and elsewhere), "western scholars", and "western historians of mathematics". One must be mindful of the fact that European scholars themselves were integral to or involved in critical advances in our knowledge of the so-called non-European cultures. "Western scholars" also deserve much credit for their historical work on diverse mathematical cultures. Joseph himself relies heavily on them in this book; an overwhelming number of entries in his bibliography are in English.

Joseph notes (p. xiii, for instance, and elsewhere) that "the concept of mathematics found outside the Greco-European praxis was very different." This is an undeniably important observation. One will note, however, that mathematical activity **in** those so-called Greco-European cultures was not monolithic either. The tendency for historians to overlook the various other strands of practice within these very cultures has led to regrettable biases. The emphasis on mathematics associated with elegant deductive style proposition-proof-type accounts over and above other mathematical activities has meant that these latter types of mathematics have been deemed less important or less relevant, and thus often left out or ignored in historical accounts. These activities include recreational, commercial, and utilitarian mathematics, and the wide spectrum of related practices such as teaching and the mathematics applied in other disciplines (such as the broader astral sciences, for instance). Various activities and byproducts in cultures that formed part of this Greco-European praxis (astrology, horoscopes, numerical tables, rough working, and so on) are just as important when it comes to giving a picture of the practice of mathematical activity in these cultures. Joseph is spot on when he comments that historians need to "confront historical bias, question the social and political values shaping the mathematics (and the writing of the history of mathematics), and search for different ways of 'knowing' or establishing mathematical truths in various traditions." But this sentiment is not to be limited to non-European mathematics. It is applicable to all cultures of mathematical inquiry.

Critical appraisal of scholarly sources can be complex, particularly when they are in conflict. One example Joseph confronts is the issue of the dating of the Bakhshālī manuscript, a work almost unique as a surviving physical exemplar of Indian mathematics from before the early modern period. Joseph notes (p. 358) that Kaye's assessment (made in 1933) that the manuscript belonged to the twelfth century CE is doubtful. He then instead appears to rely on an assessment of Hoernle[2] made in 1888, which estimates that the original was composed sometime in the early centuries of the common era. This is in light of Hayashi's recent analysis (1995), which locates the original text around the seventh century and the surviving copy as early as the eighth century CE and no later than the twelfth. Hoernle's dating, generated on the basis of a partial translation,

[2] *Whose name, incidentally, is incorrectly spelled in the reference list.*

relied on assumptions about the content, the symbolism, and the meter. Hayashi, who produced an authoritative transcription, translation, and commentary of the entire work, gives compelling reasons that rest on the media of the manuscript, paleographical evidence, and the language (a modified form of classical Sanskrit consistent with medieval northwest Indian vernaculars at that time). Given the uniqueness of this text, appeals to content for dating seem questionable, and one must be mindful not to conflate the stylistic features of a copy of an original with what the original may have looked like to establish dating. Choosing between scholarly evaluations of this sort requires a special sort of expertise. One needs familiarity with paleographical studies, epigraphy, codicology, as well as detailed knowledge of the text, to be able to appreciate the reliability of one set of evidence over another.

So which one does Joseph subscribe to? The issue of dating the Bakhshālī manuscript appears in at least three separate places in his survey (pp. 312, 317, and 358). The latter two references seem to be contradictory: on page 317 Joseph states, "On the basis of recent evidence, notably that of Hayashi, the manuscript cannot be dated earlier than the eighth century," and on page 358, "The general consensus supports Hoernle's dating [to the third century]."[3] Despite his apparent agreement with Hayashi at one point in his work, Joseph's contextualization and analysis proceed on the basis of Hoernle's dating.[4] The situation as Joseph portrays it is thus far from clear for the reader.

The popularity of *The Crest of the Peacock* rests upon Joseph's ability to synthesize scholarship that would otherwise be unpalatable for a general audience. His ample bibliography testifies to the broad range of sources on which his scholarship rests. However, all scholarly material included in the book, even that assumed to be common knowledge, still ought to be connected back to the original sources. For instance, Joseph's summary of Egyptian and Mesopotamian mathematics (pp. 181–183) relies point for point on the insights in Boyer's book, which goes unacknowledged by Joseph.[5] In another instance, Joseph refers to connections between Pānīni's grammar and the *Elements* of Euclid (p. 316) without acknowledging the promulgator of this theory, Frits Staal. Frequently invoked throughout the book (p. 103 and elsewhere) are Nesselman's criteria for the development of algebra (rhetorical, syncopated, symbolic), but Joseph does not indicate their connection to Nesselman. Out of these three instances, Boyer does appear in the general bibliography. The latter scholars do not. The reviewer provides the references here for those interested readers.[6]

Joseph relays some of the questions that should be addressed when dealing with early mathematical texts. He lists these (p. xx):

1. *What* was the content of the mathematics known to that culture?
2. *How* was that mathematics thought about and discussed?
3. *Who* was doing the mathematics?

These are good guidelines for approaching a historical document. To endorse this sentiment and complement the work done by Joseph, we offer some additional remarks to one of his examples, the history surrounding the emergence of triangular tables of binomial coefficients and associated mathematical relationships. This is to highlight the complexity of the task of addressing these questions as well as to emphasize that fully appreciating a development of this kind requires a synthesis of "western" (Greek) and "non-western" (Islamic, Chinese, Indian) approaches and sources rather than focusing exclusively on one group or the other.

Joseph discusses an instance of triangular table of binomial coefficients (sometimes known as Pascal's triangle) in his chapter on China, where he links the first explicit discussion of it to an early eleventh-century Chinese mathematician Jia Xian (whose work is lost but is discussed in a work of

[3] *The situation is not made much clearer by his summary (p. 367), which says, "The state of Indian mathematics at the middle of the first millennium AD, as represented by the Bakhshālī Manuscript…"*

[4] *Joseph also comments (p. 358) that there is no clue as to who was the author of the work. This is not entirely true. In fact, some prosopographical details do exist. The Bakhshālī manuscript contains a colophon that reveals that it was composed by a Brāhmaṇa who was the son of Chajaka, who wrote it for Hasika the son of Vasiṣṭha and his descendants. We cannot be sure, however, whether he was the author or the scribe, and nothing more is known about these individuals.*

[5] *See Carl B. Boyer,* A History of Mathematics, *2nd edition, John Wiley & Sons, New York, 1989, pp. 41–42.*

[6] *Frits Staal, "Euclid and Pānīni",* Philosophy East and West, *5.2 (1965), 99–116; J. Bronkhorst, "Pānīni and Euclid: reflections on Indian geometry",* Journal of Indian Philosophy ***29*** *(2001), 43–80; G. H. F. Nesselman, Versuch einer kritischen Geschichte der Algebra, vol 1.: Die Algebra der Griechen, (Reimer Berlin, 1842. Reprint by Minerva, Frankfurt, 1969). Furthermore, Joseph's preface discusses translation issues and invokes distinctions between "alienating" or "literal" translations with "user friendly" ones. This distinction refers to the work of Høyrup as contrasted with van der Waerden and Neugebauer and was discussed in detail by Eleanor Robson,* The Mathematics of Ancient Iraq: A Social History, *Princeton University Press, 2008, pp. 274–284.*

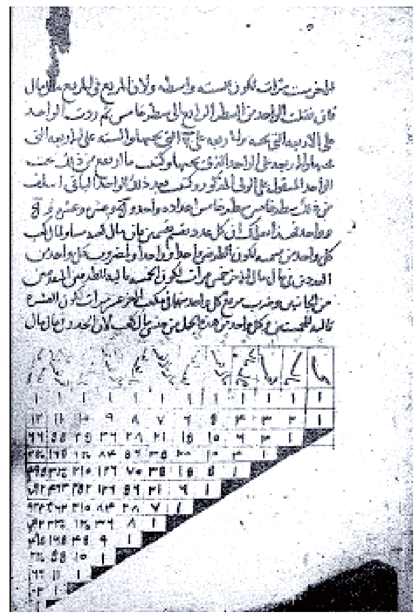
7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
square square cube	cube cube	square cube	square square	cube	square	*thing*	unit	part *thing*	part square	part cube	part square square	part square cube	part cube cube	part square square cube
128	64	32	16	8	4	2	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{4}\frac{1}{4}$	$\frac{1}{4}\frac{1}{8}$	$\frac{1}{8}\frac{1}{8}$	$\frac{1}{4}\frac{1}{4}\frac{1}{8}$
2187	729	243	81	27	9	3	1	$\frac{1}{3}$	$\frac{1}{9}$	$\frac{1}{3}\frac{1}{9}$	$\frac{1}{9}\frac{1}{9}$	$\frac{1}{3}\frac{1}{9}\frac{1}{9}$	$\frac{1}{9}\frac{1}{9}\frac{1}{9}$	$\frac{1}{3}\frac{1}{9}\frac{1}{9}\frac{1}{9}$

Table 1. Al-Samaw'al's table of powers. The factorizations in the last rows are explicitly given by al-Samaw'al also.

Yang Hui around 1261).[7] In this context, he argues, the table of binomial coefficients appears to be a byproduct of exploring methods to extract square and cube roots. Yang Hui tells us that Jia Xian wrote a table of binomial coefficients in a triangle resembling the Pascal triangle up to the sixth row.

However, the exploration of binomial coefficients by early thinkers, their arrangement and manipulation in triangular arrays, and the ways in which they were thought about and used comprise a much more complex and nuanced theme in the history of mathematics. For instance, about the same time, or even a little earlier, the Islamic scholar al-Samaw'al completed a work called *Al Bāhir fī al-Jabr*, in which he set out rules in a rhetorical form for expanding expressions equivalent to $(ab)^n$ and $(a+b)^n$ for the cases $n = 3, 4$, extending his account to expansions for higher powers.[8] Al-Samaw'al credits this part of his work to his predecessor al-Karajī (953–c. 1029). He also includes in his manuscript a triangular table of binomial coefficients as well (see Figure 1).

Joseph's three questions concerning content, scope, and practice in this case can be properly appreciated only by considering the wider context of these achievements and the ways in which other cultures of inquiry had impacted the tradition al-Samaw'al and his predecessors were working in. For one, al-Samaw'al is indebted to his Greek predecessors in ways that he explicitly acknowledges. However, his work epitomizes the decisive breaks from Greek practice that were being advanced amongst Islamic scholars at that time.[9] Also of relevance are the new and significant use of diagrams in the text and an increasingly abstract articulation of number. All of these features are critical to understanding the role and function of this table in this context. Furthermore, this passage has already attracted much scholarly interest because of its relevance to the history of mathematical induction, a technique that finds antecedents in many different cultures of inquiry.



Courtesy of Turkey Manuscripts Institution, Süleymaniye Library.

Figure 1. The table of binomial coefficients of al-Samaw'al.

Al-Samaw'al's discussion furthermore reveals how rules for laws of indices were to be manipulated and used in this context. This is contrary to Joseph's belief that in general "without convenient notation for indices the laws of indices cannot be formulated precisely" (p. 351). When one consults al-Samaw'al's text, one can immediately appreciate that al-Samaw'al has various rhetorical equivalents for his algebraic powers, and he has a clear conception of the relation between successive

[7] *It may be relevant to note the activity in India by various earlier authors. See, for instance, the contributions in Robin Wilson and John J. Watkins (eds.),* Combinatorics: Ancient and Modern, *Oxford University Press.*

[8] *This passage has been thoroughly analyzed in an upcoming publication by S. Bajri, J. Hannah, and C. Montelle.*

[9] *Joseph does refer to al-Ṭūṣī's table, which appeared in 1265, and further in the book in an endnote (p. 302, no. 8), he notes the appearance "later" in Samarquand (does he mean al-Ṭūṣī?), and on p. 507 and p. 517, no. 35, links Pascal's triangle to al-Karajī and al-Samaw'al.*

powers (see Figure 1),[10] as he presents a table of them:

While their recursive relationship is not visible numerically (by means of numerical indices or otherwise) the organization of the table reveals a sympathy for their mutual relations into successively increasing powers. To the modern eye, this relationship is effectively hidden by having the powers expressed as the appropriate combinations of the words "square" and "cube". However, it was perfectly understood by the actors of the time. The alignment and arrangement of the table reinforced the relations of successive powers. This use of "square" and "cube" is clearly a remnant of the Euclidean geometric tradition and in this context reveals how transitional al-Samaw'al's mathematical practice is. Thus by considering how the text was read and used by those within the tradition and, more generally reflecting on the ways in which it resembles as well as contrasts with other articulations such as Indian, Chinese, Italian or indeed Blaise Pascal's account itself, we get a much richer sense of what it was like for early thinkers to investigate and articulate mathematical results such as these.

No doubt Joseph's work will continue to enjoy its original popularity; it represents the importance and impact the history of mathematics can have when brought to mainstream audiences. While it is not always a reliable substitute for specialist research, the book certainly gives avid readers a taste of the scope and breadth of aspects of early mathematical cultures of inquiry.

[10]*From S. Ahmad and R. Rashed,* Al-Bāhir en Algèbre d'As-Samaw'al, *Imp. de l'Université de Damas, 1972, p. 21.*

DOCEAMUS

doceamus . . . let us teach

The CBMS 2010 Survey

Ellen Kirkman

Every five years, beginning in 1965, a survey of undergraduate mathematical science departments has been undertaken under the auspices of the Conference Board of the Mathematical Sciences (CBMS), with funding from the National Science Foundation. The written report of the most recent survey, CBMS2010, now is available online at `http://www.ams.org/cbms` and in print from the AMS. This article is an introduction to the survey report, which is designed to aid academic planners and department chairs seeking national comparison data. Here we present samples of the kinds of data available in the survey report and encourage readers to explore the full report.

In the fall semester of 2010, an online questionnaire was sent to a stratified simple random sample of mathematical science departments (with separate instruments for four-year mathematics departments, statistics departments with an undergraduate program, and mathematics programs at two-year colleges), collecting individual course enrollments, data on how courses were taught, numbers of degrees awarded, and demographics of faculty and students—enabling comparison of the 2010 data with that from previous surveys. Enrollment data were broken down into distance-learning enrollments and nondistance-learning enrollments; all data from four-year mathematics departments were broken down by the highest degree awarded by the department (bachelor's, master's, or doctoral). In addition to the data collected every five years, questions on special topics of current interest to the profession were also a part of the survey.

The 2010 survey found that, while from 1995 to 2010 four-year mathematics enrollments have not grown as fast as general four-year college and university enrollments, in the most recent five-year period, from 2005 to 2010, enrollments in mathematical science departments increased by about 26 percent, while general college enrollments grew by about 13 percent [1, Table S.1]. The enrollment growth was observed generally across all categories of courses, including advanced-level mathematics courses (where total enrollment for all levels of mathematics departments combined increased 35 percent), and for all levels of institutions (for example, advanced-level mathematics course enrollment increased 24 percent at the doctoral-level mathematics departments) [1, Table E.3]. The 2005 CBMS survey had reported a decline from the 2000 CBMS survey in mathematics enrollments, and that report had expressed concern over the limited availability of advanced-level undergraduate mathematics courses. However, the 2010 survey found greater availability; for example, the percentage of all four-year mathematics departments offering each of the following courses within a two-academic-year time period was: Modern Algebra I, 80 percent for 2009–11 (61 percent for 2004–6); Modern Algebra II, 27 percent for 2009–11 (21 percent for 2004–6); Advanced Calculus-Real Analysis I, 79 percent for 2009–11 (66 percent for 2004–6); Advanced Calculus-Real Analysis II, 31 percent for 2009–11 (26 percent for 2004–6) [1, Table SP.23]. The 2010 survey found that the largest growth in an enrollment category occurred in elementary statistics courses,

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where enrollments in courses taught in four-year mathematics departments (which were almost three times those in statistics departments) increased about 56 percent from 2005 to 2010 [1, Table S.2].

In contrast to increasing mathematics enrollments, the number of bachelor's degrees awarded by mathematics departments declined slightly from 2004–5 to 2009–10; the percentage of these degrees awarded to women was 43 percent for the 2009–10 academic year, up from 40 percent in 2004–5 (it was 43 percent in 1999–2000). Continuing a trend observed in the 2005 survey, the total number of bachelor's degrees in the mathematical sciences awarded by doctoral-level departments increased (up 8 percent over 2005), while the total number of degrees awarded by master's-level and bachelor's-level departments each decreased [1, Table E.1]. If one excludes degrees in computer science awarded through mathematics departments, the doctoral-level mathematics departments awarded the largest percentage of the bachelor's degrees awarded by four-year mathematics departments (44 percent), a trend that began in 2005; in the previous surveys the bachelor's-level departments had awarded the largest percentage of the mathematical science degrees [1, Figure E.1.4 and Table E.1].

The growth in enrollment observed in the 2010 survey was not matched by a growth in the number of faculty. In mathematics departments at four-year institutions, the number of full-time plus part-time faculty was almost the same in the 2005 and 2010 surveys, though the number of part-time faculty continued the decline observed from the 2000 to 2005 survey [1, Table S.14]. As has been noted in yearly reports from the Data Committee that are published in the *Notices of the AMS*, much of the growth in faculty has been in the category of "other full-time faculty" (full-time faculty who are not tenure-eligible). Some, but not all, of the increase in "other full-time faculty" was due to the increase in the number of postdoctoral positions (defined to be "temporary positions primarily intended to provide an opportunity to extend graduate training or to further research experience"). For example, in the doctoral mathematics departments, the number of other full-time faculty (including postdocs) increased 22 percent from 2005 to 2010, while the number of other full-time faculty, excluding postdoctoral positions, was up 16 percent; at bachelor's-level departments other full-time positions were up 58 percent from 2005 to 2010 (almost all such positions are not postdoc positions). In the doctoral-level mathematics departments the total number of tenured plus tenure-eligible faculty decreased slightly; however, the number of women in tenured or tenure-eligible positions in doctoral-level departments increased about 23 percent [1, Table F.1].

Special topics studied in the 2010 survey report included data on the mathematical education of precollege teachers, practices in dual and distance-learning courses, requirements for majors, estimates of the postgraduation plans of graduates, departmental assessment practices, and pedagogical issues in teaching college algebra and elementary statistics (the questions on teaching elementary statistics were also on the statistics department questionnaire, allowing comparison between practices at the two kinds of departments). Two chapters of the report present data on mathematics programs at two-year colleges, where enrollments increased 19 percent over 2005 [1, Table S.1], 21 percent if dual enrollment courses are included [1, Table TYE.2].

Distance-learning courses were defined to be "those courses in which the majority of instruction occurs with the instructor and students separated by time and/or place (e.g., courses in which the majority of the course is taught online, or by computer software, by television, or by correspondence)". The 2010 survey found that of four-year mathematics programs, distance-learning courses in the mathematical sciences were offered by 48 percent of the doctoral-level departments, 57 percent of the master's-level departments, and 28 percent of the bachelor's-level departments, but by 88 percent of two-year college mathematics programs. Further, of those departments offering distance-learning courses, 55 percent of the doctoral-level, 32 percent of the master's-level, 37 percent of the bachelor's-level, and 42 percent of the two-year college departments stated that the majority of tests were given at proctored testing sites. Across all levels of four-year mathematics departments, the instructional materials were said to be primarily created by faculty (as opposed to commercially produced) at 39 percent of the four-year college mathematics departments and 10 percent of the two-year college programs [1, Table SP.10].

Plans for the 2015 CBMS survey are under way currently, and suggestions for the 2015 survey are welcome.

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[1] Richelle Blair, Ellen E. Kirkman, James W. Maxwell, *Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States*, Fall 2010 CBMS Survey, American Mathematical Society, Providence, RI, 2013. Available at `http://www.ams.org/cbms`.

Can We Make School Mathematics Work for All?

Lynn Arthur Steen

This is a revised text of a paper presented under the title "Reflections on Mathematics and Democracy" at a joint AMS-MAA Special Session at MathFest 2012 in Madison, Wisconsin. The session was organized by David Mumford and Solomon Garfunkel; other speakers were William McCallum, Hyman Bass, and Joseph Malkevitch.

This Special Session was organized to discuss two pressing questions facing the mathematics community:

- What mathematics should every citizen know?
- How should K–16 education get us there?

The original motivation was an op-ed in the *New York Times*[1] that proposed a rather unorthodox answer to the second question, namely, to arrange high school mathematics into mathematically rich applied courses in which the desired mathematical skills and knowledge would emerge within realistic contexts.

As if on cue, one week prior to this session CUNY political scientist Andrew Hacker made a similar argument, also in the *Times*.[2] Although the headline on his op-ed, "Is Algebra Necessary?", makes it appear as if Hacker is arguing that algebra is not important, what he really says is that it is not working in the curriculum: "Something other than algebra is needed to enhance students' understanding of where various numbers come from and what they actually convey."

Today we are at the cusp of a twenty-five-year effort to develop a common set of standards for school mathematics (and other subjects). Not surprisingly, these proposed "Common Core" standards[3] improve on rather than overthrow orthodoxy. They generally adhere to the traditional curriculum, especially in their emphasis on algebra, while also encouraging limited innovation.

Ten years ago I addressed the first question posed to this panel in *Mathematics and Democracy*, a collection of essays from a variety of professionals both inside and outside mathematics.[4] (These essays are available for free downloading on the MAA website.) The chief message of this volume is that the mathematics taught in school bears little relationship to the mathematics needed for active citizenship. *That* mathematics we called quantitative literacy (QL) to contrast it with traditional school mathematics, which, historically, was the mathematics students needed to prepare for calculus.

Mathematics and quantitative literacy are distinct but overlapping domains. Whereas mathematics' power derives from its generality and abstraction, QL is anchored in specific contexts and real-world data. An alternative framing of the challenge for this panel is to ask whether perhaps QL might be a more effective approach to high school mathematics for all.

* * * * *

The disconnect of school mathematics from lives of citizens is not a new complaint. Twenty years ago the late *Washington Post* columnist William Raspberry stirred up a tempest by arguing

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[1] *David Mumford and Sol Garfunkel, "How to Fix Our Math Education,"* New York Times, *August 24, 2011,* www.nytimes.com/2011/08/25/opinion/how-to-fix-our-math-education.html.

[2] *Andrew Hacker, "Is Algebra Necessary?",* New York Times, *July 29, 2012,* www.nytimes.com/2012/07/29/opinion/sunday/is-algebra-necessary.html?pagewanted=all.

DOI: http://dx.doi.org/10.1090/noti1062

[3] Common Core Standards: Mathematics, www.corestandards.org/the-standards/mathematics/.

[4] *Lynn Arthur Steen, editor,* Mathematics and Democracy: The Case for Quantitative Literacy, *National Council on Education and the Disciplines, Princeton, 2001,* www.maa.org/ql/mathanddemocracy.html.

that for many students much of high school mathematics was little more than an unnecessary impediment: "It is a mistake to suppose that requiring the nonmathematical to take more advanced math courses will enhance their understanding, and not merely exacerbate their sense of inadequacy."[5]

Because it dominates high school mathematics, algebra is clearly the lightning rod for general complaints about school mathematics. A recent op-ed in *USA Today* challenged the "endemic" pressure to have younger and younger children take algebra, describing as a "canard" the misplaced belief that algebra is essential to the future success of thirteen- or fourteen-year-olds.[6]

Even NCTM past president Michael Shaughnessy has voiced concerns about "endless algebra" creating a "misguided" and "deadly" pathway from high school to college mathematics.[7] He cites a recent report by an MAA committee that studied the mathematical needs of client disciplines: it calls for a greater emphasis on modeling (including units, scaling, and dimensional analysis), multivariate topics, and computational skills that are useful in other fields.[8]

A large number of average Americans share the unease expressed by these columnists. Of course, a large number disagree, including, I suspect, a majority of mathematicians. Critics worry that diminishing the centrality of algebra in high school is tantamount to giving up on mathematics. For example, MAA past president David Bressoud, while agreeing that the "singular view" of high school mathematics as preparation for calculus is "a serious mistake," nonetheless argues that easing up on algebra "would lead to a variety of soft options in high school" that preclude further study of mathematics in college.[9]

* * * * *

So we are faced with two competing "shoulds": either improve algebra or offer something other than algebra. For a reality check, consider how these options relate to the "is" of U.S. math education.

As is widely known, the U.S. consistently trails other nations in international tests (although both the significance and relevance of this finding is widely disputed). Perhaps more relevant—and I think more disturbing—is evidence spanning the last twenty-five to thirty years showing that increased enrollment in high school mathematics does not lead to increased learning of mathematics—at least not in proportion to the effort invested.

Specifically, society's emphasis on STEM education has caused enrollments in high school mathematics to soar, especially in upper division courses, which have more than doubled in relation to the population of students. Yet indicators of learning have hardly changed: scores on the twelfth-grade NAEP mathematics test are only slightly higher than three decades ago. More tellingly, the proportion of students requiring remedial courses in college has remained more or less the same for the last thirty years at about 30–35 percent.

Hacker cites other evidence in his *Times* op-ed. For example, one in four high school students fails to graduate on time, and failure to pass algebra is one of the key reasons for this failure.

Among students who do pass Algebra I and stay enrolled in mathematics, many still fail required high school exit exams, a relatively new fad growing out of the standards and accountability movement. This year thousands of Minnesota high school seniors "repeatedly failed" the state-mandated mathematics test and were able to graduate only because of waivers granted by the state department of education.[10] Similar problems are arising in many other states.

(As it happens, Minnesota is one of only five states that have declined to sign onto the Common Core mathematics standards on the grounds that their own standards are "higher and more rigorous." It seems that there is a big difference between setting and achieving high standards.)

For whatever reason, the mathematics students learn in school is a pale shadow both of what they were taught and of what the various standards recommend. One result is a cascade of difficulties when these students arrive in college. A large proportion of college students drop out before completing their intended degree or certificate, and many blame college math requirements. As evidence, Hacker cites two studies: (i) a CUNY faculty report on student retention that concluded, "failing math at all levels affects retention more

[5] *William Raspberry, "Math Isn't for Everyone",* Washington Post, *1989, A23.*

[6] *Patrick Welsh, "Why Our Kids Hate Math",* USA Today, *July 9, 2012,* http://www.usatoday.com/news/opinion/forum/story/2012-07-09/math-education-remedial-algebra/56118128/1.

[7] *J. Michael Shaughnessy, "Endless Algebra—The Deadly Pathway from High School Mathematics to College Mathematics",* NCTM Summing Up, *February 2011,* www.nctm.org/about/content.aspx?id=182.

[8] Partner Discipline Recommendations for Introductory College Mathematics and the Implications for College Algebra, *Mathematical Assoc. of Amer., 2011,* http://www.maa.org/cupm/crafty/introreport.pdf.

[9] *David Bressoud, "The End of Algebra?",* Launchings, *Mathematical Assoc. of Amer., March 2011,* maa.org/columns/launchings/launchings_03_11.html.

[10] *Christopher Magan, "Many Students Fail Math grad Exam—But Still Graduate",* Pioneer Press, *July 24, 2012,* http://www.twincities.com/localnews/ci_21122870/minnesota-many-students-fail-math-grad-exam-but.

than any other academic factor" and (ii) a national sample of transcripts that showed that mathematics gave twice as many F's and D's as did other subjects.

* * * * *

So we have a dilemma. The traditional high school mathematics curriculum, which was designed for and is still necessary for success in calculus-based college mathematics, does not work for a large number of students. Moreover, even if it did work, the tools it provides are not those best suited to the quantitative needs of engaged citizens in our data-drenched society.

Some education and policy leaders are raising an even more fundamental question: Is this disconnect really a serious national problem that must be solved, or is it just the natural and benign result of using mathematics as the filter for access to successful careers? (Cynics, as usual, view the hype about assessments and underachievement as primarily an excuse for certain interest groups to make money—testing companies and textbook publishers come to mind.)

The most common argument for urgency is that education, especially in STEM disciplines, drives our economy. Yet contrarian economists argue that data from the past fifty years shows only a weak correlation between education and economy among nations or among states within the U.S. Many other issues (e.g., research, immigration, weather, infrastructure) dominate education as a predictor of economic growth. Moreover, some labor economists argue that the U.S. does not actually have a shortage of STEM-educated graduates or even of college graduates.

Nonetheless, parental pressure for college preparation remains high. Certainly a lot of the pressure for an algebra-centered curriculum leading to calculus is motivated by university admissions. Respondents to the *Times* op-eds express strong convictions on this point, most reflecting parental desire for traditional college-prep mathematics.

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In thinking about these issues, it may help to pay some attention to the challenging puzzle of *transfer*. Virtually all STEM teachers recognize that students find it difficult to transfer skills taught in mathematics courses to the contextually rich problems encountered in other subjects. Transfer is required not only from mathematics to chemistry or economics but also to vocational areas such as nursing, plumbing, farming, or manufacturing. All require the use of mathematics in forms not typically seen in mathematics classes.

One important insight into the problem of transfer is summarized in a recent NRC report on education for life and work in the twenty-first century.[11] This report emphasizes the importance of "transferable knowledge and skills" in contrast to "general skills" routinely used in civic, workplace, and family contexts.

General skills such as logical thinking are not, as is widely believed, a reliable consequence of the study of mathematics—or of anything else, for that matter. The NRC report is quite sweeping in this conclusion: "Over a century of research on transfer has yielded little evidence that teaching can develop *general* cognitive competencies that are transferable to any new discipline, problem or context, in or out of school" (italics added).

Many people, including many who wrote comments on the two *Times* op-eds, clearly do not believe this. (Ironically, the reasoning in many comments—trite emotional arguments that fail to address either the evidence or reasoning of each op-ed—seems to confirm the NRC conclusion.)

The difficulty students have in transferring skills from mathematics class to other subjects is well known and notorious among science teachers. Even changing x to t in equations of motion is enough to befuddle many students. More to the point, the difficulty of marshalling evidence and data into a persuasive written argument is not a natural consequence of the study of algebra or calculus—or of statistics, for that matter.

Both *Times* op-eds argue, with different particulars, for an approach to teaching mathematics that grows out of the contexts in which mathematics is used. The NRC report essentially reaffirms this approach. First, they define transferable knowledge and skills as "expertise that is intertwined with knowledge of a particular discipline" and go on to say that "teaching that emphasizes not only content knowledge, but also how, when, and why to apply this knowledge is *essential to transfer*" (italics added).

* * * * *

So we face three distinct challenges:

- Addressing the many weaknesses evident in mathematical learning.
- Reducing the gulf between the traditional precalculus curriculum and the quantitative needs of life, work, and citizenship.
- Teaching mathematics in a way that encourages transfer—for citizenship, for career, and for further study.

I suggest that these three challenges are manifestations of a single problem and that all three can be addressed in the same way: *by organizing*

[11]Education for Life and Work: Developing Transferable Knowledge and Skills in the Twenty-first Century*, report brief, National Research Council, July 2012,* http://www7.national-academies.org/bota/Education_for_Life_and_Work_report_brief.pdf.

the curriculum to pay greater attention to the goal of transferable knowledge and skills.

There are many ways to accomplish this, for example:

- by embedding mathematics in courses focused on applications of mathematics,
- by team-taught cross-disciplinary courses that blend mathematics with other subjects in which mathematical thinking arises (e.g., genetics, personal finance, medical technology),
- by project-focused curricula in which all school subjects are submerged into a class group project (e.g., design a solar-powered car),
- by career-focused curricula in which a cohort of students focuses all their school work on particular career areas (e.g., technology, communications, or business).

Each of these strategies has been employed in various school districts at different times, but they rarely spread "to scale", because they are typically more expensive in instructional effort and sometimes they appear to conflict with state standards or assessments. In principle—and if interpreted liberally—the new Common Core standards provide sufficient flexibility to permit approaches such as these. Unfortunately, experience with the relationship between standards, assessment, and instructional practices under NCLB (the 2001 No Child Left Behind Act) suggests that standards subjected to rigorous high-stakes tests will narrow instruction to focus as precisely as possible on topics and concepts needed to pass required tests.

Many worry that any approach motivated by applications rather than the structure of mathematics risks slighting some topics that would be found on any thoughtful list of standards. That's almost certainly true, because not every topic on these lists has natural uses outside mathematics itself. But the current approach virtually guarantees that large numbers of students will never learn (or at least not remember) these same rarely reinforced topics. So there may be little risk and much potential gain in trying a different approach.

* * * * *

The modern movement for standards in mathematics began in the 1980s when NCTM developed the first set of curriculum and evaluation standards for school mathematics.[12] Compared with today's Common Core, this first set of standards is less specific, often less clear, in some respects less demanding, but in other aspects more challenging. But it also emerged in a different era and had a rather different purpose than does today's Common Core.

Today advocates view the setting of high standards and the establishment of measurable goals as a strategy for improving student performance. To be sure, even the most ardent supporters of the Common Core recognize that standards alone cannot achieve this goal. Significant improvement in the preparation and training of teachers is also essential. In particular, effective teaching of mathematics (and of other subjects) requires the kind of integrated understanding that has come to be called pedagogical content knowledge.[13, 14] Many also recognize that, since poverty is the strongest predictor of school failure, widespread progress is unlikely without difficult-to-achieve improvement in the socio-economic status of many students.

What we forget, however, is that when NCTM initiated its standards work, most mathematics teachers did not actually believe in the goal of teaching mathematics to all high school students. Whereas now we argue about *how* much and *what* kind of mathematics to teach in high school, three decades ago debate centered on *who* should learn high school mathematics. At that time, the curriculum was designed to efficiently sort students into those who were capable of learning high school mathematics and those who were not. So, between grades seven and nine, somewhere between one-third and one-half of the students were placed in a course called General Math, an enervating, pointless review of arithmetic.

One of the chief purposes—and chief accomplishments—of the 1989 *Standards* was to undermine the credibility of General Math by offering mathematics teachers and school administrators a vision of mathematics education of sufficient breadth, utility, and flexibility that it could be productively studied not just by prospective scientists and engineers but by virtually all students.

That ambitious undertaking largely succeeded. In the decade between the NCTM *Standards* and the NCLB Act, General Math was nearly eliminated from schools across the country. In its own way and without using these memorable words, NCTM's standards campaign opened the eyes of mathematics teachers to the "soft bigotry of low expectations."

Another decade has passed, and our ambitions are now much higher: a common core for all, with everyone emerging from high school ready for college. In one generation the political view of high school mathematics has progressed from something only some need (or can) learn to a core subject in which all students can and must become proficient. That's quite a rapid change in ends,

[12] Curriculum and Evaluation Standards for School Mathematics, *National Council of Teachers of Mathematics, Reston, VA, 1989.*

[13] *Lee Shulman, "Knowledge and Teaching: Foundations of the New Reform",* Harvard Educational Review **57** *(1987), 1–22.*

[14] *Liping Ma,* Knowing and Teaching Elementary Mathematics, *Lawrence Erlbaum, Mahwah, N.J., 1999.*

which has been matched by a major change in means. The very idea of a common curriculum enforced with common assessments was all but unthinkable back in the 1980s.

Advocates of the Common Core often argue that, without a single high bar such as Algebra II for all, we will continue to leave poor and minority students behind. Too often, however, the bar itself leaves just as many students behind. In the 1980s the reason that half the students left high school without knowing any mathematics is that they never took any real mathematics courses while in high school. Today roughly the same proportion still leave school without confidence or skills in high school mathematics. But now the reason is very different: these students retain little or nothing of the mathematics they have been taught.

By itself, raising the bar won't change that. By privileging one type of ability over others, a single bar that is ratcheted up on the precalculus scale would quite likely increase the proportion of students whose educational experience creates dislike for mathematics. We don't seem to have learned much from the failure of NCLB to achieve its goals (remember "first in the world in math and science"?). In the next few years, as new assessments based on the Common Core are put in place with high-stakes consequences for students and teachers, we may simply see the same history repeated.

One respondent to Hacker's *Times* column cites management guru Peter Drucker as saying that society squanders vast resources encouraging people to eliminate their weaknesses. "We would be served better by accentuating their strengths." I wonder what would happen if we applied that philosophy to high school mathematics:

- It would require a different kind of standards document: one with significant content choices and explicit opportunities for project-based or interdisciplinary learning.
- It would tolerate—indeed, celebrate—a variety of strengths both within mathematics and in its uses, with the confidence that spot weaknesses could be remedied later whenever the need arose.
- It would virtually eliminate the possibility of uniform standardized assessments, which would not please politicians but would be welcomed by legions of teachers.
- And it would go a long way to addressing each of these current challenges:

—the persistent weakness in mathematics learning,

—the gap between high school mathematics and the QL needs of citizens,

—the inability of students to transfer skills from math class to other areas.

Lie Algebra Sudoku

A traditional Sudoku puzzle involves a 9 x 9 grid and the numbers 1 through 9. However, any set of nine symbols can be used. Through happy coincidence, there are nine complex simple Lie algebras: the four series of classical algebras and the five exceptional algebras. Therefor, it is possible to have a Sudoku puzzle using Lie algebras.

Instructions: Fill in the grid with complex simple Lie algebras so that each row and column and each highlighted 3 x 3 sub-grid contains each of the algebras A_n, B_n, C_n, D_n, G_2, F_4, E_6, E_7, and E_8 without repeats.

—Puzzle by Edward Dunne

Solution on page 1473.

	E_7		C_n				E_6	
B_n	E_6		E_8	A_n				
		C_n		B_n		E_8	F_4	
		G_2	A_n			E_6		B_n
E_6		A_n			G_2	C_n		
	E_8	D_n		E_6		F_4		
				E_8	C_n		A_n	E_6
	A_n				F_4		E_8	

Mathematics People

Pardalos Receives 2013 Carathéodory Prize

Panos Pardalos of the University of Florida has been awarded the Constantin Carathéodory Prize of the International Society of Global Optimization in recognition of his lifetime contributions to global optimization. These include work in such varied areas as complexity analysis, phase transition problems, and optimality conditions for nonconvex optimization; nonconvex network optimization problems; global optimization algorithms for quadratic optimization and general linear complementarity problems; continuous approaches for discrete optimization (including nonlinear assignment problems and maximum clique); multi-objective optimization; applications of global optimization in diverse areas such as neuroscience, energy systems, and finance; and data mining and optimization for the analysis of very large and massive datasets.

The Carathéodory Prize is awarded biannually to an individual (or a group) for fundamental contributions to theory, algorithms, and applications of global optimization. The prize is awarded for outstanding work that reflects contributions that have stood the test of time. The criteria include scientific excellence, innovation, significance, depth, and impact. The prize carries a cash award of US$2,000 and a certificate.

—From an International Society of Global Optimization announcement

Chatterjee Awarded Loève Prize

Sourav Chatterjee of Stanford University has been awarded the 2013 Line and Michel Loève International Prize in Probability for work of "extraordinary breadth". According to the prize citation, he has "brought new ideas to bear upon classical topics—an extension of Lindeberg's proof of the central limit theorem to an invariance principle for arbitrary smooth functions of weakly dependent random variables, a simpler proof of the famous KMT theorem on strong approximation of a random walk by Brownian motion, and a new version of Stein's method, reducing a large class of normal approximation problems to variance bounding exercises. On another side he has taken up Talagrand's Challenge to Mathematicians (to give rigorous analysis of spin glass models from statistical physics) by providing analyses of random overlap structures and showing that the Sherrington-Kirkpatrick model is chaotic under small perturbations of the couplings at any temperature in the absence of an external field. Other topics to which he has made substantial contributions include large deviations for random graphs and random matrices, first-passage percolation, and probabilistic methods for discrete nonlinear Schrödinger equations."

The prize commemorates Michel Loève, professor at the University of California Berkeley from 1948 until his untimely death in 1979. The prize was established by his widow, Line, shortly before her death in 1992. Awarded every two years, it is intended to recognize outstanding contributions by researchers in probability who are under forty-five years old. It carries a cash award of US$30,000.

—From a University of California Berkeley announcement

Hauenstein Receives DARPA Young Faculty Award

Jonathan Hauenstein of North Carolina State University has been awarded a 2013 DARPA Young Faculty Award by the Defense Advanced Research Projects Agency (DARPA) for his work on numerical algebraic geometric methods for data analysis. He was awarded a grant of US$492,613 for the years 2013–2015. He received his Ph.D. in mathematics in 2009 from the University of Notre Dame. He has also held postdoctoral fellowships at the Fields Institute (2009) and at the Institut Mittag-Leffler (2011). He is currently assistant professor at North Carolina State.

The DARPA Young Faculty Award (YFA) program provides funding, mentoring, and industry and Department of Defense (DoD) contacts to young scientists within five years of appointment to a tenure-track position and helps them to develop their research ideas in the context of DoD needs. The long-term goal of the YFA program is to develop the next generation of academic scientists, engineers, and mathematicians in key disciplines who will focus a significant portion of their careers on DoD and national security issues. At the end of two years, up to four YFA recipients will be selected to continue as DARPA Director's Fellows, receiving up to US$500,000 in additional funding over one year to further advance their research toward achieving breakthrough DoD capabilities.

—From a DARPA announcement

Pe Pereira Awarded Rubio de Francia Prize

Maria Pe Pereira of the Institut de Mathématiques de Jussieu has been awarded the 2013 Rubio de Francia Prize of the Royal Spanish Mathematical Society (RSME) for her work on the Nash problem for surfaces, which started in her Ph.D. dissertation. Subsequently, Pe Pereira and Fernandez de Bobadilla solved the problem in an article "The Nash problem for surfaces", published in *Annals of Mathematics* in 2012.

The prize honors the memory of J. L. Rubio de Francia (1949–1988), an internationally renowned Spanish analyst. It is awarded annually to a young mathematician from Spain or residing in Spain, and it is the highest distinction given by the RSME. The prize carries a monetary award of 3,000 euros (approximately US$4,000).

The prize jury consisted of Noga Alon, Jesús Bastero Eleizalde (chair), Pablo Mira, Gilles Pisier, Marta Sanz-Solé, Agata Smoktunowicz, and Cédric Villani. Recent prize recipients, in chronological order, include A. Enciso, C. Beltran, Á. Pelayo, and F. Gancedo.

—From a Royal Spanish Mathematical Society announcement

Prizes of the Canadian Mathematical Society

John Grant McLoughlin of the University of New Brunswick has been named the recipient of the 2013 Adrien Pouliot Award of the Canadian Mathematical Society (CMS) in recognition of his outstanding contributions to mathematics education in Canada. He was honored for his teaching and mentorship, both across Canada and overseas, particularly in Bhutan and in Trinidad and Tobago. He has been active as a guest teacher in elementary schools, in recreational mathematical exhibits in public settings, in organizing a public library lecture series, and in such local events as math camps and efforts to improve the numeracy skills of nursing students.

The Adrien Pouliot Award was inaugurated in 1995 to recognize individuals who have made significant and sustained contributions to mathematics education in Canada. The award is named for Adrien Pouliot, the second CMS president, who taught mathematics at Université Laval for fifty years and was instrumental in developing Laval's engineering and science faculty.

Marc Ryser of McGill University has been awarded the 2013 Doctoral Prize for his work in mathematical modeling in bone biology and nonlinear SPDEs. His thesis examines bone remodeling and the stochastic Allen-Cahn equation and related models. His work on bone remodeling, part of his thesis, was published in the *SIAM Journal of Applied Mathematics*.

The CMS Doctoral Prize is awarded annually to recognize a Canadian doctoral student who has demonstrated exceptional performance in the area of mathematical research.

—From CMS announcements

Holmström Awarded 2013 CME/MSRI Prize

Bengt Holmström of the Massachusetts Institute of Technology has been awarded the 2013 CME Group-MSRI Prize in Innovative Quantitative Applications by the CME Group and the Mathematical Sciences Research Institute (MSRI) for his work in the fields of contracting and incentives. He has made major contributions to the theory of moral hazard and mechanism design, the theory of the firm, corporate governance, and most recently the demand and supply of liquidity and its relationship to financial crises.

The annual prize is awarded to an individual or a group to recognize originality and innovation in the use of mathematical, statistical, or computational methods for the study of the behavior of markets and, more broadly, of economics. The award carries a cash prize of US$25,000.

—From a CME-MSRI announcement

NDSEG Fellowships Awarded

Sixteen young mathematicians have been awarded National Defense Science and Engineering Graduate (NDSEG) Fellowships by the Department of Defense (DoD) for 2013. The fellowships are sponsored by the United States Army, Navy, and Air Force. 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 following are the names of the fellows in mathematics, their institutions, and the offices that awarded the fellowships: Noah Arbesfeld, Columbia University, Air Force Office of Scientific Research (AFOSR); Andrew Binder, University of Minnesota-Twin Cities, AFOSR; Adam Bloniarz, University of California Berkeley, AFOSR; Martin Copenhavor, Massachusetts Institute of Technology, Office of Naval Research (ONR); Kaveh Danesh, Harvard University, Army Research Office (ARO); Samuel Elder, Massachusetts Institute of Technology, ONR; Zhou Fan, Stanford University, ARO; William Franks, Rutgers University, ONR; Ewain Gwynne, Massachusetts Institute of Technology, ARO; David A. Hyde, Stanford University, AFOSR; Steven Kim, Brown University, ONR; Eric Larson, Massachusetts Institute of Technology, ONR; Sarah

Mousley, University of Illinois at Urbana-Champaign, ONR; Samuel Pimentel, University of Pennsylvania, ARO; Gil Tabak, Stanford University, AFOSR; Jonathan Wang, University of Chicago, ONR.

—From an NDSEG announcement

B. H. Neumann Awards Given

The Australian Mathematics Trust has awarded several B. H. Neumann Awards for service to the mathematics profession. The honorees are Jan Cavanagh, Mike Clapper, Karen Diehl, Jim Green, Jillian Neale, Jacqui Ramagge, Gregory Taylor, and Anthony Telford. The awards honor Bernhard H. Neumann, who supported mathematics and mathematics teaching at all levels in Australia.

—From an Australian Mathematics Trust announcement

2013 Davidson Fellows

Three high school students who did mathematics projects were among the twenty students named 2013 Davidson Fellows. Hannah Larson of Eugene, Oregon, received the top-level US$50,000 scholarship for her project "Classification of Some Fusion Categories of Rank 4". Receiving US$10,000 scholarships were Joshua Brakensiek of Phoenix, Arizona, for "Bounds on the Size of Sound Monotone Switching Networks Accepting Permutation Sets of Directed Trees" and William Kuszmaul of Lexington, Massachusetts, for "Equivalence Classes of Permutations Created under Pattern-Replacement Relations". The Davidson Fellows Scholarship awards scholarships worth US$50,000, US$25,000, and US$10,000 to extraordinary young people age eighteen and under who have completed a significant piece of work. The Davidson Fellows is a program of the Davidson Institute for Talent Development.

—From a Davidson Fellows announcement

Royal Society of Canada Elections

The Royal Society of Canada (RSC) has elected eighty-four new fellows in 2013. Prakash Panangaden of McGill University, whose research career has spanned computer science, mathematics and physics, was elected a new fellow. He has worked on programming languages, probabilistic systems, quantum computation and relativity, and is particularly known for deep connections between domain theory and continuous state Markov processes.

—From a Royal Society of Canada announcement

Solution to Lie Algebra Sudoku puzzle
(from page 1470)

G_2	E_7	E_8	C_n	F_4	D_n	B_n	E_6	A_n
B_n	E_6	F_4	E_8	A_n	E_7	G_2	C_n	D_n
A_n	D_n	C_n	G_2	B_n	E_6	E_8	F_4	E_7
D_n	F_4	G_2	A_n	C_n	E_8	E_6	E_7	B_n
E_8	C_n	E_7	E_6	D_n	B_n	A_n	G_2	F_4
E_6	B_n	A_n	F_4	E_7	G_2	C_n	D_n	E_8
C_n	E_8	D_n	E_7	E_6	A_n	F_4	B_n	G_2
F_4	G_2	B_n	D_n	E_8	C_n	E_7	A_n	E_6
E_7	A_n	E_6	B_n	G_2	F_4	D_n	E_8	C_n

Mathematics Opportunities

AMS-AAAS Mass Media Summer Fellowships

The American Mathematical Society provides support each year for a graduate student in the mathematical sciences to participate in the American Association for the Advancement of Science (AAAS) Mass Media Science and Engineering Fellows Program. This summer fellowship program pairs graduate students with major media outlets nationwide where they will research, write, and report on science news and use their skills to bring technical subjects to the general public.

The principal goal of the program is to increase the public's understanding of science and technology by strengthening the connection between scientists and journalists to improve coverage of science-related issues in the media. Past AMS-sponsored fellows have held positions at National Public Radio, *Scientific American*, Voice of America, the *Oregonian*, the *Chicago Tribune*, and the *Milwaukee Journal Sentinel*.

Fellows receive a weekly stipend of US$500, plus travel expenses, to work for ten weeks during the summer as reporters, researchers, and production assistants in newsrooms across the country. They observe and participate in the process by which events and ideas become news, improve their ability to communicate about complex technical subjects in a manner understandable to the public, and increase their understanding of editorial decision making and of how information is effectively disseminated. Each fellow attends an orientation and evaluation session in Washington, D.C., and begins the internship in mid-June. Fellows submit interim and final reports to AAAS. A wrap-up session is held at the end of the summer.

Mathematical sciences faculty are urged to make their graduate students aware of this program. The deadline to apply for fellowships for the summer of 2014 is **January 15, 2014**. Further information about the fellowship program and application procedures is available online at `http://www.aaas.org/programs/education/MassMedia`; or applicants may contact Dione Rossiter, Manager, Mass Media Program, AAAS Mass Media Science and Engineering Fellows Program, 1200 New York Avenue, NW, Washington, DC 20005; telephone: 202-326-6645; fax: 202-371-9849; email: `drossite@aaas.org`. Further information is also available at `http://www.ams.org/programs/ams-fellowships/media-fellow/massmediafellow` and through the AMS Washington Office, 1527 Eighteenth Street, NW, Washington, DC 20036; telephone: 202-588-1100; fax: 202-588-1853; email: `amsdc@ams.org`.

—AMS Washington Office

Call for Proposals for the 2015 AMS Short Courses

The AMS Short Course Subcommittee invites submissions of preliminary proposals for Short Courses to be given at the 2015 Joint Mathematics Meetings. Members are also invited to submit names of colleagues who they think would conduct an inspiring Short Course. A Short Course consists of a coherent sequence of survey lectures and discussions on a single theme of applied mathematics. A Short Course ordinarily extends over a period of two days immediately preceding the Joint Mathematics Meetings held in January.

Preliminary proposals may be as short as one page. After reviewing the preliminary proposals, the Subcommittee may ask for more details from some of the proposers. Proposals should be sent via email to Ellen Maycock at `ejm@ams.org`. For full consideration for the 2015 Short Courses, proposals should be submitted by **December 20, 2013**.

—Ellen Maycock,
AMS Associate Executive Director

STaR Program for Early-Career Mathematics Educators

Service, Teaching, and Research are the focal points of the STaR Program. It was initially funded by the National Science Foundation and consists of a summer institute, academic-year networking via electronic means, and a regroup session in conjunction with the annual meeting of the Association of Mathematics Teacher Educators (AMTE).

The STaR Program is now operated under the supervision of the AMTE and is dependent on contributions from individuals, foundations, and professional organizations for its continued operation. To date, 148 early-career mathematics educators working at 113 institutions of higher education (in 41 states) have completed the program. A list of previous STaR Fellows and some current activities are available at `http://starfellows.com`.

The fifth cohort of STaR Fellows will meet in a summer institute in Park City, Utah, during the week of June 21–25, 2014. Eligibility is limited to new faculty with a doctorate in mathematics education in their first or second year of a tenure-track appointment as a mathematics educator at a U.S. institution of higher education. The faculty appointment may be in a department of mathematics or a school, college, or department of education.

The application is available at http://matheddb.missouri.edu/star/. Completed applications are due by **December 1, 2013**. If you have any questions, contact Robert Reys at reysr@missouri.edu.

—Robert Reys
University of Missouri, Columbia

MfA Fellowship Program

The Math for America Foundation (MfA) sponsors the MfA Fellowship Program, which trains mathematically talented individuals to become high school mathematics teachers in New York City, Boston, Los Angeles, Washington DC, or Utah. The fellowship provides an aggregate stipend of up to US$100,000 over five years, a full-tuition scholarship for a master's-level teaching or teacher-credentialing program at one of MfA's partner universities, and ongoing support mechanisms, including mentoring and professional development.

Candidates should hold a bachelor's degree as of June 2014 with substantial coursework in mathematics and should be new to teaching and able to demonstrate a strong interest in teaching. Candidates must be U.S. citizens or permanent residents of the United States. The deadline for applications for the Boston fellowship is **January 1, 2014**. The deadline for the Los Angeles, New York, Utah, and Washington DC fellowships is **February 9, 2014**. For priority consideration for the Los Angeles and New York City fellowships, the deadline is **January 12, 2014**. For more detailed information, see the website at http://www.mathforamerica.org/.

—From an MfA announcement

NSF Program in Computational and Data-Enabled Science and Engineering in Mathematical and Statistical Sciences

Computational and data-enabled science and engineering (CDS&E) is emerging as a distinct intellectual and technological discipline lying at the interface of mathematics, statistics, computational science, core sciences, and engineering disciplines. CDS&E, broadly interpreted, now affects virtually every area of science and technology, revolutionizing the way science and engineering are done. The CDS&E program in the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF), in partnership with the Office of Cyberinfrastructure, supports fundamental research at the core of this emerging discipline. It supports broadly innovative, ambitious, and transformative research that will lead to significant advancement in CDS&E. The emphasis will be on mathematical, statistical, computational, and algorithmic developments, as well as their applications in advancing modern cyberinfrastructure and scientific discovery. Multidisciplinary collaboration and the training of the next generation of data and computational scientists firmly grounded and trained in mathematics and statistics will be strongly encouraged. The research topics supported by CDS&E in mathematical and statistical sciences will be rooted in mathematics and statistics and will address computational and big data challenges and directly promote discoveries and innovations at the frontiers of science and engineering. The overall impact in the mathematical and statistical sciences of the proposed work will be a review criterion.

The window for submission of proposals is **November 25–December 9, 2013**. For more details see http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504687&WT.mc_id=USNSF_25&WT.mc_ev=click.

—From an NSF announcement

NDSEG 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 any of fifteen scientific disciplines.

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 2014. Fellows selected in spring 2014 must begin their fellowship tenures in fall 2014. Fellowships are tenable only at U.S. institutions of higher education offering doctoral degrees in the scientific and engineering disciplines specified. Fellows will receive full tuition and stipends for 12-month tenures: US$30,500 for the first year, US$31,000 for the second year, and US$31,500 for the third year. 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.

Complete applications must be submitted electronically by **December 20, 2013**. Application forms are available online at http://ndseg.asee.org/apply_online. For further information, see http://ndseg.asee.org/.

—From an NDSEG announcement

News from IPAM

The Institute for Pure and Applied Mathematics (IPAM), a National Science Foundation (NSF) mathematics institute located at the University of California Los Angeles, offers programs that encourage cross-disciplinary collaboration. IPAM holds a long program (three months) and workshops (three to five days) throughout the academic year for junior and senior mathematicians and scientists who work in academia, the national laboratories, and industry. IPAM seeks program proposals from the scientific community. Please send your idea for a workshop or long program to director@ipam.ucla.edu.

Join IPAM at the Joint Math Meetings in Baltimore, Maryland, January 15–18, 2014. A reception sponsored by all of the mathematical sciences institutes will take place on Wednesday, January 15, from 5:30 to 8:00 p.m. Please consult the conference schedule for the location. Additionally, several students from our summer undergraduate research programs in Los Angeles and Hong Kong will participate in the Mathematical Association of America (MAA) Undergraduate Poster Session on Friday, January 17, 2014. They will present posters of their research projects sponsored by the Los Angeles Police Department, Google, the Aerospace Corporation, Baidu, BGI, and others.

In the summer of 2014, IPAM will sponsor the program Hands-on Summer School: Electronic Structure Theory for Materials and (Bio)molecules from July 21 through August 1, 2014. Please check IPAM's website for more information and an application. IPAM will also offer its undergraduate program Research in Industrial Projects for Students (RIPS) in both Los Angeles and Hong Kong and a new graduate-level RIPS in Berlin. The application deadline for all three RIPS programs is **February 12, 2014**.

Finally, IPAM is pleased to announce that Avi Wigderson, professor of mathematics at the Institute for Advanced Study, Princeton, New Jersey, will give the third annual Green Family Lecture Series the week of May 19, 2014. Details will be announced in the spring.

Following is a list of upcoming programs at IPAM. Please go to www.ipam.ucla.edu for detailed information and to find application and registration forms.

Winter Workshops. You may apply for support or register for each workshop online.

January 6–10, 2014: Mathematics of Social Learning.

January 16–18, 2014: Mathematical Challenges in Ophthalmology.

January 27–31, 2014: Rough Paths: Theory and Applications.

February 10–14, 2014: Translating Cancer Data and Models to Clinical Practice.

February 24–28, 2014: Stochastic Gradient Methods.

Long Programs. You may apply online for support to be a core participant for the entire program or to attend any of the following individual workshops.

March 10–June 13, 2014: Algebraic Techniques for Combinatorial and Computational Geometry.

March 11–14, 2014: Tutorials.

March 24–28, 2014: Workshop I: Combinatorial Geometry Problems at the Algebraic Interface.

April 7–11, 2014: Workshop II: Tools from Algebraic Geometry.

May 5–9, 2014: Workshop III: The Kakeya Problem, Restriction Problem, and Sum-Product Theory.

May 19–23, 2014: Workshop IV: Finding Algebraic Structures in Extremal Combinatorial Configurations.

September 8–December 12, 2014: Mathematics of Turbulence.

September 9–12, 2014: Tutorials.

September 29–October 3, 2014: Workshop I: Mathematical Analysis of Turbulence.

October 13–17, 2014: Workshop II: Turbulent Transport and Mixing.

October 27–31, 2014: Workshop III: Geophysical and Astrophysical Turbulence.

November 17–21, 2014: Workshop IV: Turbulence in Engineering Applications.

—From an IPAM announcement

For Your Information

Departments Coordinate Job Offer Deadlines

For the past fourteen years, the American Mathematical Society has led the effort to gain broad endorsement for the following proposal:

That mathematics departments and institutes agree not to require a response prior to a certain date (usually early in February of a given year) to an offer of a postdoctoral position that begins in the fall of that year.

This proposal is linked to an agreement made by the National Science Foundation (NSF) that the recipients of the NSF Mathematical Sciences Postdoctoral Fellowships would be notified of their awards, at the latest, by the end of January.

This agreement ensures that our young colleagues entering the postdoctoral job market have as much information as possible about their options before making a decision. It also allows departmental hiring committees adequate time to review application files and make informed decisions. From our perspective, this agreement has worked well and has made the process more orderly. There have been very few negative comments. Last year one hundred sixty-five mathematics and applied mathematics departments and four mathematics institutes endorsed the agreement.

Therefore we propose that mathematics departments again collectively enter into the same agreement for the upcoming cycle of recruiting, with the deadline set for Monday, February 3, 2014. The NSF's Division of Mathematical Sciences has already agreed that it will complete its review of applications by January 24, 2014, at the latest, and that all applicants will be notified electronically at that time.

The American Mathematical Society is facilitating the process by sending an email message to all doctoral-granting mathematics and applied mathematics departments and mathematics institutes. The list of departments and institutes endorsing this agreement was widely announced on the AMS website beginning November 1, 2013, and is updated weekly.

We ask that you view a proposed updated version of last year's formal agreement at `http://www.ams.org/employment/postdoc-offers.html` along with **last year's list** of adhering departments.

Important: To streamline this year's process for all involved, we ask that you notify Ellen Maycock at the AMS (`ejm@ams.org`) **if and only if**:

(1) your department is not listed and you would like to be listed as part of the agreement or

(2) your department is listed and you would like to withdraw from the agreement and be removed from the list.

Please feel free to email us with questions and concerns. Thank you for consideration of the proposal.

—Donald McClure,
AMS Executive Director

Ellen Maycock,
AMS Associate Executive Director

Correction

Due to a typesetting error, the announcement of the 2013 Simons Investigators (*Notices*, October 2013, page 1181) misspelled the name of Ngô Bao Châu of the University of Chicago. The *Notices* apologizes for this error.

Inside the AMS

My Summer at NPR

Each year the AMS sponsors a fellow to participate in the Mass Media Fellowship program of the American Association for the Advancement of Science (AAAS). This program places science and mathematics graduate students in summer internships at media outlets. In this article the 2013 Fellow, Anna Haensch, describes her experiences during her fellowship at National Public Radio. For information about applying for the fellowship, see the "Mathematics Opportunities" section in this issue of the Notices *or visit the website* `http://www.ams.org/programs/ams-fellowships`. *The application deadline is **January 15, 2014**.*

With a Ph.D. in hand and a tenure-track job drawing near on the horizon, I set out for ten weeks at National Public Radio headquarters in Washington, D.C. What could be better? I was finally off my graduate student leash, and I was on my way to learn the fine art of science communication at NPR, the greatest bastion of mainstream intellectualism—the mother ship. I couldn't wait to talk shop with Richard Harris, swap stories with Joe Palca, and probe the insightful mind of Shankar Vendantam.

On the first day I was directed to my spacious intern desk and attendant intern sofa. Almost immediately I got to work scanning the journals for the hottest new research to cover in NPR's science blogs.

I quickly and firmly planted my flag in the ground at "Shots", the NPR health blog. This felt like the place for me, and I was surprised at how fluidly my ability to read technical math papers translated to an ability to read complicated papers in genomics and bioinformatics—further evidence of the fact that higher education is all about learning how to learn.

What started as a carefree jaunt through the world of science journalism quickly became an exploration of the darker and deeper questions of the nature of science reporting. On the health beat, I soon realized that there are essentially only two types of stories being hawked by public information officers of the major research institutions: type I, in which scientists find that disease x is caused by y, and type II, in which scientists find a possible cure for disease x. That's it. And I wasn't comfortable writing about either type.

Stories of the first type exemplify the worst genre of news. These are the nightly news stories that try to convince you that too much sleep will make you obese or that your toaster oven is emitting dangerous cancer-causing nanoparticles. Although irresistibly clickable, these stories are sensationalized, typically based on pretty flimsy research, and serve no purpose other than to shock and alarm the reader. Furthermore, there is a fine line between reporting on developments in health research and advising readers on how to manage their own health, and I was not keen to cross this line.

Stories of the second type, by contrast, are more often based on sound science. The rub is that news coverage of these stories tends to lean towards speculation and is prone to hype. Science, by nature, moves forward very slowly. A real breakthrough is the culmination of years of effort, yielding dozens of papers about each minuscule step of the research. One of these steps might lend itself to a catchy news release, which then lands on the desks of reporters.

The reporter then faces the challenge of how to describe this tiny epsilon-sized piece of a gigantic puzzle. Often the only choices are to bore people with the minutiae or to blow the result just a teeny bit out of proportion. I would err on the side of the former, but people are more likely to read the latter. For a reporter, these types of stories present somewhat of a minefield in the never-ending battle between maintaining rigorous scientific truth and creating an exciting science communication dialogue.

To be clear, this is not intended as an indictment of health reporters, but rather a commentary on the difficulty of the task at hand. Paradoxically, this task was made more difficult by my own background in research.

Research, whether mathematical or medical, has two components: process and outcome. The process is the time spent banging your head against the chalkboard proving dull technical lemmas that provide the critical stepping stones to the end result. The outcome is the main theorem, which is usually stated neatly at the end of ten pages of gruesome-looking mathematics. But, often, it is the auxiliary lemmas and techniques in their proofs, not the main theorems themselves, that give us new insight into the result.

So when someone is reporting on a new medical paper, what's the most important thing to say about it? The result or how it was obtained?

Clearly this dilemma extends well beyond health reporting and deep into the realm of general math and science reporting. Are we interested in telling stories about science being done? Or are we in the business of selling results? This really gets to the heart of one of the principal questions in science reporting: should the science reporter be teaching science?

Largely, I think that the answer is no and that the role of a reporter is to deliver results in a neatly contextualized black box. But of course the notion of handing over results without giving the backstory and logical underpinnings is at tremendous odds with my own chosen career path: professor.

What I thought would be a summer spent in leisurely scientific inquiry turned out to be spent in inquiry of a more metaphysical nature. This was indeed an enriching pursuit, but not in the way that I had initially thought.

The upshot is that I have never been more sure in my life that I want to be a mathematician. Examining the "doing" of science and interviewing experts to hear them speak so passionately about their own work only fanned the flames of my own desire to reach the upper echelon of my own research field.

The exposure to the complex world of science reporting left me with an appreciation of the difficulty of communicating science. It also highlighted for me the need for talented scientists and deep thinkers to consider a career, or at least a brief summer sojourn, in the newsroom.

—Anna Haensch,
Duquesne University

Project NExT Fellows Chosen

Five mathematicians have been selected as AMS Project NExT fellows for the 2013–2014 academic year. Their names, affiliations, and areas of research are: Susan Durst, Rutgers University, associative rings and algebras; John Engbers, Marquette University, graph theory/discrete mathematics; Rebecca Glover, University of Rochester, complex geometry/symplectic geometry; Andrew Greene, Manhattan College, functional analysis; and Mitchel Keller, Washington and Lee University, combinatorics of partially ordered sets.

Project NExT (New Experiences in Teaching) is a professional development program for new and recent Ph.D.'s in the mathematical sciences (including pure and applied mathematics, statistics, operations research, and mathematics education). It addresses all aspects of an academic career: improving the teaching and learning of mathematics, engaging in research and scholarship, and participating in professional activities. It also provides the participants with a network of peers and mentors as they assume these responsibilities. The AMS provides funding for a number of the fellowships.

—From an MAA announcement

2013 Trjitzinsky Memorial Awards Presented

The AMS has made awards to eight undergraduate students through the Waldemar J. Trjitzinsky Memorial Fund. The fund is made possible by a bequest from the estate of Waldemar J., Barbara G., and Juliette Trjitzinsky. The will of Barbara Trjitzinsky stipulates that the income from the bequest should be used to establish a fund in honor of the memory of her husband to assist needy students in mathematics.

For the 2013 awards, the AMS chose seven geographically distributed schools to receive one-time awards of US$3,000 each. The mathematics departments at those schools then chose students to receive the funds to assist them in pursuit of careers in mathematics. The schools are selected in a random drawing from the pool of AMS institutional members.

Waldemar J. Trjitzinsky was born in Russia in 1901 and received his doctorate from the University of California, Berkeley, in 1926. He taught at a number of institutions before taking a position at the University of Illinois, Urbana-Champaign, where he remained for the rest of his professional life. He showed particular concern for students of mathematics and in some cases made personal efforts to ensure that financial considerations would not hinder their studies. Trjitzinsky was the author of about sixty mathematics papers, primarily on quasi-analytic functions and partial differential equations. A member of the AMS for forty-six years, he died in 1973.

Following are the names of the selected schools for 2013, the names of the students receiving Trjitzinsky awards, and brief biographical sketches of the students.

Kean University: John Douglas Helbig Jr. Helbig was born in New Jersey to a mother who had immigrated from Colombia; neither his mother nor his father completed high school. His father passed away when John was in fifth grade but had already instilled in him the importance of studying mathematics and computers. He is studying mathematics at Kean and plans to pursue a master's degree in instruction and curriculum.

State University of New York, Binghamton: Chaoren Lin. Lin is carrying a double major in mathematics and computer science and has research experience in programming language design and computer graphics. He is strongly interested in algebra and number theory and is preparing for graduate study in cryptography.

Vanderbilt University: Paul Ponmattam. Ponmattam carries a 4.0 GPA in mathematics and has already taken and excelled in beginning-level graduate courses.

Winthrop University: Ruth Mariko Fujino. Fujino grew up in Japan, where her parents were missionaries. Her future plans include working among marginalized people in other countries, and she believes that the foundational thinking and problem-solving skills she gains from studying mathematics will help her to realize her dreams.

University of North Dakota: Paige Ferguson. Ferguson's passion for mathematics began at an early age and was nourished by encouraging, energetic teachers. She is majoring in mathematics with a secondary teaching certification and a minor in middle school education. She especially enjoys logic and seeing how a problem can be viewed and solved in many different ways.

University of New Mexico: Michael W. Brown and Shalaine L. Buck. Brown carries a dual major in mathematics and physics. He is president of the undergraduate Mathematics and Statistics Club and recently visited local high school students to encourage them to consider college majors in mathematics. He plans to study for a Ph.D. in mathematics. Buck is majoring in applied mathematics with a minor in statistics. She is a Native American from the Navajo tribe. She mentors other students in math and statistics with the STEM program at the University of New Mexico. She plans to earn a graduate degree in statistics and eventually to return to the Navajo Nation to work in data collection and analysis.

Idaho State University: Michael VanDyke. VanDyke has served in the United States Army and worked as a civilian air traffic controller. After deciding to return to college, he discovered a passion for mathematics. He hopes one day to teach mathematics at the college level.

—Elaine Kehoe

Altmetric

Powerful New Tool Allows Authors and Researchers to Measure Digital Footprint of Intellectual Output

The American Mathematical Society has incorporated a new tool for monitoring article-level metrics into a selection of its mathematical journals. The metrics, which are provided by London-based startup Altmetric, allow authors and readers to track and measure online attention surrounding selected scholarly works. The innovative Altmetric system aggregates and links to mentions of journal articles from social networking sites, blogs, reviews, mainstream news outlets, magazines, and other sources. Results are then compiled into reports that may be used by authors, researchers, readers, librarians, and publishers to analyze the societal and digital impact of these works.

The implementation is consistent with the Society's efforts to address current trends and best serve the mathematical community during this burgeoning technological era.

The Altmetric tool has currently been integrated into four AMS journals: *Journal of the American Mathematical Society*, *Mathematics of Computation*, *Proceedings of the American Mathematical Society*, and *Transactions of the American Mathematical Society*. Individual article pages within these journals now contain Altmetric icons, which, when clicked, link the user to a corresponding article details page that provides a granular breakdown of exactly where and how often the article is being shared across the Web. Users can also click the "Track This Article" link on the metrics page to receive email alerts when a particular article has been shared or discussed.

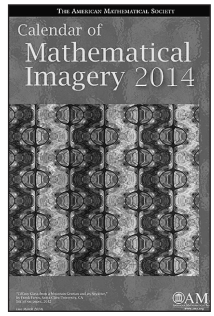
"In keeping with the AMS mission, as we move into an increasingly digital era, the American Mathematical Society is committed to providing its authors and readers with the most current tools for tracking the impact of scholarly research," said Robert M. Harington, Associate Executive Director of Publishing at the American Mathematical Society. "As the mathematical community continues to embrace online media and social channels as a means for sharing research interests, our partnership with Altmetric will allow us to provide our community with detailed article-level social metrics. Authors and readers will be able to track and quantify, in real-time, the online impact and reach of selected pieces of scholarly work. This service will be of great benefit to authors and researchers across mathematics and related disciplines."

Altmetric founder Euan Adie also weighed in on the partnership, saying: "We're delighted to be working with the AMS. This marks the first time we've delivered altmetrics for the mathematical sciences, and their expert knowledge of the field has been invaluable help." For more information about Altmetric and how the product works, please visit `www.altmetric.com`. Users interested in viewing the metrics in context can visit the journal pages referenced above at `www.ams.org/journals`.

—Donald McClure
AMS Executive Director

From the AMS Public Awareness Office

Visual Insight: Mathematics Made Visible. This blog by John Baez is a place to share striking images that help explain advanced topics in mathematics. He invites those who have created images to share them on the blog. Early posts are "{6,3,3} Honeycomb in Upper Half Space", "Algebraic Numbers", and "Tübingen Tiling". Baez, professor of mathematics at the University of California Riverside, also works at the Centre for Quantum Technologies in Singapore and started the Azimuth Project, an international collaboration to create a focal point for scientists and engineers interested in saving the planet. He continues to enjoy explaining mathematics, and Visual Insight is one way to do that: `http://blogs.ams.org/visualinsight/`.



2014 Calendar of Mathematical Imagery. To request a complimentary copy of the 2014 calendar featuring selected images from Mathematical Imagery (`www.ams.org/mathimagery`), please email `paoffice@ams.org` with the subject line "2014 calendar-notices". Please limit your order to three copies so that others may also have the opportunity to receive a copy.

—Annette Emerson and Mike Breen
AMS Public Awareness Officers
`paoffice@ams.org`

Deaths of AMS Members

Simmie S. Blakney, of Toledo, Ohio, died on July 15, 2013. Born on June 1, 1928, he was a member of the Society for 44 years.

Franki Dillen, professor, KU Leuven, Belgium, died on April 17, 2013. Born on March 15, 1963, he was a member of the Society for 20 years.

Harley Flanders, of Ann Arbor, Michigan, died on July 26, 2013. Born on September 13, 1925, he was a member of the Society for 66 years.

Frank N. Huggins, of Arlington, Texas, died on July 10, 2013. Born on October 25, 1926, he was a member of the Society for 49 years.

C. J. Scriba, of Hamburg, Germany, died on July 26, 2013. Born on October 6, 1929, he was a member of the Society for 42 years.

Dorothy B. Shaffer, of Stamford, Connecticut, died on April 3, 2013. Born on February 12, 1923, she was a member of the Society for 64 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.wustl.edu` in the case of the editor and `smf@ams.org` in the case of the managing editor. The fax numbers are 314-935-6839 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines

November 20, 2013: Applications for NRC-Ford Foundation Predoctoral Fellowships. See `http://sites.nationalacademies.org/pga/fordfellowships/` or contact: Fellowships Office, Keck 576, National Research Council, 500 Fifth Street, NW, Washington, DC 20001; tel: 202-334-2872; fax: 202-334-3419; email: `infofell@nas.edu`.

November 25–December 9, 2013: Proposals for NSF Program in Computational and Data-Enabled Science and Engineering in Mathematical and Statistical Sciences (CDS&E). See "Mathematics Opportunities" in this issue.

December 1, 2013: Applications for AMS Centennial Fellowship. See `http://www.ams.org/ams-fellowships/`. For paper copies of the form, write to the Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294; `prof-serv@ams.org`; 401-455-4105.

December 1, 2013: Applications for MSRI research memberships and postdoctoral fellowships. See `https://www.msri.org/web/msri/scientific/member-application`.

December 1, 2013: Applications for PIMS postdoctoral fellowships. See the website `http://www.pims.math.ca/scientific/postdoctoral` or contact `assistant.director@pims.math.ca`.

Where to Find It

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

December 2, 2013: Nominations for Ferran Sunyer i Balaguer Prize. See http://ffsb.iec.cat.

December 15, 2013: Applications for AMS Epsilon Fund. See http://www.ams.org/programs/edu-support/epsilon/emp-epsilon or contact the AMS Membership and Programs Department by email at prof-serv@ams.org or by telephone at 800-321-4267, ext. 4113.

December 15, 2013: Applications for Service, Teaching, and Research (STaR) Program. See "Mathematics Opportunities" in this issue.

December 20, 2013: Proposals for 2015 AMS Short Courses. See "Mathematics Opportunities" in this issue.

December 20, 2013: Applications for National Defense Science and Engineering Graduate (NDSEG) Fellowships. See "Mathematics Opportunities" in this issue.

December 24, 2013: Registration for free workshop on "Writing a Competitive Grant Proposal to NSF-EHR" held prior to the Joint Mathematics Meetings. See http://tinyurl.com/ka4fcdu.

December 31, 2013: Nominations for Otto Neugebauer Prize. See the website http://www.euro-math-soc.eu/otto_neugebauer_prize.html.

January 1, 2014: Applications for Boston fellowships for Math for America (MfA). See "Mathematics Opportunities" in this issue.

January 12, 2014: Applications for priority consideration for Los Angeles and New York City fellowships for Math for America (MfA). See "Mathematics Opportunities" in this issue.

January 13, 2014: Applications for Jefferson Science Fellowships. See http://sites.nationalacademies.org/PGA/Jefferson/PGA_046612; email: jsf@nas.edu; telephone: 202-334-2643.

January 15, 2014: Applications for AMS-AAAS Mass Media Summer Fellowships. See "Mathematics Opportunities" in this issue.

January 31, 2014: Entries for AWM Essay Contest. Contact the contest organizer, Heather Lewis, at hlewis5@naz.edu or see https://sites.google.com/site/awmmath/home.

February 1, 2014: Applications for AWM Travel Grants, Mathematics Education Research Travel Grants, Mathematics Mentoring Travel Grants, and Mathematics Education Research Mentoring Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; telephone: 703-934-0163; or email: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

February 9, 2014: Applications for Los Angeles, New York, Utah, and Washington, DC, fellowships for Math for America (MfA). See "Mathematics Opportunities" in this issue.

February 12, 2014: Applications for Research in Industrial Projects for Students (RIPS) of the Institute for Pure and Applied Mathematics (IPAM). See "Mathematics Opportunities" in this issue.

February 15, 2014: Applications for AMS Congressional Fellowship. See http://www.ams.org/programs/ams-fellowships/ams-aaas/ams-aaas-congressional-fellowship or contact the AMS Washington Office at 202-588-1100, email: amsdc@ams.org.

February 15, 2014: Nominations for AWM-Joan & Joseph Birman Prize in Topology and Geometry. See the website http://www.awm-math.org.

April 15, 2014: Applications for fall 2014 semester of Math in Moscow. See http://www.mccme.ru/mathinmoscow or contact: Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax: +7095-291-65-01; email: mim@mccme.ru. Information and application forms for the AMS scholarships are available on the AMS website at http://www.ams.org/programs/travel-grants/mimoscow or contact: Math in Moscow Program, Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294; email: student-serv@ams.org.

May 1, 2014: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; telephone: 703-934-0163; or email: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 1, 2014: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; telephone: 703-934-0163; or email: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

Book List

The Book List highlights recent books that have mathematical themes and are aimed at a broad audience potentially including mathematicians, students, and the general public. Suggestions for books to include on the list may be sent to notices-booklist@ams.org.

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

An Accidental Statistician: The Life and Memories of George E. P. Box, by George E. P. Box. Wiley, April 2013. ISBN-13: 978-1-118-40088-3.

Assessing the Reliability of Complex Models: Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification, by the National Research Council. National Academies Press, 2012. ISBN-13: 978-0-309-25634-6.

Charles S. Peirce on the Logic of Number, by Paul Shields. Docent Press, October 2012. ISBN-13: 978-0-9837004-7-0.

Classic Problems of Probability, by Prakash Gorroochurn. Wiley, May 2012. ISBN-13: 978-1-1180-6325-5. (Reviewed November 2013.)

Conflict in History, Measuring Symmetry, Thermodynamic Modeling and Other Work, by Dennis Glenn Collins. Author House, November 2011. ISBN-13: 978-1-4670-7641-8.

The Continuity Debate: Dedekind, Cantor, du Bois-Reymond, and Peirce on Continuity and Infinitesimals, by Benjamin Lee Buckley. Docent Press, December 2012. ISBN-13: 978-0-9837004-8-7.

**The Crest of the Peacock: Non-European Roots of Mathematics,* by George Gheverghese Joseph. Third edition. Princeton University Press, October 2010. ISBN-13: 978-0-691-13526-7. (Reviewed in this issue.)

Decoding the Heavens: A 2,000-Year-Old Computer—and the Century-Long Search to Discover Its Secrets, by Jo Marchant. Da Capo Press, February 2009. ISBN-13: 978-03068-174-27. (Reviewed June/July 2013).

Do I Count?: Stories from Mathematics, by Günter Ziegler (translation of *Darf ich Zahlen?: Geschichte aus der Mathematik,* Piper Verlag, 2010). CRC Press/A K Peters, July 2013. ISBN-13: 978-1466564916

Figures of Thought: A Literary Appreciation of Maxwell's Treatise on Electricity and Magnetism, by Thomas K. Simpson. Green Lion Press, February 2006. ISBN-13: 978-18880-093-16. (Reviewed October 2013.)

The Fractalist: Memoir of a Scientific Maverick, by Benoît Mandelbrot. Pantheon, October 2012. ISBN-13: 978-03073-773-57.

Fueling Innovation and Discovery: The Mathematical Sciences in the 21st Century, by the National Research Council. National Academies Press, 2012. ISBN-13: 978-0-309-25473-1.

Games and Mathematics: Subtle Connections, by David Wells. Cambridge University Press, November 2012. ISBN-13: 978-11076-909-12.

Girls Get Curves: Geometry Takes Shape, by Danica McKellar. Plume, July 2013. ISBN-13: 978-04522-987-43.

The Golden Ticket: P, NP, and the Search for the Impossible, by Lance Fortnow. Princeton University Press, March 2013. ISBN-13: 978-06911-564-91.

Google's PageRank and Beyond: The Science of Search Engine Rankings, by Amy Langville and Carl Meyer. Princeton University Press, February 2012. ISBN-13: 978-06911-526-60.

Gösta Mittag-Leffler: A Man of Conviction, by Arild Stubhaug (translated by Tiina Nunnally). Springer, November 2010. ISBN-13: 978-36421-167-11. (Reviewed September 2013.)

Heavenly Mathematics: The Forgotten Art of Spherical Trigonometry, by Glen Van Brummelen. Princeton University Press, December 2012. ISBN-13: 978-06911-489-22.

Henri Poincaré: Impatient Genius, by Ferdinand Verhulst. Springer, August 2012. ISBN-13: 978-14614-240-62.

Henri Poincaré: A Scientific Biography, by Jeremy Gray. Princeton University Press, November 2012. ISBN-13: 978-06911-527-14.

How to Study As a Mathematics Major, by Lara Alcock. Oxford University Press, March 2013. ISBN-13: 978-0199661312.

I Died for Beauty: Dorothy Wrinch and the Cultures of Science, by Marjorie Senechal. Oxford University Press, December 2012. ISBN-13:978-01997-325-93.

Ibn al-Haytham's Theory of Conics, Geometrical Constructions and Practical Geometry, by Roshdi Rashed. Routledge, February 2013. ISBN-13: 978-0-415-58215-5.

Imagined Civilizations: China, the West, and Their First Encounter, by Roger Hart. Johns Hopkins University Press, July 2013. ISBN-13:978-14214-060-60.

Invisible in the Storm: The Role of Mathematics in Understanding Weather, by Ian Roulstone and John Norbury. Princeton University Press, February 2013. ISBN-13: 978-06911-527-21. (Reviewed September 2013.)

Late Style: Yuri I. Manin Looking Back on a Life in Mathematics. A DVD documentary by Agnes Handwerk and Harrie Willems. Springer, March 2012. ISBN NTSC: 978-3-642-24482-7; ISBN PAL: 978-3-642-24522-0. (Reviewed January 2013.)

Levels of Infinity: Selected Writings on Mathematics and Philosophy, by Hermann Weyl. Edited by Peter Pesic. Dover Publications, February 2013. ISBN-13: 978-0486489032.

The Logician and the Engineer: How George Boole and Claude Shannon Created the Information Age, by Paul J. Nahin, Princeton University Press, October 2012. ISBN-13: 978-06911-510-07. (Reviewed October 2013.)

Manifold Mirrors: The Crossing Paths of the Arts and Mathematics, by Felipe Cucker. Cambridge University Press, June 2013. ISBN-13: 978-05217-287-68.

**The Math Book: From Pythagoras to the 57th Dimension, 250 Milestones in the History of Mathematics,* by Clifford A. Pickover. Sterling. February 7, 2012. ISBN-13: 978-14027-882-91.

**Math is Murder,* by Robert C. Brigham. iUniverse, March 28, 2012. ISBN-13 978-14697-972-81.

Math on Trial: How Numbers Get Used and Abused in the Courtroom, by Leila Schneps and Coralie Colmez. Basic Books, March 2013. ISBN-13: 978-04650-329-21. (Reviewed August 2013.)

A Mathematician Comes of Age, by Steven G. Krantz. Mathematical Association of America, December 2011. ISBN-13: 978-08838-557-82.

A Mathematician's Lament: How School Cheats Us Out of Our Most Fascinating and Imaginative Art Form, by Paul Lockhart. Bellevue Literary Press, April 2009. ISBN-13: 978-1-934137-17-8. (Reviewed April 2013.)

Mathematicians in Bologna 1861–1960, edited by Salvatore Coen. Springer, 2012. ISBN-13: 978-30348-0226-0.

**Mathematics in Nineteenth-Century America: The Bowditch Generation,* by Todd Timmons. Docent Press, July 2013. ISBN-13: 978-0-9887449-3-6.

Mathematics in Victorian Britain, by Raymond Flood, Adrian Rice, and Robin Wilson. Oxford University Press, October 2011. ISBN-13: 978-019-960139-4.

Mathematics under the Microscope: Notes on Cognitive Aspects of Mathematical Practice, by Alexandre V. Borovik. AMS, January 2010. ISBN-13: 978-0-8218-4761-9.

Maverick Genius: The Pioneering Odyssey of Freeman Dyson, by Phillip F. Schewe. Thomas Dunne Books, February 2013. ISBN-13:978-03126-423-58.

Meaning in Mathematics, edited by John Polkinghorne. Oxford University Press, July 2011. ISBN-13: 978-01996-050-57. (Reviewed May 2013.)

**My Brief History*, by Stephen Hawking. Bantam Dell, September 2013. ISBN-13: 978-03455-352-83.

The New York Times Book of Mathematics: More Than 100 Years of Writing by the Numbers, edited by Gina Kolata. Sterling, June 2013. ISBN-13: 978-14027-932-26.

The Noether Theorems: Invariance and Conservation Laws in the Twentieth Century, by Yvette Kosmann-

Schwarzbach. Springer, December 2010. ISBN-13: 978-03878-786-76. (Reviewed August 2013.)

Paradoxes in Probability Theory, by William Eckhardt. Springer, September 2012. ISBN-13: 978-94007-513-92. (Reviewed March 2013.)

Peirce's Logic of Continuity: A Conceptual and Mathematical Approach, by Fernando Zalamea. Docent Press, December 2012. ISBN-13: 978-0-9837004-9-4.

**Perfect Mechanics: Instrument Makers at the Royal Society of London in the Eighteenth Century,* by Richard Sorrenson. Docent Press, September 2013. ISBN-13: 978-0-9887449-2-9.

Relations between Logic and Mathematics in the Work of Benjamin and Charles S. Peirce, by Allison Walsh. Docent Press, October 2012. ISBN-13: 978-0-9837004-6-3.

The Search for Certainty: A Journey through the History of Mathematics, 1800–2000, edited by Frank J. Swetz. Dover Publications, September 2012. ISBN-13: 978-04864-744-27.

Seduced by Logic: Emilie Du Châtelet, Mary Somerville and the Newtonian Revolution, by Robyn Arianrhod. Oxford University Press, September 2012. ISBN-13: 978-01999-316-13. (Reviewed June/July 2013).

Selected Papers: Volume II: On Algebraic Geometry, including Correspondence with Grothendieck, by David Mumford. Edited by Amnon Neeman, Ching-Li Chai, and Takahiro Shiota. Springer, July 2010. ISBN-13: 978-03877-249-11. (Reviewed February 2013.)

The Signal and the Noise: Why So Many Predictions Fail—But Some Don't, by Nate Silver. Penguin Press, September 2012. ISBN-13:978-15942-041-11.

Sources in the Development of Mathematics: Series and Products from the Fifteenth to the Twenty-first Century, by Ranjan Roy. Cambridge University Press, June 2011. ISBN-13: 978-05211-147-07. (Reviewed November 2013.)

**Strange Attractors* (comic book), by Charles Soule, Greg Scott, and Robert Saywitz. Archaia Entertainment, May 2013. ISBN-13: 978-19363-936-26.

Symmetry: A Very Short Introduction, by Ian Stewart. Oxford University Press, July 2013. ISBN-13: 978-01996-519-86.

Thinking in Numbers: On Life, Love, Meaning, and Math, by Daniel Tammet. Little, Brown and Company, July 2013. ISBN-13: 978-03161-873-74.

Thinking Statistically, by Uri Bram. CreateSpace Independent Publishing Platform, January 2012. ISBN-13: 978-14699-123-32.

Transcending Tradition: Jewish Mathematicians in German Speaking Academic Culture, edited by Birgit Bergmann, Moritz Epple, and Ruti Ungar. Springer, January 2012. ISBN-13: 978-36422-246-38. (Reviewed February 2013.)

Turbulent Times in Mathematics: The Life of J. C. Fields and the History of the Fields Medal, by Elaine McKinnon Riehm and Frances Hoffman. AMS, November 2011. ISBN-13: 978-0-8218-6914-7.

Turing's Cathedral: The Origins of the Digital Universe, by George Dyson. Pantheon/Vintage, December 2012. ISBN-13: 978-14000-759-97.

Mathematics under the Microscope: Notes on Cognitive Aspects of Mathematical Practice, by Alexandre V. Borovik. AMS, January 2010. ISBN-13: 978-0-8218-4761-9.

Visions of Infinity: The Great Mathematical Problems, by Ian Stewart. Basic Books, March 2013. ISBN-13: 978-04650-224-03.

A Wealth of Numbers: An Anthology of 500 Years of Popular Mathematics Writing, edited by Benjamin Wardhaugh. Princeton University Press, April 2012. ISBN-13: 978-06911-477-58. (Reviewed March 2013.)

Who's #1?: The Science of Rating and Ranking, by Amy N. Langville and Carl D. Meyer. Princeton University Press, February 2012. ISBN-13: 978-06911-542-20. (Reviewed January 2013.)

Classified Advertisements

Positions available, items for sale, services available, and more

ALABAMA

UNIVERSITY OF ALABAMA
Department of Mathematics
Computational Positions

The Department of Mathematics at the University of Alabama invites applications for two tenure-track positions at the Assistant Professor level. One position is in the area of Numerical Linear Algebra in Data Mining with application to any field of science and engineering. The other position is in Computational Statistics in Data Mining with the focus being specifically in the area of Cyber-Security. The appointments will begin on August 16, 2014. Candidates must possess a doctorate in mathematics, statistics, or a closely related field. Applicants must apply online at `http://facultyjobs.ua.edu` and arrange for three letters of recommendation, one of which may address teaching, to be sent to `math@ua.edu`. The review process starts on December 1, 2013, and continues until the position is filled. The University of Alabama is an Equal Opportunity/Affirmative Action Employer and actively seeks diversity among its employees. Women and minority candidates are strongly encouraged to apply. More information about the department and the university is available at `http://math.ua.edu`.

000092

UNIVERSITY OF ALABAMA
Department of Mathematics
Functional Analysis

The Department of Mathematics at the University of Alabama invites applications for two tenure-track Assistant Professor positions in the general area of Functional Analysis with the appointment to begin on August 16, 2014. We are particularly interested in the areas of Operator Theory and Harmonic Analysis; however, other major areas of modern analysis may be considered. Candidates must possess a doctoral degree in mathematics or a closely related field by August 16, 2014. Experience in teaching and research is expected. Applicants should apply online at `http://facultyjobs.ua.edu`; attach a curriculum vita along with a letter of application and arrange for four letters of recommendation (one letter concerning teaching) to be sent to: `math@ua.edu`. Applications will be reviewed on an ongoing basis and will continue to be accepted until the position is filled. The University of Alabama is an Equal Opportunity/Affirmative Action Employer and actively seeks diversity among its employees. Women and minority candidates are strongly encouraged to apply. For more information about the department and the university visit our website at `http://math.ua.edu`.

000091

CALIFORNIA

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
Olga Taussky and John Todd Instructorships in Mathematics

Description: Appointments are for three years. There are three terms in the Caltech academic year, and instructors typically are expected to teach one course in all but two terms of the total appointment. These two terms will be devoted to research. During the summer months there are no duties except research.

Eligibility: Offered to persons within three years of having received the Ph.D. who show strong research promise in one of the areas in which Caltech's mathematics faculty is currently active.

Deadline: January 1, 2014.

Application information: Please apply online at `http://mathjobs.org`. You can also find information about this position at `www.math.caltech.edu/positions.html`. To avoid duplication of paperwork, your application may also be considered for a Harry Bateman Research Instructorship. Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

000049

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
Scott Russell Johnson Senior Postdoctoral Scholar in Mathematics

Description: There are three terms in the Caltech academic year. The fellow is typically expected to teach one course in two terms each year, and is expected to be in residence even during terms when not teaching. The initial appointment is for three years with an additional three-year terminal extension expected.

Eligibility: Offered to a candidate within six years of having received the Ph.D. who shows strong research promise in one of the areas in which Caltech's mathematics faculty is currently active.

Deadline: January 1, 2014.

Application information: Please apply online at `http://mathjobs.org`. You can also find information about this position at `www.math.caltech.edu/`

positions.html. To avoid duplication of paperwork, your application may also be considered for an Olga Taussky and John Todd Instructorship. Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

000050

CALIFORNIA INSTITUTE OF TECHNOLOGY
Department of Mathematics
Harry Bateman Research Instructorships in Mathematics

Description: Appointments are for two years with one-year terminal extension expected. The academic year runs from approximately October 1 to June 1. Instructors typically are expected to teach one course per quarter for the full academic year and to devote the rest of their time to research. During the summer months there are no duties except research.

Eligibility: Open to persons who have recently received their doctorates in mathematics.

Deadline: January 1, 2014.

Application information: Please apply online at http://mathjobs.org. You can also find information about this position at www.math.caltech.edu/positions.html. To avoid duplication of paperwork, your application may also be considered for an Olga Taussky and John Todd Instructorship. Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

000054

CALIFORNIA STATE UNIVERSITY, FULLERTON
Pure Mathematics Tenure-Track Positions

The Department of Mathematics invites applications for two tenure-track positions at the Assistant Professor level beginning August 18, 2014. The first position is in the area of general topology and/or geometric topology, and the second position is in the area of geometric analysis. The successful candidates will contribute to the mathematics community at Cal State Fullerton through teaching, research, professional activities, and service. A Ph.D. in mathematics or related field must be completed by the starting date. The positions are at the rank of assistant professor. Salary is competitive and will be commensurate with rank, experience, and qualifications. Review of complete applications will begin on December 2, 2013, and continue until the position is closed. Please see full ad at mathjobs.org. Job #5088. Cal State Fullerton is an Equal Opportunity/Title IX/503/504/VEVRA/ADA Employer.

000081

UNIVERSITY OF CALIFORNIA SAN DIEGO
Department of Mathematics
Assistant Professorship

The Department of Mathematics, within the Division of Physical Sciences at the University of California, San Diego (http://www.math.ucsd.edu), invites applications for tenure-track positions from outstanding candidates. This is a broad search that is open to applicants from all areas of pure and applied mathematics. Successful candidates must have a Ph.D. and demonstrated potential for excellence in both teaching and research. Preferred candidates will have the potential for leadership in areas contributing to diversity, equity, and inclusion and will have a desire to play a future role in helping to shape and expand the university's diversity initiatives (http://diversity.ucsd.edu/). We especially welcome candidates who have experience with and wish to contribute to programs that increase the access and success of underrepresented students and faculty in mathematics.

Candidates must receive their Ph.D. prior to their first quarter of teaching. Salary is commensurate with qualifications and based on UC pay scales. The starting date for the positions, pending funding approval, will be July 1, 2014. To receive full consideration, applications should be submitted online through http://apptrkr.com/391121 by December 1, 2013.

AA/EOE

000089

CONNECTICUT

UNIVERSITY OF CONNECTICUT
Department of Mathematics
Assistant Professor
Probability/Analysis

The Department of Mathematics at the University of Connecticut invites applications for two tenure-track Assistant Professor positions beginning in fall 2014, at the Storrs campus. The fields of the search are probability and analysis. Candidates for the rank of Associate professor or Full Professor may be considered in exceptional cases. The successful candidate will be expected to teach mathematics courses at all levels and to develop a vigorous externally funded research program.

Minimum Qualifications: A Ph.D. or an equivalent foreign degree in mathematics or a closely related area by August 22, 2014, demonstrated evidence of excellent teaching and outstanding research.

Preferred Qualifications: Research excellence in a priority area of the search with the potential to attract external funding, and the ability to contribute through research, teaching and/or public engagement to the diversity and excellence of the learning experience at UConn.

The review of applications will begin on December 1, 2013, and will continue until the position is filled. Apply online at http://www.mathjobs.org/jobs, including at least four letters of reference, one of which addresses the applicant's teaching. Questions or requests for further information should be sent to the Hiring Committee at mathhiring@uconn.edu.

The University of Connecticut is an EEO/AA Employer and actively solicits applications from minorities, women, and people with disabilities.

000075

WASHINGTON, DC

GEORGE WASHINGTON UNIVERSITY
Department of Mathematics

The university invites applications to a tenure-track assistant professor position. Our priorities are applied mathematics and computational mathematics, but truly exceptional candidates in other areas may also be considered. Applicants must possess a Ph.D. in mathematics or applied mathematics. For additional information on the position, including a detailed description of the qualifications, and the application procedure, please see full position announcement, and apply online at http://www.mathjobs.org. The George Washington University is an Equal Opportunity/Affirmative Action Employer.

000069

INDIANA

IUPUI SCHOOL OF SCIENCE
Chairperson Position in Mathematical Sciences

The IUPUI School of Science invites applications for the position of chairperson in mathematical sciences. A Ph.D. degree in mathematics or a related field is required. For further information visit http://science.iupui.edu/sites/default/files/math_ad_-_final_9-24-2013.pdf. An Equal Opportunity/Affirmative Action Institution.

000086

MASSACHUSETTS

NORTHEASTERN UNIVERSITY
Department of Mathematics
Assistant/Associate Professor–Applied Mathematics
Tenure-Track Position

The Department of Mathematics at Northeastern University invites applicants for one or more tenure-track positions at the Assistant/Associate Professor level, Associate Professor level is preferred, in

Applied Mathematics to start as early as September of 2014.

Appointments are based on exceptional research contributions in mathematics combined with strong commitment and demonstrated success in teaching. Applications from those with an interest and ability to connect across units in the university to the advantage of research at the interface of mathematics and other disciplines are a top priority and the expectation is this would result in building an applied cluster. Outstanding candidates with research in discrete and computational mathematics, fluid dynamics, and probability/statistics are encouraged to apply.

Candidates must have a Ph.D. in mathematics or a related field by the start date, strong record of research, and demonstrated evidence of excellent teaching ability. Responsibilities will include teaching undergraduate and graduate courses, mentoring students, and conducting an independent research program.

Review of applications will begin immediately. Complete applications received by October 31, 2013, will be guaranteed full consideration.

Please be sure to include 3 references, a teaching statement, and a research statement.

To apply, visit "Careers at Northeastern" at `https://neu.peopleadmin.com`. Click on "Full-time Faculty Positions" and search for the current position under the College of Science. You can also apply by visiting the College of Science website at `http://www.northeastern.edu/cos` and clicking on the "Faculty Positions" button.

Northeastern University is an Equal Opportunity, Affirmative Action Educational Institution and Employer, Title IX University. Northeastern University particularly welcomes applications from minorities, women, and persons with disabilities. Northeastern University is an E-Verify Employer.

000077

NORTHEASTERN UNIVERSITY
Department of Mathematics
Assistant/Associate Professor–Pure Mathematics
Tenure-Track Position

The Department of Mathematics at Northeastern University invites applicants for one or more tenure-track positions at the Assistant/Associate Professor level, Associate Professor level is preferred, in Pure Mathematics to start as early as September of 2014.

Appointments are based on exceptional research contributions in mathematics combined with strong commitment and demonstrated success in teaching. Applications from those with an interest and ability to connect across units in the university to the advantage of research at the interface of mathematics and other disciplines are a top priority. Outstanding candidates with research in combinatorics, geometry, topology, and analysis are encouraged to apply. Candidates must have a Ph.D. in mathematics or a related field by the start date, strong record of research, and demonstrated evidence of excellent teaching ability. Responsibilities will include teaching undergraduate and graduate courses, mentoring students, and conducting an independent research program.

Review of applications will begin immediately. Complete applications received by October 31, 2013, will be guaranteed full consideration.

Please be sure to include 3 references, a teaching statement, and a research statement. To apply, visit "Careers at Northeastern" at `https://neu.peopleadmin.com`. Click on "Full-time Faculty Positions" and search for the current position under the College of Science. You can also apply by visiting the College of Science website at `http://www.northeastern.edu/cos` and clicking on the "Faculty Positions" button.

Northeastern University is an Equal Opportunity, Affirmative Action Educational Institution and Employer, Title IX University. Northeastern University particularly welcomes applications from minorities, women, and persons with disabilities. Northeastern University is an E-Verify Employer.

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BOSTON UNIVERSITY
Department of Mathematics and Statistics
Postdoctoral Position Dynamical Systems

The Department of Mathematics and Statistics, at Boston University, invites applications for a three-year postdoctoral position in Dynamical Systems, starting July 2014 pending final budgetary approval. Strong commitment to research and teaching is essential. Submit AMS cover sheet, CV, research statement, teaching statement and at least four letters of recommendation, one of which addresses teaching, to `http://mathjobs.org`. Alternatively, send all material to Dynamical Systems Postdoctoral Search Committee, Department of Mathematics and Statistics, Boston University, 111 Cummington Mall, Boston, MA 02215. Application deadline December 15, 2013. Boston University is an Affirmative Action/Equal Opportunity Employer.

000083

UNIVERSITY OF MASSACHUSETTS AMHERST
Department of Mathematics and Statistics

The Department of Mathematics and Statistics (`http://www.math.umass.edu`) invites applications for three three-year Visiting Assistant Professor/Lecturer positions (non-tenure-track) to start September 1, 2014. Candidates should have completed the Ph.D. by the beginning of the appointment. Exceptional promise in research and a commitment to outstanding teaching at all levels of the curriculum are expected. The search will encompass the following areas: Algebra and Number Theory, Algebraic Geometry, Analysis and Partial Differential Equations, Applied and Computational Mathematics, Differential Geometry and Topology, Mathematical Physics, Probability, Representation Theory and Lie Theory, and Statistics. Applications should be submitted electronically through the AMS website `http://www.mathjobs.org`. Alternatively, applicants may send a curriculum vitae and research and teaching statements, and arrange to have four letters of recommendation, one of which must address the candidate's teaching, sent to: VAP Search Committee, Department of Mathematics and Statistics, Lederle Graduate Research Center, 710 North Pleasant St., Amherst, MA 01003-9305.

Review of applications will begin January 6, 2014. Applications will continue to be accepted until all positions are filled.

The university provides an intellectual environment committed to providing academic excellence and diversity including mentoring programs for faculty. The college and department are committed to increasing the diversity of the faculty, student body, and the curriculum. The University of Massachusetts is an Affirmative Action/Equal Opportunity Employer. Women and minorities are encouraged to apply.

000076

WILLIAMS COLLEGE
Department of Mathematics and Statistics

The Williams College Department of Mathematics and Statistics invites applications for two tenure-track positions in mathematics, beginning fall 2014, at the rank of assistant professor (in an exceptional case, a more advanced appointment may be considered). We are seeking highly qualified candidates who have demonstrated excellence in teaching, who will establish an active and successful research program, and who will have a Ph.D. by the time of appointment. Williams College is a private, coeducational, residential, highly selective liberal arts college with an undergraduate enrollment of approximately 2,000 students. The teaching load is two courses per 12-week semester and a winter term course every other January.

Applicants are encouraged to apply electronically at `http://mathjobs.org` or send a vita and have three letters of recommendation on teaching and research sent to Susan Loepp, Chair of the Hiring Committee, Department of Mathematics and Statistics, Williams College, 18 Hoxsey Street, Williamstown, MA 01267. Teaching and research statements are also welcome. Evaluation of applications will begin on or after November 15 and will continue until the position is filled. All offers of employment are contingent upon completion of a background check. Further information is available upon request. For more information on the Department of Mathematics and Statistics, visit http://math.williams.edu.

Williams College is a coeducational liberal arts institution located in the Berkshire Hills of western Massachusetts with easy access to the culturally rich cities of Albany, Boston, and New York City. The college is committed to building and supporting a diverse population of students, and to fostering an inclusive faculty, staff, and curriculum. Williams has built its reputation on outstanding teaching and scholarship and on the academic excellence of its students. Please visit the Williams College website http://www.williams.edu/. Beyond meeting fully its legal obligations for non-discrimination, Williams College is committed to building a diverse and inclusive community where members from all backgrounds can live, learn, and thrive.

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NEBRASKA

UNIVERSITY OF NEBRASKA-LINCOLN
Department of Mathematics

Invites applications for the following positions:

(1) One tenure-track Assistant Professor position in Scientific Computing/Computational Mathematics. Review of applications will begin November 15, 2013, and continue until a suitable candidate is found.

(2) One Professor of Practice position, at the Assistant Professor level, to be the Director of the First Year Mathematics Program. Review of applications will begin December 1, 2013, and continue until a suitable candidate is found.

(3) One or more postdoctoral positions. Review of applications will begin December 1, 2013, and continue until a suitable candidate (or candidates) is found. Each of these positions begins August 2014. For more information about these positions and information on how to apply for them, please go to: http://www.math.unl.edu/department/jobs/. The University of Nebraska is committed to a pluralistic campus community through Affirmative Action, Equal Opportunity, work-life balance, and dual careers.

000079

NEW HAMPSHIRE

DARTMOUTH COLLEGE
Department of Mathematics
John Wesley Young Research Instructorships

2-3 years, new or recent Ph.D. graduates whose research overlaps a department member's. Teach 3 ten-week courses spread over 3 terms. Appointment for 26 months, with possible 12 month renewal; monthly salary of $5,100, including two-month research stipend for Instructors in residence during 2 of 3 summer months; if not in residence, salary adjusted accordingly. To initiate an application go to http://www.mathjobs.org. Position ID: JWY #4928. You can also access the application through a link at http://www.math.dartmouth.edu/activities/recruiting/. General inquiries can be directed to Tracy Moloney, Administrator, Department of Mathematics, tfmoloney@math.dartmouth.edu. Applications completed by January 5, 2014, considered first. Dartmouth College is committed to diversity and strongly encourages applications from women and minorities.

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NEW YORK

GENERAL ELECTRIC
Global Research Center
Applied Mathematician

The General Electric Global Research Center seeks applicants for the position of Applied Mathematician at its corporate research and development headquarters in Niskayuna, NY. This position requires a doctorate degree in mathematics, applied mathematics, or related areas with solid experience in the broad areas falling within the AMS subject classifications 11-xx through 14-xx (Number theory, algebra, algebraic geometry) or 51-xx through 58-xx (geometry, differential geometry, topology, related areas). At least 3 years of post-Ph.D. experience in mathematics, applied mathematics, or related fields is required. Candidates should have strong interest in applying mathematical theory to industry problems, and superior communication and programming skills (major mathematical software/programming languages). Also desirable is experience or interest in data analysis or large networks. You must submit your application for employment against job number 1767313 at http://www.gecareers.com to be considered for this position. GE is an Equal Opportunity Employer, offering a great work environment, challenging career opportunities, professional training, and competitive compensation.

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SOUTH CAROLINA

COLLEGE OF CHARLESTON
Department ofmathematics

Applications are invited for a tenure-track position at the Assistant Professor level beginning August 16, 2014. The Mathematics Department at the College of Charleston, when fully staffed, has 34 full-time faculty members and offers the B.S., B.A., and M.S. degrees in mathematics. Candidates must have a Ph.D. in one of the mathematical sciences, high potential for continuing research, and commitment to excellence in teaching. Some preference will be given to individuals in the area of modeling with applications to data analytics, cryptography, mathematical biology, discrete modeling, probabilistic modeling, or operations research and who have the potential to contribute to interdisciplinary offerings. However, exceptionally strong candidates in all areas will be considered. The normal teaching load is nine hours per week, and the salary is competitive. A minimal application will consist of a vita, narratives on research and teaching, and at least three letters of recommendation which, combined, must address both teaching and research. All materials should be submitted to the College of Charleston on http://mathjobs.org. For demographic purposes only, candidates must respond yes or no to the Citizen/Residency field. Additional information about the department and its programs, including the interdisciplinary undergraduate Data Science program, is available at http://math.cofc.edu and http://cofc.edu/academics/majorsandminors/data-science.php. Review of applications for on-campus interviews will begin as applications are received, and applications will be accepted throughout the academic year until the position is filled. The College of Charleston is an Equal Opportunity/Affirmative Action Employer and encourages applications from minority and women candidates.

000080

UNIVERSITY OF SOUTH CAROLINA
Department of Mathematics
Endowed Chair in Data Analysis, Simulation, Imaging and Visualization

The Department of Mathematics at the University of South Carolina invites inquiries, nominations and applications for the Endowed Chair in Data Analysis, Simulation, Imaging, and Visualization (CDASIV) in conjunction with the Williams-Hedberg-Hedberg Endowed Chair of Mathematics. This position is sponsored in part by the South Carolina Centers of Economic Excellence (CoEE) program (http|smartstatesc.org/data-analysis|) and carries a total endowment of $4M. Position requires a Ph.D. in mathematics or a related area and an outstanding record of research and teaching. For a complete description of qualifications, go to: http://imi.cas.sc.edu/django/site_media/static/pdf/COEE.pdf.

Applications should be submitted electronically to Professor Pencho Petrushev (coee@math.sc.edu). Applicants are encouraged to submit a letter describing their interests and credentials, curriculum vitae, a list of publications, a statement of research interests and accomplishments, and three letters of reference. Applications will be evaluated as they are received by the Search Committee and the position will remain open until filled.

The University of South Carolina is an Affirmative Action, Equal Opportunity Employer. Minorities and women are encouraged to apply. The University of South Carolina does not discriminate in educational or employment opportunities or decisions for qualified persons on the basis of race, color, religion, sex, national origin, age, disability, sexual orientation, or veteran status.

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UNIVERSITY OF SOUTH CAROLINA
Department of Mathematics
Tenure-Track Assistant Professor

Applications are invited for a tenure-track Assistant Professor position in applied and computational mathematics for research related to modeling and computation of soft matter and/or complex biological systems. Candidates should have a Ph.D. in mathematics or a related field, and have sufficient background in mathematical modeling, mathematical/numerical analysis, simulation, and/or high performance computation of soft matter or complex biological systems to participate in a vigorous interdisciplinary research program in mathematical biology and/or computational science. The successful candidate is expected to interact effectively with researchers in the College of Engineering and Computing, the College of Arts and Sciences, and the College of Medicine at the University of South Carolina.

Applicants must apply electronically at http://www.mathjobs.org. A complete application should contain a cover letter, standard AMS cover sheet, curriculum vitae, description of research plans, statement of teaching philosophy, and four letters of recommendation. One of the letters should appraise the candidate's teaching ability.

The beginning date for the position will be August 16, 2014. Review of applications will begin on November 15, 2013, and continue until the position is filled. To ensure consideration, applications should be received by November 15, 2013. Please address inquiries to qwang@math.sc.edu.

The Mathematics Department, located in the heart of the historic campus, currently has 34 tenured and tenure-track faculty, 5 instructors, 48 graduate students, over 250 majors, and 40 minors. Faculty research interests include algebra, analysis, applied and computational math, biomath, discrete math, geometry, logic, and number theory.

The University of South Carolina's main campus is located in the state capital, close to mountains and coast. The Carnegie Foundation for the Advancement of Teaching has designated the University of South Carolina as one of only 73 public and 32 private academic institutions with "very high research activity". The Carnegie Foundation also lists USC as having strong community engagement. The university has over 29,500 students on the main campus (and over 44,500 students system-wide), more than 350 degree programs, and a nationally-ranked library system that includes one of the nation's largest public film archives. Columbia, the capital of South Carolina, is the center of an increasingly sophisticated greater metropolitan area with a population over 750,000.

The University of South Carolina is an Affirmative Action, Equal Opportunity Employer. Minorities and women are encouraged to apply. The University of South Carolina does not discriminate in educational or employment opportunities or decisions for qualified persons on the basis of race, color, religion, sex, national origin, age, disability, sexual orientation, or veteran status.

000074

TEXAS

TEXAS A&M UNIVERSITY, KINGSVILLE
Mathematics Education Tenure-Track Position

The Department of Mathematics at Texas A&M University-Kingsville invites applications for a tenure-track position in mathematics education at the assistant professor level, beginning spring 2014. A Ph.D. in mathematics education is required from a regionally accredited university or institution. For application and further information visit http://javjobs.tamuk.edu. An Equal Opportunity/Affirmative Action Employer.

000082

WISCONSIN

UNIVERSITY OF WISCONSIN-MADISON
Department of Mathematics

The Department of Mathematics is accepting applications for the academic staff position Associate Director of the Undergraduate Program (Student Services Coordinator at the Associate, No-prefix or Senior level depending on experience), to begin as early as February 15, 2014. The minimum requirement is a Master's degree in mathematics or related field, with a Ph.D. preferred. Teaching experience in the typical undergraduate mathematics course sequences is preferred (see the list of our undergraduate courses at http://www.math.wisc.edu/UCourses). Experience in undergraduate advising is also preferred. An application packet should include a completed AMS Standard Cover Sheet, a curriculum vitae, and a brief description of professional experiences and goals. Application packets should be submitted electronically to http://www.mathjobs.org. Applicants should also arrange to have sent to the above URL address, at least three letters of recommendation which must discuss the applicant's relevant experiences, capabilities and potential. To ensure full consideration, application packets must be received by January 12, 2014. Applications will be accepted until the position is filled. The University of Wisconsin-Madison is an Affirmative Action, Equal Opportunity Employer and encourages applications from women and minorities. Unless confidentiality is requested in writing, information regarding the applicants must be released upon request. Finalists cannot be guaranteed confidentiality. A background check will be required prior to employment.

000085

BRAZIL

UNIVERSITY OF SÃO PAULO
Postdoctoral Opportunities

The recently established Research, Innovation and Dissemination Center on Neuromathematics (NeuroMat), hosted by the University of São Paulo, Brazil, and funded by FAPESP (São Paulo Research Foundation) is offering several postdoctoral fellowships for recent Ph.D's with outstanding research potential. Candidates should have strong background in probability theory with emphasis on stochastic processes or alternatively in statistics with emphasis on statistical model selection. Previous knowledge of rigorous statistical mechanics, random graphs, or stochastic modeling in biosciences will be favorably considered. The initial appointments are for two years, with a possible extension to up to four years conditional on research progress. Salary is competitive at international level and fellows benefit from extra funds for travel and research expenses, plus limited support for relocation expenses. Application instructions are found at http://neuromat.numec.prp.usp.br/postdoc.

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CANADA

UNIVERSITY OF TORONTO
ST. GEORGE CAMPUS
Department of Mathematics

The Department of Mathematics at St. George campus, University of Toronto, invites applications for a tenure-stream appointment at the rank of Assistant Professor. Candidates with research expertise in Geometry and Number Theory will be given preference; however, exceptional candidates in any field of mathematics are encouraged to apply. The expected start date of the appointment is July 1, 2014. All qualified candidates are invited to apply by clicking the following link `http://www.mathjobs.org/jobs/jobs/5117`. To receive full consideration, applications should be received by December 17, 2013.

The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

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UNIVERSITY OF TORONTO
Department of Mathematics

The Department of Mathematics, University of Toronto, invites applications for a tenured appointment at the rank of Associate or Full Professor. The successful candidate will also be appointed as Associate Faculty at the Perimeter Institute for Theoretical Physics (Waterloo, Ontario). The expected start date of the appointment is July 1, 2014. All qualified candidates are invited to apply by clicking the following link `www.mathjobs.org/jobs/jobs/5038`. To receive full consideration, applications should be received by January 15, 2014.

The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

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CZECH REPUBLIC

CHARLES UNIVERSITY PRAGUE
Faculty of Mathematics and Physics

Postdoc position in a group led by S. Hencl and J. Maly, commencing September 2014. The candidate should have strong background in Geometric Function Theory, Quasiconformal Mappings, Function Spaces, Calculus of Variations, or related fields. The position requires no teaching and carries a monthly salary of 40000 CZK. Applications containing CV and three reference letters should be sent to S. Hencl, MFFUK, Sokolovska 83, Praha 8, 18000, Czech Republic by the end of February 2014. More information `http://www.karlin.mff.cuni.cz/~hencl/`.

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KOREA

INSTITUTE FOR BASIC SCIENCE (IBS)
Center for Geometry and Physics

The IBS Center for Geometry and Physics (IBS-CGP) invites applications for several tenure-track and postdoctoral research fellowship positions. IBS-CGP is working to bring the world's leading scientists in mathematics together with young researchers to collaborate on research projects with passion and commitment. To this end, IBS recruits based on scientific excellence and creative ideas, rather than pre-determined goals or demonstrated practical outcomes. IBS provides an open and autonomous research environment. The existing members of IBS-CGP are working in symplectic geometry and topology, dynamical systems, mirror symmetry, algebraic geometry, and mathematical aspects of quantum field and string theory.

Postdoctoral research fellowship positions. Successful candidates will be new or recent Ph.D.'s with outstanding research potential. These non-tenure-track appointments are for three years, and the salary range is KRW 57,000,000–66,000,000 (approximately USD 50,800–58,800).

Tenure-track positions. Successful candidates must have exceptional research qualifications. Starting salary with three years of experience beyond Ph.D. is KRW 92,880,000 (may vary by experience). Relocation expenses and housing allowance for up to 2 years may be provided for qualified overseas candidates.

IBS-CGP offers annual travel funds of KRW 8,000,000 for postdoctoral position and KRW 15,000,000 for tenure-track position in addition to basic research equipment and comprehensive benefits including medical and travel insurance and retirement funds.

A complete application packet should include a cover letter, a curriculum vitae which includes a publication list, a research statement, and at least three letters of recommendation for postdoctoral positions and four for tenure-track positions. For full consideration, application packets must be submitted electronically to `cgp@ibs.re.kr` by December 15, 2013. IBS encourages applications from individuals of diverse backgrounds. IBS-CGP website: `http://cgp.ibs.re.kr`.

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IBS CENTER FOR GEOMETRY AND PHYSICS
Group Leader Positions

The IBS Center for Geometry and Physics (IBS-CGP) invites applications for up to 2 Group Leader positions from mathematicians of exceptional research record and leadership in the area of contact topology, dynamical systems, or algebraic geometry (related to GW invariants and homological mirror symmetry). IBS-CGP is working to bring the world's leading scientists in mathematics together with young researchers to collaborate on research projects with passion and commitment. IBS provides an open and autonomous research environment. The existing members of IBS-CGP are working on symplectic geometry and topology, dynamical systems, mirror symmetry, algebraic geometry, and mathematical aspects of quantum field and string theory. IBS-CGP offers globally competitive compensation which will be determined based on experience and qualifications of each candidate. IBS-CGP also offers comprehensive benefits including medical and travel insurance, worker's compensation, and retirement fund. More specifics for successful candidates are as follows:

Internationally competitive salary (negotiable).

Dual appointment at POSTECH as a tenured or tenure-track faculty member depending on the candidate's qualifications. (this is subject to review and approval by the Department of Mathematics and the administration of POSTECH. However, POSTECH will respect the recommendations of the IBS-CGP director and the IBS Headquarters as long as the candidate's qualifications meet the POSTECH requirements.)

Teaching load of one graduate course per year at POSTECH.

Generous and flexible research grant.

Can hire 1-2 tenure-track and 3-4 postdoctoral researchers for his/her research group. (Unlike Group Leader, researchers will not be given appointments at POSTECH.)

Free housing of about 105 m^2 in size at the POSTECH Faculty Apartment for 10 years.

For qualified overseas candidates, relocation expenses and some educational allowance for up to 2 children will be provided.

A complete application packet should include:

- Cover letter
- Curriculum vitae including a publication list
- Research statement
- At least 5 letters of recommendation

For full consideration, complete application packets must be submitted electronically to `cgp@ibs.re.kr` by February 15, 2014. IBS and POSTECH encourage applications from individuals of diverse backgrounds. Non-Korean citizens are also welcome to apply. IBS-CGP website: `http://cgp.ibs.re.kr`.

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Mathematics Calendar

Please submit conference information for the Mathematics Calendar through the Mathematics Calendar submission form at http://www.ams.org/cgi-bin/mathcal-submit.pl.

December 2013

2–4 **Quasilinear PDEs and Game Theory**, Uppsala University, Uppsala, Sweden. (Oct. 2013, p. 1201)

2–6 **Deterministic and Stochastic Dynamics in Economics and Finance**, Centro di Ricerca Matematica Ennio De Giorgi, Palazzo Puteano, Piazza dei Cavalieri 3, Pisa, Italy. (Oct. 2013, p. 1201)

3–5 **6th Minimeeting on Differential Geometry**, Center for Research in Mathematics (CIMAT), Guanajuato, Mexico. (Oct. 2013, p. 1201)

7–8 **Infinite-Dimensional Geometry**, University of California, Berkeley (740 Evans Hall), California. (Sept. 2013, p. 1104)

7–11 **"ATCM+TIME 2013": A joint session of 18th Asian Technology Conference in Mathematics and 6th Technology & Innovations in Mathematics Education**, Department of Mathematics, Indian Institute of Technology, Powai, Mumbai 400076, India. (Mar. 2013, p. 363)

* 8–14 **Géo2. Géométrie et Analyse Microlocale**, Kasdi Merbah University, Ouarglae, Algeria.

Description: The purpose of this winter school is to bring together Ph.D. students and good Master, working in complex geometry, symplectic geometry, microlocal analysis and related fields to present important areas of current research. The Winter School is also an opportunity for young students to meet leading researchers in a relaxed atmosphere, and begin to build relationships with their peers.

Information: http://sites.google.com/site/mygeometries/.

13–15 **International Conference on Special Functions & their Applications (ICSFA 2013) and symposium on "Applications in Diverse Fields of Engineering and Technology"**, Department of Mathematics. Malviya National Institute of Technology, J.L.N. Marg, Jaipur-302017, Rajasthan, India. (Nov. 2013, p. 1397)

* 16 **DIMACS Workshop on Algorithms for Green Data Storage**, DIMACS Center, CoRE Building, Rutgers University, Piscataway, New Jersey, 08854-8018.

Description: A large body of recent literature proposes using erasure and network coding as a more bandwidth and storage efficient way to provide reliability and accessibility of stored content. These smart storage algorithms promise to significantly cut data-center energy use, but have so far been studied and evaluated mostly in simplified theoretical settings, without taking into account all systems issues that may arise by introducing the algorithms into practical storage systems. The working group and workshop intend to bring experts in coding and queueing theory for distributed storage together with distributed storage systems experts in order to better understand and find ways to evaluate how well the practice would match the theoretical predictions of energy savings. Furthermore, other problems that arise in data storage practice and could potentially benefit from smarter algorithms will be presented.

Organizers: Emina Soljanin, Bell Labs, emina@research.bell-labs.com. Presented under the auspices of the Special Focus on Energy and Algorithms.

Local Arrangements: Workshop Coordinator, DIMACS Center, workshop@dimacs.rutgers.edu, 732-445-5928

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

16–18 **International Conference on Role of Statistics in the Advancement of Science and Technology**, Department of Statistics, University of Pune, Pune, Maharashtra, India. (Sept. 2013, p. 1104)

16–19 **deLeónfest 2013**, ICMAT, Campus de Cantoblanco, Madrid, Spain. (Oct. 2013, p. 1201)

16–19 **International Conference on Advances in Applied Mathematics**, Hammamet, Tunisia. (Sept. 2013, p. 1105)

16–20 **Fundamental Groups in Arithmetic and Algebraic Geometry**, Centro di Ricerca Matematica Ennio De Giorgi, Pisa, Italy. (Mar. 2013, p. 363)

16–20 **2013 Taiwan International Conference on Geometry**, National Taiwan University, Taipei, Taiwan. (Oct. 2013, p. 1201)

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

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

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

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

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

The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through the AMS website on the World Wide Web. To access the AMS website, use the URL: http://www.ams.org/.

16–20 **The XXIVth Edition of the International Workshop on Operator Theory and its Applications (IWOTA)**, Indian Institute of Sciences, Bangalore, India. (Sept. 2013, p. 1105)

17–20 **International Conference on Mathematics Education and Mathematics in Engineering and Technology**, Mohandas College of Engineering & Technology (MCET), Anad, Nedumangad, Thiruvananthapuram, Kerala state, India. (Oct. 2013, p. 1201)

17–20 **Marrakesh International Conference on Probability and Statistics (MICPS-2013)**, Marrakesh, Morocco. (Sept. 2013, p. 1105)

18–20 **6th Indian International Conference on Artificial Intelligence**, Tumkur (near Bangalore), India. (May 2013, p. 655)

18–21 **HiPC 2013: 20th IEEE International Conference on High Performance Computing**, Park Plaza Bengaluru Hotel, Bengaluru, Bangalore, India. (Sept. 2013, p. 1105)

21–22 **The International Congress on Science and Technology**, Allahabad, U.P., India. (Sept. 2013, p. 1105)

21–23 **7th International Conference of IMBIC on "Mathematical Sciences for Advancement of Science and Technology" (MSAST 2013)**, Hotel Indismart, Kolkata, India. (Sept. 2013, p. 1105)

24–26 **International Conference on "Recent Advances in Mathematical Sciences and Applications" (ICRAMSA–2013)**, University Institute of Technology, Rajiv Gandhi Proudyogiki Vishwavidyalaya, Airport By-Pass Road, Gandhi Nagar, Bhopal (M. P.), India.

28–30 **3rd International Conference on Mathematics & Information Science (ICMIS 2013)**, Luxor, Egypt. (Oct. 2012, p. 1303)

* 29–31 **International Conference on Computer Analysis of the Problems of Science and Technology**, Tajik National University, Dushanbe, Tajikistan.
Description: International Conference on Computer Analysis of the Problems of Science and Technology.
Topics: Mathematical and computer analysis of the problems of crisis, the risk of accidents and turbulence in the living and non-living systems; mathematical aspects of computer science; problems of computer and information security.
Information: `http://www.yunusi.tj`.

January 2014

* 3–5 **International Symposium on Analysis and Applications**, Centro Vacacional IMSS Metepec, Atlixco, Puebla, Mexico.
Description: The International Symposium on Analysis and Applications 2014 (ISAA 2014) is organized by the Analysis Group at Universidad Autónoma Metropolitana, Iztapalapa, Mexico. Its aim is to discuss of recent developments in the study of evolution equations, their invariant states and the asymptotic behavior of their solutions, including: quantum Markov semigroups, non-linear evolution equations, quantum dispersion theory and mathematical finance. Another aim is to introduce graduate and undergraduate students as well as young researchers to the above topics and others that are relevant in Mathematical Analysis.
Information: `http://isaa.izt.uam.mx`.

5–7 **ACM-SIAM Symposium on Discrete Algorithms (SODA14), being held with Analytic Algorithmics and Combinatorics (ANALCO14) and Algorithm Engineering and Experiments (ALENEX14)**, Hilton Portland & Executive Tower, Portland, Oregon. (Dec. 2012, p. 1597)

6–10 **Mathematics of Social Learning**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Sept. 2013, p. 1106)

6–11 **Stochastic Partial Differential Equations and Applications**, Bellavista Relax Hotel, Levico (prov. Trento), Italy. (Oct. 2013, p. 1201)

* 6–17 **Introduction to Categorification**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, Montréal (Québec), Canada.
Description: This mini-course will serve to introduce students to the new and exciting field of categorification.
Information: `http://www.crm.umontreal.ca/2014/Catego14/index_e.php`.

6–July 4 **Free Boundary Problems and Related Topics**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Dec. 2012, p. 1597)

15–18 **Joint Mathematics Meetings**, Baltimore, Maryland. (Sept. 2013, p. 1106)

16–18 **Mathematical Challenges in Ophthalmology**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Sept. 2013, p. 1106)

20–23 **International Conference on Recent Advances in Mathematics (ICRAM 2014)**, Department of Mathematics, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur Maharashtra State, India. (Sept. 2013, p. 1106)

20–24 **An international symposium on orthogonality and quadrature (ORTHOQUAD 2014)**, Puerto de la Cruz, Tenerife, Canary Islands, Spain. (Sept. 2013, p. 1106)

20–24 **ICERM Topical Workshop: From the Clinic to Partial Differential Equations and Back: Emerging Challenges for Cardiovascular Mathematics**, ICERM, Providence, Rhode Island. (Sept. 2013, p. 1106)

* 20–24 **Representation theory days in Patagonia**, Punta Arenas, Chile.
Description: The purpose of the conference is to bring together leading experts in geometric representation theory and related physics. Topics will include affine flag varieties, affine and double affine Hecke algebras and their applications in topology, categorification, string theory, conformal field theory and the Langlands program.
Information: `http://inst-mat.utalca.cl/~patagonia/`.

20–May 23 **Algebraic Topology Program**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2012, p. 1482)

20–May 23 **Model Theory and Number Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1177)

23–24 **Connections for Women: Algebraic Topology**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1177)

25–30 **From Random Walks to Lévy Processes**, Australian National University, Kioloa, Australia. (Nov. 2013, p. 1397)

27–30 **Symmetries, Differential Equations and Applications (SDEA-II)**, Center for Advanced Mathematics & Physics (CAMP), National University of Sciences & Technology (NUST), Campus H - 12, Islamabad, 44000, Pakistan. (Sept. 2013, p. 1107)

27–31 **Introductory Workshop: Algebraic Topology**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1177)

27–31 **Rough Paths: Theory and Applications**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Sept. 2013, p. 1107)

February 2014

* 3–4 **3rd Annual International Conference on Computational Mathematics, Computational Geometry & Statistics (CMCGS 2014)**, Hotel Fort Canning, 11 Canning Walk, Singapore, Singapore 17881.
Description: The goal of the conference is to bring together active researchers from the various disciplines to showcase their state-of-the-art research results and hopefully to forge new cross-disciplinary interactions among the participants. The conference provides a unique opportunity for in-depth

technical discussions and exchange of ideas in mathematical and computational sciences, as well as explores the potential of their applications in natural and social sciences, engineering and technology and industry and finance. The objectives of this conference are to provide a forum for researchers, educators, students, contributors, users of mathematical knowledge and industries to exchange ideas and communicate and discuss research findings and new advancements in mathematics and statistics; to explore possible avenues to foster academic and student exchange, as well as scientific activities.
Information: http://www.mathsstat.org/.

3–7 **Introductory Workshop: Model Theory, Arithmetic Geometry and Number Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2012, p. 1482)

3–May 9 **ICERM Semester Program on "Network Science and Graph Algorithms"**, ICERM, Providence, Rhode Island. (Jan. 2013, p. 117)

4–7 **Function Theory on Infinite Dimensional Spaces XIII**, ICMAT, Campus de Cantoblanco, Madrid, Spain. (Oct. 2013, p. 1202)

10–11 **Connections for Women: Model Theory and its interactions with number theory and arithmetic geometry**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1177)

10–14 **ICERM Workshop: Semidefinite Programming and Graph Algorithms**, ICERM, Providence, Rhode Island. (Sept. 2013, p. 1107)

10–14 **Translating Cancer Data and Models to Clinical Practice**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Sept. 2013, p. 1108)

10–21 **Higher Structures in Algebraic Analysis**, University of Padova, Department of Mathematics, Padova, Italy.

17–21 **Hot Topics: Perfectoid Spaces and their Applications**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2013, p. 1397)

24–28 **Stochastic Gradient Methods**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Sept. 2013, p. 1108)

* 2–March 7 **Winter School II**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, Montréal (Québec), Canada.
Description: The first week of the course will focus on the category O for finite-dimensional simple Lie algebras, and will cover the material found in the first few chapters of Humphrey's book "Representations of semisimple Lie algebras in the BGG category O". The second week will deal with the case of affine Lie algebras.
Information: http://www.crm.umontreal.ca/2014/Algebras14/index_e.php.

* 25–28 **XIX SIMMAC - International Symposium on Mathematical Methods Applied to the Sciences**, University of Costa Rica, San Jose, Costa Rica.
Description: The XIXth International Symposium on Mathematical Methods Applied to the Sciences (XIX SIMMAC) is the most important event in applied mathematics in Central America. It is organized by the Center for Research in Pure and Applied Mathematics (CIMPA) of the University of Costa Rica every two years, with the support of the School of Mathematics. Since 1978, this activity has been developped with the participation of several mathematicians and scientists of affine disciplines, coming from Central America, Europe, North America and South America. Registration to the SIMMAC begins on Monday 24th at 2 p.m., at the Physic-Mathematic building. Registration on Tuesday opens at 8 a.m.
Information: http://www.cimpa.ucr.ac.cr/simmac/en/.

March 2014

3–7 **AIM Workshop: Postcritically finite maps in complex and arithmetic dynamics**, American Institute of Mathematics, Palo Alto, California. (Sept. 2013, p. 1108)

4–7 **11th German Probability and Statistics Days 2014 - Ulmer Stochastik-Tage**, University Ulm, Ulm, Germany. (Sept. 2013, p. 1108)

5–7 **International Workshop on Discrete Structures (IWODS)**, Centre for Advanced Mathematics and Physics, National University of Sciences and Technology, H-12 Islamabad, Pakistan. (Oct. 2013, p. 1202)

10–26 **School and Workshop on Classification and Regression Trees**, Institute for Mathematical Sciences, National University of Singapore, Singapore. (May 2013, p. 655)

10–June 13 **Algebraic Techniques for Combinatorial and Computational Geometry**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Oct. 2013, p. 1202)

* 11–14 **Algebraic Techniques for Combinatorial and Computational Geometry: Tutorials**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.
Description: The long program opens with four days of tutorials that will provide an introduction to major themes of the 3-month "Algebraic Techniques for Combinatorial and Computational Geometry" program and the four workshops. The goal is to build a foundation for the participants of this program who have diverse scientific backgrounds. Registration for tutorials is free, to encourage broad participation. An application/registration form is available at: http://www.ipam.ucla.edu/elements/choose.aspx?pc=ccgtut. The application form is for those requesting financial support to attend the workshop. We urge you to apply as early as possible. Applications received by Monday, January 13, 2014, will receive fullest consideration, http://www.ipam.ucla.
Information: http://www.ipam.ucla.edu/programs/ccgtut/.

12–14 **IAENG International Conference on Operations Research 2014**, Hong Kong, China. (Oct. 2013, p. 1202)

* 13–15 **48th Annual Spring Topology and Dynamical Systems Conference**, University of Richmond, Richmond, Virginia.
Description: One of the largest long-running topology conferences, the conference features 19 plenary/semi-plenary talks as well as 5 parallel sessions in set theoretic topology, continuum theory, dynamical systems, geometric topology, and geometric group theory. The local organizers for the 2014 conference are Van Nall (vnall@richmond.edu) and Judy Kennedy (kennedy9905@gmail.com).
Information: http://math.richmond.edu/resources/topology-conference/index.html.

14–28 **Representation Theory and Geometry of Reductive Groups**, Kloster Heiligkreuztal, a Monastary in Germany, Altheim, Germany. (Nov. 2013, p. 1397)

17–21 **ICERM Workshop: Stochastic Graph Models**, ICERM, Providence, Rhode Island. (Sept. 2013, p. 1108)

21–23 **Sectional Meeting**, University of Tennessee, Knoxville, Knoxville, Tennessee. (Sept. 2013, p. 1108)

* 24–25 **2nd Annual International Conference on Architecture and Civil Engineering (ACE 2014)**, Hotel Fort Canning, 11 Canning Walk, Singapore, Singapore 17881.
Description: Biotechnology is a field of applied biology that involves the use of living organisms and bioprocesses in engineering, technology, medicine and other fields requiring bioproducts. The concept encompasses a wide range of procedures for modifying living organisms according to human purposes—going back to domestication of animals, cultivation of plants, and "improvements" to these through breeding programs that employ artificial selection and hybridization. This multi-disciplinary conference aims to provide a challenging forum and vibrant opportunity for researchers and industry practitioners to share their original research results and practical development experiences on specific new challenges and emerging issues.

Information: http://www.ace-conference.org/.

24–28 **Combinatorial Geometry Problems at the Algebraic Interface**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Oct. 2013, p. 1202)

24–April 17 **Mathematical, Statistical and Computational Aspects of the New Science of Metagenomics**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Mar. 2013, p. 363)

28–30 **38th Annual SIAM Southeastern Atlantic Section (SEAS) Conference**, Florida Institute of Technology, Melbourne, Florida. (Nov. 2013, p. 1397)

29–30 **Sectional Meeting**, University of Maryland, Baltimore County, Baltimore, Maryland. (Sept. 2013, p. 1108)

31–April 3 **SIAM Conference on Uncertainty Quantification (UQ14)**, Hyatt Regency Savannah, Savannah, Georgia. (Dec. 2012, p. 1597)

April 2014

1–5 **Ischia Group Theory 2014**, Grand Hotel delle Terme Re Ferdinando, Ischia, Naples, Italy.

3–4 **13th New Mexico Analysis Seminar**, University of New Mexico, Albuquerque, New Mexico. (Nov. 2013, p. 1398)

4 **An Afternoon in Honor to Cora Sadosky**, University of New Mexico, Albuquerque, New Mexico. (Nov. 2013, p. 1398)

5–6 **Sectional Meeting**, University of New Mexico, Albuquerque, New Mexico. (Sept. 2013, p. 1108)

7–11 **AIM Workshop: The many facets of the Maslov index**, American Institute of Mathematics, Palo Alto, California. (Sept. 2013, p. 1109)

7–11 **ICERM Workshop: Electrical Flows, Graph Laplacians, and Algorithms: Spectral Graph Theory and Beyond**, ICERM, Providence, Rhode Island. (Sept. 2013, p. 1109)

7–11 **Reimagining the Foundations of Algebraic Topology**, Mathematical Sciences Research Institute, Berkeley, California. (May 2013, p. 719)

7–11 **Tools from Algebraic Geometry**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Oct. 2013, p. 1202)

11–13, 2014 **Sectional Meeting**, Texas Tech University, Lubbock, Texas. (Sept. 2013, p. 1109)

* 21–25 **Combinatorial representation theory**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, Montréal (Québec), Canada.
Description: The representation theory of Lie algebras, quantum groups and algebraic groups represents a major area of mathematical research in the twenty-first century with numerous applications in other areas of mathematics (geometry, number theory, combinatorics, finite and infinite groups,) and mathematical physics(conformal field theory, statistical mechanics, integrable systems).
Information: http://www.crm.umontreal.ca/2014/Combinatorial14/index_e.php.

22–May 16 **Advanced Monte Carlo Methods for Complex Inference Problems**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Mar. 2013, p. 364)

* 23–25 **International Arab Conference on Mathematics and Computations**, Zarqa University, Zarqa, Jordan.
Description: This event is a periodic conference which will be held at Zarqa University. Scopes of the conference are pure mathematics, applied mathematics, and statistics
Information: http://www.iacmc.org.

28–May 2 **AIM Workshop: Exact crossing numbers**, American Institute of Mathematics, Palo Alto, California. (Oct. 2013, p. 1202)

May 2014

1–30 **Self-normalized Asymptotic Theory in Probability, Statistics and Econometrics**, Institute for Mathematical Sciences, National University of Singapore, Singapore. (Nov. 2013, p. 1398)

5–9 **AIM Workshop: Projective modules and A1-homotopy theory**, American Institute of Mathematics, Palo Alto, California. (Nov. 2013, p. 1398)

5–9 **The Kakeya problem, Restriction problem, and Sum-product Theory**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Oct. 2013, p. 1203)

* 8–12 **Hall and Cluster Algebras**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, Montréal (Québec), Canada.
Description: The workshop will focus on some of the important directions of research in the theory of Hall algebras and cluster algebras. Cluster algebras interact with many areas of mathematics, and the workshop will include speakers studying cluster algebras and their generalizations from a broad range of perspectives. There will be a particular emphasis on the categorification of cluster algebras and the construction of cluster algebras as Hall algebras of cluster categories.
Information: http://www.crm.umontreal.ca/2014/Cluster14/index_e.php.

12–14 **SIAM Conference on Imaging Science (IS14)**, Hong Kong Baptist University, Hong Kong, China. (Aug. 2012, p. 1021)

12–16 **28th Automorphic Forms Workshop**, Moab, Utah. (Oct. 2013, p. 1203)

12–16 **ICERM Topical Workshop: Robust Discretization and Fast Solvers for Computable Multi-Physics Models**, ICERM, Providence, Rhode Island. (Sept. 2013, p. 1109)

12–16 **Model Theory in Geometry and Arithmetic**, Mathematical Sciences Research Institute, Berkeley, California. (June/July 2012, p. 870)

19 **Bers 100 celebration**, City University of New York, Graduate Center New York, New York. (Nov. 2013, p. 1398)

19–22 **SIAM Conference on Optimization (OP14)**, Town and Country Resort & Convention Center, San Diego, California. (Oct. 2013, p. 1203)

19–23 **Finding Algebraic Structures in Extremal Combinatorial Configurations**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Oct. 2013, p. 1203)

* 19–23 **Lie Theory and Mathematical Physics**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, Montréal (Québec), Canada.
Description: There has always been a close and extremely fruitful interaction between Lie theory and mathematical physics—an old example is Gell-Mann's flavour symmetry using the representation theory of the Lie algebra su_3. But this interaction has clearly deepened and blossomed significantly with the arrival of string theory.
Information: http://www.crm.umontreal.ca/2014/Lie14/index_e.php.

19–23 **Representations of reductive groups: A conference dedicated to David Vogan on his 60th birthday**, MIT, Cambridge, Massachusetts. (Sept. 2013, p. 1109)

20–22 **Sixth Iberoamerican congress on geometry**, City University of New York, Graduate Center New York, New York. (Nov. 2013, p.1398)

22–25 **13th Serbian Mathematical Congress**, Vrnjacka Banja, Serbia. (Oct. 2013, p. 1203)

* 23–June 1 **GEAR Junior Retreat**, University of Michigan, Ann Arbor, Michigan.
Description: The GEAR Junior Retreat is designed is to build bridges between the different interest groups in the GEAR network—and more broadly among mathematicians working in areas relating to geometric structures and representation varieties. The meeting is mainly aimed at Ph.D. students and recent post-docs, and during the ten days the following themes will be featured: 1. Dynamics on Moduli Spaces, Geometric and Analytical Group Theory 3, Geometric Structures and Teichmüller spaces, Higgs bundles, Hyperbolic 3-manifolds.
Information: `http://www.math.uiuc.edu/~schapos/Junior_Retreat.html`.

25–28 **XVIII Geometrical Seminar**, Vrnjačka Banja, Serbia. (Oct. 2013, p. 1203)

26–29 **VI Workshop on Dynamical Systems: On the occasion of Marco Antonio Teixeira's 70th birthday (MAT70)**, Campinas, SP, Brazil. (Sept. 2013, p. 1109)

26–30 **Constructive Functions 2014**, Vanderbilt University, Nashville, Tennessee. (May 2013, p. 655)

27–30 **International Conference on Nonlinear Differential and Difference Equations: Recent Developments and Applications**, Side, Antalya, Turkey. (Nov. 2013, p. 1398)

28–30 **IWCIA 2014 – 16th International Workshop on Combinatorial Image Analysis**, Brno University of Technology, Technická 2, Brno, Czech Republic. (Sept. 2013, p. 1110)

* 28–30 **Recent Trends in Nonlinear Partial Differential Equations and Applications**, University of Trieste, Trieste, Italy.
Description: The purpose of this conference is to celebrate the 60th birthday of Enzo Mitidieri. In this occasion, some collaborators and friends of Enzo will report on recent research developments, in particular in different fields of Nonlinear Differential Equations.
Information: `http://npde2014.units.it/`.

June 2014

2–6 **Computational Nonlinear Algebra**, Institute for Computational and Experimental Research in Mathematics, (ICERM), Brown University, Providence, Rhode Island. (Nov. 2013, p. 1398)

* 2–6 **Discrete Groups and Geometric Structures, with Applications V**, KU Leuven, Arenberg Castle, Heverlee (nearby Leuven), Belgium.
Description: This is the 7th edition of a conference series which started in 1996. Main topics include (non-exhaustively) geometric group theory, $\mathrm{Out}(F_n)$ and $\mathrm{Aut}(F_n)$, groups acting on manifolds, crystallographic groups and their generalisations, affine and nil-affine structures for groups, left-symmetric structures on Lie algebras, problems related to these topics in different settings.
Main invited speakers: include Mladen Bestvina, Emmanuel Breuillard, Martin Bridson, Danny Calegari, Serge Cantat, Karen Vogtmann, Dan Wise. The program will be set up to include lectures by participants, as well as short communications. We welcome in particular Ph.D. students and post-doc researchers.
Information: `http://www.kuleuven-kulak.be/workshop`.

3–6 **Moduli - Operads - Dynamics II**, Tallinn University of Technology, Tallinn, Estonia. (Oct. 2013, p. 1203)

9–13 **AIM Workshop: The Cauchy-Riemann equations in several variables**, American Institute of Mathematics, Palo Alto, California. (Sept. 2013, p. 1110)

* 5–7 **Number Theory at Illinois: A Conference in Honor of the Batemans**, University of Illinois, Urbana, Illinois.
Description: A Number Theory Conference in memory of Paul and Felice Bateman will be held at the University of Illinois. The Batemans were long-time members of the faculty and Paul was department head for 14 years. Paul was a member of the American Mathematical Society for 71 years and among his other services, was a Trustee of the AMS. This meeting continues a long tradition of number theory conferences at Illinois.
Invited talks: There will be twenty invited talks as well as opportunities for contributed talks. These will cover a broad spectrum of number theory, representing Paul's many interests. A banquet will be held on June 6. There will be a refereed proceedings volume of conference talks. The conference will be preceded by the Midwest Number Theory Conference for Graduate Students, June 3–4, 2014 (which is being announced separately).
Information: `http://www.math.illinois.edu/nt2014`.

* 9–13 **Categorification and Geometric Representation Theory**, Centre de recherches mathématiques, Université de Montréal, Pavillon André-Aisenstadt, Montréal (Québec), Canada.
Description: Categorification and geometric representation theory are two of the most active and exciting branches of modern representation theory and are gradually increasing their importance in the field. These approaches have led to the introduction of new and powerful tools and a deeper understanding of underlying structures.
Information: `http://www.crm.umontreal.ca/2014/Categorification14/index_e.php`.

9–13 **String Math 2014**, University of Alberta, Edmonton, Alberta, Canada. (Sept. 2013, p. 1110)

9–13 **Tenth edition of the Advanced Course in Operator Theory and Complex Analysis**, Sevilla, Spain. (Sept. 2013, p. 1110)

9–July 4 **Interactions between Dynamics of Group Actions and Number Theory**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Sept. 2013, p. 1110)

10–13 **Geometry of Banach Spaces - A conference in honor of Stanimir Troyanski**, Albacete, Spain. (Nov. 2013, p. 1398)

12–14 **Riemann, topology and physics**, Institut de Recherche Mathematique Avancee, University of Strasbourg, Strasbourg, France. (Oct. 2013, p. 1203)

15–20 **4th European Seminar on Computing (ESCO 2014)**, Pilsen, Czech Republic. (Nov. 2013, p. 1398)

16–19 **8th Annual International Conference on Mathematics & Computer Science**, Athens, Greece. (Oct. 2013, p. 1204)

16–27 **Summer Graduate School: Dispersive Partial Differential Equations**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2013, p. 1399)

21–August 3 **MSRI-UP 2014: Arithmetic Aspects of Elementary Functions**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2013, p. 1399)

23–25 **17th Conference on Integer Programming and Combinatorial Optimization (IPCO 2014)**, University of Bonn, Bonn, Germany. (Sept. 2013, p. 1110)

23–27 **Boltzmann, Vlasov and related equations: Last results and open problems**, University of Cartagena, Cartagena, Colombia. (Nov. 2013, p. 1399)

* 23–27 **Microlocal analysis and applications**, Université de Nice Sophia Antipolis, Nice, France.
Description: This conference is organized for the sixtieth birthday of Gilles Lebeau. It is devoted to microlocal analysis and its applications to a number of topics in the analysis of PDEs, among which are Control of PDEs, Spectral theory and semi-classical analysis, Nonlinear dispersive PDEs, Microlocal analysis and Geometry.
Information: `http://math.unice.fr/MAA2014/`.

23–27 **What Next? The mathematical legacy of Bill Thurston**, Cornell University, Ithaca, New York. (Sept. 2013, p. 1110)

23–28 **6th International Conference on Advanced Computational Methods in Engineering**, NH Gent Belfort, Gent, Belgium. (Sept. 2013, p. 1110)

29–July 3 **26th International Conference on Formal Power Series and Algebraic Combinatorics (FPSAC)**, DePaul University, Chicago, Illinois. (Sept. 2013, p. 1110)

July 2014

7–11 **10th AIMS Conference on Dynamical Systems, Differential Equations and Applications**, Universidad Autónoma de Madrid, Madrid, Spain. (Sept. 2013, p. 1111)

* 7–11 **Conferences on Intelligent Computer Mathematics, CICM 2014**, University of Coimbra, Coimbra, Portugal.
Description: As computers and communications technology advance, greater opportunities arise for intelligent mathematical computation. While computer algebra, automated deduction, mathematical publishing and novel user interfaces individually have long and successful histories, we are now seeing increasing opportunities for synergy among these areas.
Organizer: The conference is organized by Pedro Quaresma, takes place at University of Coimbra and consists of four tracks. Track A: Calculemus (chair: James Davenport). Track B: Digital Mathematical Libraries (DML) (chair: Petr Sojka). Track C: Mathematical Knowledge Management (MKM) (chair: Josef Urban). Track D: Systems & Projects (chair: Alan Sexton). The overall programme is organized by the General Program Chair Stephen Watt. The publicity chair is Serge Autexier.
Information: `http://cicm-conference.org/2014/cicm.php`.

7–18 **Summer Graduate School: Stochastic Partial Differential Equations**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2013, p. 1399)

7–August 29 **The Geometry, Topology and Physics of Moduli Spaces of Higgs Bundles**, Institute for Mathematical Sciences, National University of Singapore, Singapore. (Nov. 2013, p. 1399)

* 8–11 **2014 World Conference on Natural Resource Modeling**, Vilnius University, Vilnius, Lithuania.
Description: The Resource Modeling Association is an international body of scientists working at the intersection of mathematical modeling, environmental science, and natural resource management. Its annual meetings provide a platform for genuine interdisciplinary communication and networking. Our theme for the conference is "Modelling our way back to the future" and what better way to go back to the future than to be transported back in time in the ancient city of Vilnius (ca 1009 AD) with its narrow cobbled streets weaving among buildings of Gothic, Renaissance, and Baroque styles. Delegates will sit amidst the architectural splendour of Vilnius University, a scholarly institution established in 1579, whilst engaging in dialogue with colleagues from around the globe about how we can pave the way for natural resource modeling to have relevance and practical application in a future world increasingly challenged by climatic change and rising consumption from an expanding human population.
Information: `http://www.resourcemodellingconference2014.com`.

* 9–11 **10th International Workshop on Automated Deduction in Geometry, ADG 2014**, University of Coimbra, Coimbra, Portugal.
Description: ADG (Automated Deduction in Geometry) is a forum dedicated to the exchange of ideas and views, to the presentation of research results and progress, and to the demonstration of software tools on the intersection between geometry and automated deduction. ADG organizes a workshop every two years. The previous editions were held in Edinburgh (UK) 2012, Munich (Germany) 2010, Shangha (China) 2008, Pontevedra (Spain) 2006, Gainesville (USA) 2004, Linz (Austria) 2002, Zurich (Switzerland) 2000, Beijing (China) 1998, and Toulouse (France) 1996.
Information: `http://www.uc.pt/en/congressos/adg/adg2014/`.

* 9–12 **Applications of Computer Algebra, ACA 2014**, Fordham University, New York, New York.
Description: This conference is an annual meeting, devoted to promoting the applications and development of Computer Algebra and Symbolic Computation. Topics include computer algebra and symbolic computation in engineering, the sciences, medicine, pure and applied mathematics, education, communication and computer science.
Organizers: Robert H. Lewis, Tony Shaska, Illias Kotsireas.
Information: `http://faculty.fordham.edu/rlewis/aca2014/`.

13–15 **8th International Conference on Modelling in Industrial Maintenance and Reliability (MIMAR)**, St. Catherine's, Oxford, United Kingdom. (Oct. 2013, p. 1204)

14–18 **AIM Workshop: Mori program for Brauer log pairs in dimension three**, American Institute of Mathematics, Palo Alto, California. (Sept. 2013, p. 1111)

14–18 **The 30th International Colloquium on Group Theoretical Methods in Physics**, Ghent University, Ghent, Belgium. (Sept. 2013, p. 1111)

14–August 8 **Theory of Water Waves**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Sept. 2013, p. 1111)

20–25 **Sixteenth International Conference on Fibonacci Numbers and Their Applications**, Rochester Institute of Technology, Rochester, New York. (Oct. 2013, p. 1204)

21–25 **Geometric and Asymptotic Group Theory with Applications (GAGTA)**, The University of Newcastle, Australia.

21–August 15 **Quantum Control Engineering: Mathematical Principles and Applications**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Sept. 2013, p. 1111)

* 23–25 **International Symposium on Symbolic and Algebraic Computation (ISSAC 2014)**, Kobe University, Japan.
Description: The International Symposium on Symbolic and Algebraic Computation is the premier conference for research in symbolic computation and computer algebra. ISSAC 2014 is the 39th meeting in the series. The conference presents a range of invited speakers, tutorials, poster sessions and software demonstrations with a centre-piece of contributed original research papers. The topics include algorithmic aspects (exact and symbolic linear, polynomial and differential algebra, symbolic-numeric, homotopy, perturbation and series methods, computational algebraic geometry, group theory and number theory, computer arithmetic, summation, recurrence equations, integration, solution of ODEs & PDEs, complexity of algebraic algorithms and algebraic complexity), software aspects (design of symbolic computation packages and systems, language design and type systems for symbolic computation, data representation, considerations).
Information: `http://www.issac-conference.org/2014`.

28–August 8 **Summer Graduate School: Geometry and Analysis**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2013, p. 1399)

August 2014

4–9 **10th International Conference on Clifford Algebras and their Applications in Mathematical Physics (ICCA10)**, University of Tartu, Tartu, Estonia. (Sept. 2013, p. 1111)

11–14 **SIAM Conference on Nonlinear Waves and Coherent Structures (NW14)**, Churchill College, University of Cambridge, Cambridge, United Kingdom. (Sept. 2013, p. 1111)

11–15 **AIM Workshop: Neglected infectious diseases**, American Institute of Mathematics, Palo Alto, California. (Oct. 2013, p. 1204)

11–December 12 **New geometric methods in number theory and automorphic forms**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2013, p. 1111)

11–December 19 **Understanding Microbial Communities; Function, Structure and Dynamics**, Isaac Newton Institute, Cambridge, United Kingdom. (Oct. 2013, p. 1204)

14–15 **Connections for Women: New Geometric Methods in Number Theory and Automorphic Forms**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2013, p. 1111)

18–December 19 **Geometric Representation Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2013, p. 1111)

September 2014

1–December 19 **Trimester program on Non-commutative Geometry and its Applications**, Hausdorff Research Institute for Mathematics, Bonn, Germany. (Nov. 2013, p. 1399)

2–5 **Introductory Workshop: Geometric Representation Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2013, p. 1112)

2–7 **12th AHA Conference-Algebraic Hyperstructures and its Applications**, Democritus University of Thrace, School of Engineering, Department of Production and Management Engineering 67100, Xanthi, Greece International Algebraic Hyperstructures Association (IAHA). (Oct. 2013, p. 1204)

8–December 12 **Mathematics of Turbulence**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Oct. 2013, p. 1204)

18–20 **Riemann, Einstein and geometry**, Institut de Recherche Mathématique Avancée, University of Strasbourg, France. (Oct. 2013, p. 1204)

20–21 **Sectional Meeting**, University of Wisconsin-Eau Claire, Eau Claire, Wisconsin. (Sept. 2013, p. 1112)

* 21–26 **12th International Conference of The Mathematics Education into the 21st Century Project: The Future of Mathematics Education in a Connected World**, Hunguest Hotel Sun Resort, Herceg Novi, Montenegro.
Description: This long running series of conferences (since 1999) brings together many innovative movers and shakers from around the world, and is renowned for its friendly and productive atmosphere. We now welcome proposals for papers and workshops in all areas of innovation in mathematics, science, computing and statistics education. There will be four working days including a half day excursion to the nearby UNESCO World Heritage old town of Dubrovnik. The hotel is in a beautiful bay on the Balkan Adriatic coast and is easily accessible from Dubrovnik and Tivot airports.
Information: `http://www.hunguesthotels.hu/en/hotel/herceg_novi/hunguest_hotel_sun_resort/`.

October 2014

18–19 **Sectional Meeting**, Dalhousie University, Halifax, Canada. (Sept. 2013, p. 1112)

23–26 **Ahlfors-Bers Colloquium VI**, Yale University, New Haven, Connecticut. (Oct. 2013, p. 1204)

25–26 **Sectional Meeting**, San Francisco State University, San Francisco, California. (Sept. 2013, p. 1112)

November 2014

8–9 **Sectional Meeting**, University of North Carolina, Greensboro, North Carolina. (Sept. 2013, p. 1112)

11–January 25 **Inverse Moment Problems: The Crossroads of Analysis, Algebra, Discrete Geometry and Combinatorics**, Institute for Mathematical Sciences, National University of Singapore, Singapore. (Sept. 2013, p. 1112)

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

December 2014

* 9–19 **Recent Advances in Operator Theory and Operator Algebras-2014**, Bangalore, India.
Description: This conference is a continuation of the earlier conferences and workshops on operator theory and operator algebras held in Indian Statistical Institute, Bangalore. The main goal of the workshop and the conference is to bring together the leading worldwide experts and young researchers, including postdocs and advanced doctoral students working in operator theory, operator algebra and related topics. The topics of interest include, but are not limited to: operator algebras, operator theory, function theory, multivariable operator theory, free probability, groups and dynamical system. The meeting will start with a workshop December 9–13, 2014, followed by a conference December 15–19, 2014. The purpose of the workshop is to bring experts and students as well as researchers together to discuss the most recent developments
Information: `http://www.isibang.ac.in/~jay/OTOA2014/OTOA14.html`.

July 2015

* 20–24 **The 11th International Conference on Fixed Point Theory and its Applications**, Galatasaray University, Istanbul, Turkey.
Description: The purpose of the conference is to bring together leading experts and researchers in fixed point theory and to assess new developments, ideas and methods in this important and dynamic field. A special emphasis will be put on applications in related areas, as well as other sciences, such as the natural sciences, medicine, economics and engineering. The conference will continue the tradition of the previous fixed point theory meetings which were held in Marseille (1989), Halifax (1991), Seville (1995), Kazimierz Dolny (1997), Haifa (2001), Valencia (2003), Guanajuato (2005), Chiang Mai (2007), Changhua (2009) and Cluj-Napoca (2012).
Information: `http://www.icfpta.org/`.

September 2015

* 14–18 **The European Numerical Mathematics and Advanced Applications (ENUMATH) Conference**, Institute of Applied Mathematics, Middle East Technical University, Ankara, Turkey.
Description: The European Numerical Mathematics and Advanced Applications (ENUMATH) conferences are a forum for discussion of basic aspects and new trends in numerical mathematics and challenging scientific and industrial applications on the highest level of international expertise. They started in Paris in 1995 and were subsequently held at the universities of Heidelberg (1997), Jyvaskyla (1999), Ischia Porto (2001), Prague (2003), Santiago de Compostela (2005), Graz (2007), Uppsala (2009), Leicester (2011), Lausanne (2013).
Information: `http://enumath2015.iam.metu.edu.tr/`.

About the Cover

Binomial coefficients in *Al-Bāhir fī Al-jabr*

This month's cover was taken from the book review by Clemency Montelle (page 1459, this issue). It shows a page from the manuscript Ayasofya 2718, which is now held at the Suleymaniye Library in Istanbul. She and her colleague John Hannah tell us,

> This table of binomial coefficients is from a manuscript copy dated 1324 of a work by Islamic mathematician al-Samaw'al (b. ca. 1130) which he wrote at the prodigious age of 19. The work, entitled *Al-Bāhir fī Al-Jabr*, literally the Splendid Book of Algebra, contains a key passage in which al-Samaw'al demonstrates the identity which we would capture nowadays as $(ab)^n = a^n b^n$ for the cases $n = 3, 4$ but using a form of rhetorical (non-symbolic) algebra. After this he computes the expansion of the binomial $(a + b)^n$ for the same values of n and outlines the construction of a triangle of binomial coefficients, better known today as the Pascal triangle, up to its 12th row. He credits this to his predecessor al-Karajī. In addition, several statements al-Samaw'al makes in this passage point to the recognition of an early form of mathematical induction.
>
> Using the following dictionary of Arabic numerals and their European equivalents
>
> ٠ ١ ٢ ٣ ٤ ٥ ٦ ٧ ٨ ٩
> 0 1 2 3 4 5 6 7 8 9
>
> in the Hindu-Arabic place value system of numeration, the table can be transcribed as follows (preserving the right to left orientation of the Arabic original):

1	1	1	1	1	1	1	1	1	1	1	1
12	11	10	9	8	7	6	5	4	3	2	1
66	55	45	36	28	21	15	10	6	3	1	
220	165	120	84	56	35	20	10	4	1		
495	330	210	126	70	35	15	5	1			
792	462	252	126	56	21	6	1				
924	462	210	84	28	7	1					
792	330	120	36	8	1						
495	165	45	9	1							
220	55	10	1								
66	11	1									
12	1										
1											

> Al-Samaw'al carefully describes how to construct the triangle from scratch. The following excerpt contains his instructions for how to construct the first three columns and the corresponding binomial expansions: "…on a board you place one and one below it. Then move the (first) one into another column and add the (first) one to the one below it, then there is two. Place it under it. Then you place the last one below it. Then there results one and two and one. This shows you that for every number combined from two numbers, if you multiply each of them by itself once, since the two ends are one and one, and if you multiply one of them by the other twice, since the middle term is two, there results the square of that number. Then we move the one from the second column to another column, and we add the one to the two. There results three and we write it under the one. We add the two to the one below it, then we obtain three. We write it below the three. [Then we place the last one below it.] There results from this the third column, which is, individually: one and three and three and one. This teaches you that the cube of any number combined from two numbers is the cube of each of them and the product of each of them by the square of the other taken three times …"

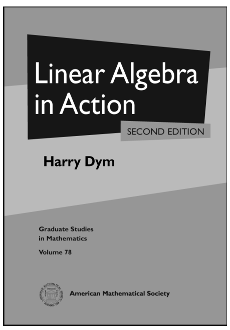
We thank the Türkiye Yazma Eserler Kurumu Başkanliği (Presidency of Turkey Manuscripts Institution) for supplying the image and for giving us permission to use it. We particularly thank Ferruh Ozpilavci, the head of the Publishing and Translation Department, for his help.

—Bill Casselman
Graphics Editor
(notices-covers@ams.org)

New Publications Offered by the AMS

To subscribe to email notification of new AMS publications, please go to http://www.ams.org/bookstore-email.

Algebra and Algebraic Geometry



Linear Algebra in Action

Second Edition

Harry Dym, *Weizmann Institute of Science, Rehovot, Israel*

It is a wonderful book: very accessible and rigorous [at] the same time, containing basic and not-so-basic facts, discussing many (sometimes unexpected) applications... Given that and the wonderful way this book was written and organized, I think it can be used by many readers: engineering students, mathematics students, research mathematicians, and researchers in any other field where linear algebra is applied. I strongly recommend this book to anyone interested in "working" linear algebra.

—***MAA Reviews***

Linear algebra permeates mathematics, perhaps more so than any other single subject. It plays an essential role in pure and applied mathematics, statistics, computer science, and many aspects of physics and engineering. This book conveys in a user-friendly way the basic and advanced techniques of linear algebra from the point of view of a working analyst. The techniques are illustrated by a wide sample of applications and examples that are chosen to highlight the tools of the trade. In short, this is material that many of us wish we had been taught as graduate students.

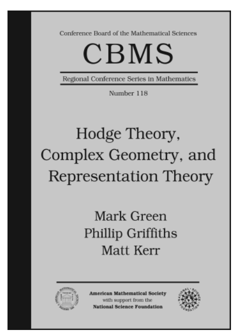
Roughly the first third of the book covers the basic material of a first course in linear algebra. The remaining chapters are devoted to applications drawn from vector calculus, numerical analysis, control theory, complex analysis, convexity and functional analysis. In particular, fixed point theorems, extremal problems, matrix equations, zero location and eigenvalue location problems, and matrices with nonnegative entries are discussed. Appendices on useful facts from analysis and supplementary information from complex function theory are also provided for the convenience of the reader.

In this new edition, most of the chapters in the first edition have been revised, some extensively. The revisions include changes in a number of proofs, either to simplify the argument, to make the logic clearer or, on occasion, to sharpen the result. New introductory sections on linear programming, extreme points for polyhedra and a Nevanlinna-Pick interpolation problem have been added, as have some very short introductory sections on the mathematics behind Google, Drazin inverses, band inverses and applications of SVD together with a number of new exercises.

Contents: Vector spaces; Gaussian elimination; Additional applications of Gaussian elimination; Eigenvalues and eigenvectors; Determinants; Calculating Jordan forms; Normed linear spaces; Inner product spaces and orthogonality; Symmetric, Hermitian and normal matrices; Singular values and related inequalities; Pseudoinverses; Triangular factorization and positive definite matrices; Difference equations and differential equations; Vector valued functions; The implicit function theorem; Extremal problems; Matrix valued holomorphic functions; Matrix equations; Realization theory; Eigenvalue location problems; Zero location problems; Convexity; Matrices with nonnegative entries; Appendix A. Some facts from analysis; Appendix B. More complex variables; Bibliography; Notation index; Subject index.

Graduate Studies in Mathematics, Volume 78

February 2014, approximately 607 pages, Hardcover, ISBN: 978-1-4704-0908-1, LC 2013029538, 2010 *Mathematics Subject Classification:* 15-01, 30-01, 34-01, 39-01, 52-01, 93-01, **AMS members US$72.80**, List US$91, Order code GSM/78.R



Hodge Theory, Complex Geometry, and Representation Theory

Mark Green, *University of California, Los Angeles, CA*, **Phillip Griffiths**, *Institute of Advanced Study, Princeton, NJ*, and **Matt Kerr**, *Washington University, St. Louis, MO*

This monograph presents topics in Hodge theory and representation theory, two of the most active and important areas in contemporary mathematics. The underlying theme is the use of complex geometry to understand the two subjects and their relationships to one another—an approach that is complementary to what is in the literature. Finite-dimensional representation theory and complex geometry enter via the concept of Hodge representations and Hodge domains. Infinite-dimensional representation theory, specifically the discrete series and their limits, enters through the realization of these representations through complex geometry as pioneered by Schmid, and in the subsequent description of automorphic cohomology. For the latter topic, of particular importance is the recent work of Carayol that potentially introduces a new perspective in arithmetic automorphic representation theory.

The present work gives a treatment of Carayol's work, and some extensions of it, set in a general complex geometric framework.

Additional subjects include a description of the relationship between limiting mixed Hodge structures and the boundary orbit structure of Hodge domains, a general treatment of the correspondence spaces that are used to construct Penrose transforms, and selected other topics from the recent literature.

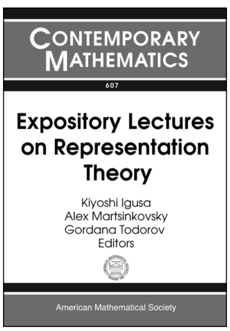
This item will also be of interest to those working in geometry and topology.

A co-publication of the AMS and CBMS.

Contents: The classical theory: Part I; The classical theory: Part II; Polarized Hodge structures and Mumford-Tate groups and domains; Hodge representations and Hodge domains; Discrete series and $\mathfrak{n}$-cohomology; Geometry of flag domains: Part 1; Geometry of flag domains: Part II; Penrose transforms in the two main examples; Automorphic cohomology; Miscellaneous topics and some questions; Bibliography; Index; Notations used in the talks.

CBMS Regional Conference Series in Mathematics, Number 118

December 2013, approximately 305 pages, Softcover, ISBN: 978-1-4704-1012-4, 2010 *Mathematics Subject Classification:* 14M15, 17B56, 22D10, 32G20, 32M10; 14D07, 14M17, 17B45, 20G99, 22E45, 22E46, 22F30, 32N10, 32L25, 32Q28, 53C30, **All Individuals US$52**, List US$65, Institutional member US$52, Order code CBMS/118



Expository Lectures on Representation Theory

Kiyoshi Igusa, *Brandeis University, Waltham, MA*, and **Alex Martsinkovsky** and **Gordana Todorov**, *Northeastern University, Boston, MA*, Editors

This volume contains the proceedings of the Maurice Auslander Distinguished Lectures and International Conference, held April 25–30, 2012, in Falmouth, MA.

The representation theory of finite dimensional algebras and related topics, especially cluster combinatorics, is a very active topic of research. This volume contains papers covering both the history and the latest developments in this topic. In particular, Otto Kerner gives a review of basic theorems and latest results about wild hereditary algebras, Yuri Berest develops the theory of derived representation schemes, and Markus Schmidmeier presents new applications of arc diagrams.

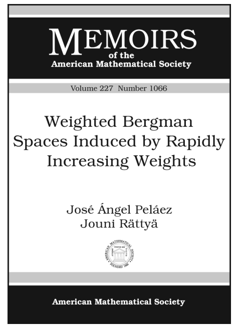
This item will also be of interest to those working in discrete mathematics and combinatorics.

Contents: B. Huisgen-Zimmermann, Fine and coarse moduli spaces in the representation theory of finite dimensional algebras; **O. Kerner**, More representations of wild quivers; **I. Herzog**, Phantom morphisms and Salce's lemma; **K. Yamagata** and **O. Kerner**, Morita theory, revisited; **F. M. Bleher**, Universal deformation rings of group representations, with an application of Brauer's generalized decomposition numbers; **Y. Berest**, **G. Felder**, and **A. Ramadoss**, Derived representation schemes and noncommutative geometry; **A. B. Buan**, Classifying torsion pairs for tame hereditary algebras and tubes; **C. Chaio**, Problems solved by using degrees of irreducible morphisms; **J. Kosakowska** and **M. Schmidmeier**, Arc diagram varieties.

Contemporary Mathematics, Volume 607

February 2014, approximately 227 pages, Softcover, ISBN: 978-0-8218-9140-7, LC 2013030296, 2010 *Mathematics Subject Classification:* 16G10, 16G20, 16G60, 16G70, 20C20, 16W25, 14L30, **AMS members US$71.20**, List US$89, Order code CONM/607

Analysis



Weighted Bergman Spaces Induced by Rapidly Increasing Weights

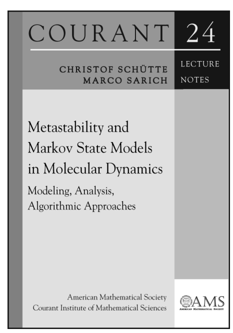
José Ángel Peláez, *Universidad de Málaga, Spain*, and **Jouni Rättyä**, *University of Eastern Finland, Joensuu, Finland*

Contents: Preface; Basic notation and introduction to weights; Description of q-Carleson measures for A^p_ω; Factorization and zeros of functions in A^p_ω; Integral operators and equivalent norms; Non-conformally invariant space induced by T_g on A^p_ω; Schatten classes of the integral operator T_g on A^2_ω; Applications to differential equations; Further discussion; Bibliography; Index.

Memoirs of the American Mathematical Society, Volume 227, Number 1066

January 2014, 124 pages, Softcover, ISBN: 978-0-8218-8802-5, 2010 *Mathematics Subject Classification:* 30H20; 47G10, **Individual member US$46.20**, List US$77, Institutional member US$61.60, Order code MEMO/227/1066

Applications



Metastability and Markov State Models in Molecular Dynamics

Modeling, Analysis, Algorithmic Approaches

Christof Schütte, *Freie Universität Berlin, Germany, and Zuse Institut Berlin, Germany*, and **Marco Sarich**, *Freie Universität Berlin, Germany*

Applications in modern biotechnology and molecular medicine often require simulation of biomolecular systems in atomic representation with immense length and timescales that are far beyond the capacity of computer power currently available. As a consequence, there is an increasing need for reduced models that describe the relevant dynamical properties while at the same time being less complex. In this book the authors exploit the existence of metastable sets for constructing such a reduced molecular dynamics model, the so-called Markov state model (MSM), with good approximation properties on the long timescales.

With its many examples and illustrations, this book is addressed to graduate students, mathematicians, and practical computational scientists wanting an overview of the mathematical background for the ever-increasing research activity on how to construct MSMs for very different molecular systems ranging from peptides to proteins, from RNA to DNA, and via molecular sensors to molecular aggregation. This book bridges the gap between mathematical research on molecular dynamics and its practical use for realistic molecular systems by providing readers with tools for performing in-depth analysis of simulation and data-analysis methods.

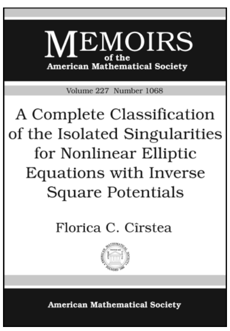
Titles in this series are co-published with the Courant Institute of Mathematical Sciences at New York University.

Contents: Transfer operator approach to conformation dynamics; Dynamics; Metastability; Transfer operators and generators; Projected transfer operators; Transition path theory; Concluding remarks; Some mathematical aspects of transfer operators; Definition of exit rates; Bibliography.

Courant Lecture Notes, Volume 24

January 2014, approximately 133 pages, Softcover, ISBN: 978-0-8218-4359-8, 2010 *Mathematics Subject Classification:* 60J20, 60-08, 47D07, 60J70, 92-08, **AMS members US$27.20**, List US$34, Order code CLN/24

Differential Equations



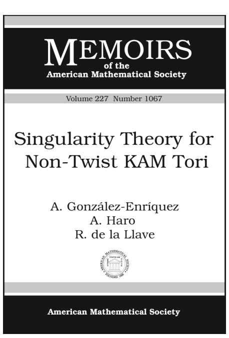
A Complete Classification of the Isolated Singularities for Nonlinear Elliptic Equations with Inverse Square Potentials

Florica C. Cîrstea, *University of Sydney, Australia*

Contents: Introduction; Main results; Radial solutions in the power case; Basic ingredients; The analysis for the subcritical parameter; The analysis for the critical parameter; Illustration of our results; Appendix A. Regular variation theory and related results; Bibliography.

Memoirs of the American Mathematical Society, Volume 227, Number 1068

January 2014, 85 pages, Softcover, ISBN: 978-0-8218-9022-6, 2010 *Mathematics Subject Classification:* 35J60, 35B40; 35J25, 35B33, **Individual member US$42.60**, List US$71, Institutional member US$56.80, Order code MEMO/227/1068



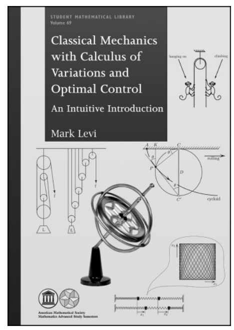
Singularity Theory for Non-Twist KAM Tori

A. González-Enríquez and **A. Haro**, *Universitat de Barcelona, Spain*, and **R. de la Llave**, *Georgia Institute of Technology, Atlanta, GA*

Contents: *Part 1: Introduction and preliminaries:* Introduction; Preliminaries; *Part 2: Geometrical properties of KAM invariant tori:* Geometric properties of an invariant torus; Geometric properties of fibered Lagrangian deformations; *Part 3: KAM results:* Nondegeneracy on a KAM procedure with fixed frequency; A KAM theorem for symplectic deformations; A Transformed Tori Theorem; *Part 4: Singularity theory for KAM tori:* Bifurcation theory for KAM tori; The close-to-integrable case; *Appendices:* Appendix A. Hamiltonian vector fields; Appendix B. Elements of singularity theory; Bibliography.

Memoirs of the American Mathematical Society, Volume 227, Number 1067

January 2014, 115 pages, Softcover, ISBN: 978-0-8218-9018-9, 2010 *Mathematics Subject Classification:* 37J20, 37J40, **Individual member US$45.60**, List US$76, Institutional member US$60.80, Order code MEMO/227/1067



Classical Mechanics with Calculus of Variations and Optimal Control

An Intuitive Introduction

Mark Levi, *Pennsylvania State University, University Park, PA*

This is an intuitively motivated presentation of many topics in classical mechanics and related areas of control theory and calculus of variations. All topics throughout the book are treated with zero tolerance for unrevealing definitions and for proofs which leave the reader in the dark.

Some areas of particular interest are: an extremely short derivation of the ellipticity of planetary orbits; a statement and an explanation of the "tennis racket paradox"; a heuristic explanation (and a rigorous treatment) of the gyroscopic effect; a revealing equivalence between the dynamics of a particle and statics of a spring; a short geometrical explanation of Pontryagin's Maximum Principle, and more.

In the last couple of chapters, aimed at more advanced readers, the Hamiltonian and the momentum are compared to forces in a certain static problem. This gives a palpable physical meaning to some seemingly abstract concepts and theorems. With minimal prerequisites consisting of basic calculus and basic undergraduate physics, this book is suitable for courses from an undergraduate to a beginning graduate level, and for a mixed audience of mathematics, physics and engineering students. Much of the enjoyment of the subject lies in solving almost 200 problems in this book.

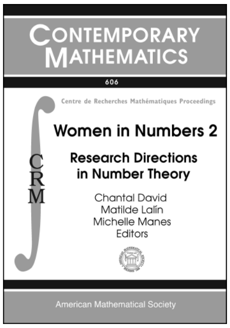
This item will also be of interest to those working in mathematical physics.

Contents: One degree of freedom; More degrees of freedom; Rigid body motion; Variational principles of mechanics; Classical problems of calculus of variations; The conditions of Legendre and Jacobi for a minimum; Optimal control; Heuristic foundations of Hamiltonian mechanics; Bibliography; Index.

Student Mathematical Library, Volume 69

February 2014, approximately 316 pages, Softcover, ISBN: 978-0-8218-9138-4, LC 2013030550, 2010 *Mathematics Subject Classification:* 34-XX, 37-XX, 49-XX, 70-XX, 00A07, **AMS members US$33.60**, List US$42, Order code STML/69

Number Theory



Women in Numbers 2

Research Directions in Number Theory

Chantal David, *Concordia University, Montreal, Quebec, Canada*, **Matilde Lalín**, *University of Montreal, Quebec, Canada*, and **Michelle Manes**, *University of Hawaii, Honolulu, HI*, Editors

The second Women in Numbers workshop (WIN2) was held November 6–11, 2011, at the Banff International Research Station (BIRS) in Banff, Alberta, Canada. During the workshop, group leaders presented open problems in various areas of number theory, and working groups tackled those problems in collaborations begun at the workshop and continuing long after.

This volume collects articles written by participants of WIN2. Survey papers written by project leaders are designed to introduce areas of active research in number theory to advanced graduate students and recent PhDs. Original research articles by the project groups detail their work on the open problems tackled during and after WIN2. Other articles in this volume contain new research on related topics by women number theorists.

The articles collected here encompass a wide range of topics in number theory, including Galois representations, the Tamagawa number conjecture, arithmetic intersection formulas, Mahler measures, Newton polygons, the Dwork family, elliptic curves, cryptography, and supercongruences.

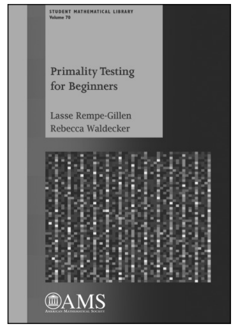
WIN2 and this proceedings volume are part of the Women in Numbers network, aimed at increasing the visibility of women researchers' contributions to number theory and at increasing the participation of women mathematicians in number theory and related fields.

This book is co-published with the Centre de Recherches Mathématiques.

Contents: J. Johnson-Leung, The local equivariant Tamagawa number conjecture for almost abelian extensions; **R. Davis**, Images of metabelian Galois representations associated to elliptic curves; **R. Bellovin**, **S. A. Garthwaite**, **E. Ozman**, **R. Pries**, **C. Williams**, and **H. J. Zhu**, Newton polygons for a variant of the Kloosterman family; **J. Anderson**, **J. S. Balakrishnan**, **K. Lauter**, **J. Park**, and **B. Viray**, Comparing arithmetic intersection formulas for denominators of Igusa class polynomials; **A. Salerno**, An algorithmic approach to the Dwork family; **A. Silverberg**, Ranks "cheat sheet"; **A. Silverberg**, Fully homomorphic encryption for mathematicians; **M.-J. Bertin** and **M. Lalín**, Mahler measure of multivariable polynomials; **M.-J. Bertin**, **A. Feaver**, **J. Fuselier**, **M. Lalín**, and **M. Manes**, Mahler measure of some singular $K3$-surfaces; **S. Akhtari**, **C. David**, **H. Hahn**, and **L. Thompson**, Distribution of squarefree values of sequences associated with ellitpic curves; **S. Chisholm**, **A. Deines**, and **H. Swisher**, Recent advances for Ramanujan type supercongruences.

Contemporary Mathematics, Volume 606

January 2014, 206 pages, Softcover, ISBN: 978-1-4704-1022-3, LC 2013027435, 2010 *Mathematics Subject Classification:* 11G05, 11G40, 11N37, 11R06, 11R11, 11T24, 11Y16, 14J28, 33C20, 94A60, **AMS members US$60.80**, List US$76, Order code CONM/606



Primality Testing for Beginners

Lasse Rempe-Gillen, *University of Liverpool, United Kingdom*, and **Rebecca Waldecker**, *Martin-Luther-Universität Halle-Wittenberg, Germany*

How can you tell whether a number is prime? What if the number has hundreds or thousands of digits? This question may seem abstract or irrelevant, but in fact, primality tests are performed every time we make a secure online transaction. In 2002, Agrawal, Kayal, and Saxena answered a long-standing open question in this context by presenting a deterministic test (the AKS algorithm) with polynomial running time that checks whether a number is prime or not. What is more, their methods are essentially elementary, providing us with a unique opportunity to give a complete explanation of a current mathematical breakthrough to a wide audience.

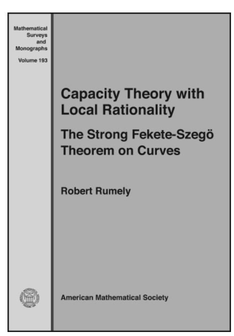
Rempe-Gillen and Waldecker introduce the aspects of number theory, algorithm theory, and cryptography that are relevant for the AKS algorithm and explain in detail why and how this test works. This book is specifically designed to make the reader familiar with the background that is necessary to appreciate the AKS algorithm and begins at a level that is suitable for secondary school students, teachers, and interested amateurs. Throughout the book, the reader becomes involved in the topic by means of numerous exercises.

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

Contents: Introduction; *Foundations:* Natural numbers and primes; Algorithms and complexity; Foundations of number theory; Prime numbers and cryptography; *The AKS algorithm:* The starting point: Fermat for polynomials; The theorem for Agrawal, Kayal, and Saxena; The algorithm; Open questions; Solutions and comments to important exercises; Bibliography; List of symbols; Index.

Student Mathematical Library, Volume 70

February 2014, approximately 248 pages, Softcover, ISBN: 978-0-8218-9883-3, LC 2013032423, 2010 *Mathematics Subject Classification:* 11-01, 11-02, 11Axx, 11Y11, 11Y16, **AMS members US$31.20**, List US$39, Order code STML/70



Capacity Theory with Local Rationality

The Strong Fekete-Szegö Theorem on Curves

Robert Rumely, *University of Georgia, Athens, GA*

This book is devoted to the proof of a deep theorem in arithmetic geometry, the Fekete-Szegö theorem with local rationality conditions. The prototype for the theorem is Raphael Robinson's theorem on totally real algebraic integers in an interval, which says that if $[a, b]$ is a real interval of length greater than 4, then it contains infinitely many Galois orbits of algebraic integers, while if its length is less than 4, it contains only finitely many. The theorem shows this phenomenon holds on algebraic curves of arbitrary genus over global fields of any characteristic, and is valid for a broad class of sets.

The book is a sequel to the author's work *Capacity Theory on Algebraic Curves* and contains applications to algebraic integers and units, the Mandelbrot set, elliptic curves, Fermat curves, and modular curves. A long chapter is devoted to examples, including methods for computing capacities. Another chapter contains extensions of the theorem, including variants on Berkovich curves.

The proof uses both algebraic and analytic methods, and draws on arithmetic and algebraic geometry, potential theory, and approximation theory. It introduces new ideas and tools which may be useful in other settings, including the local action of the Jacobian on a curve, the "universal function" of given degree on a curve, the theory of inner capacities and Green's functions, and the construction of near-extremal approximating functions by means of the canonical distance.

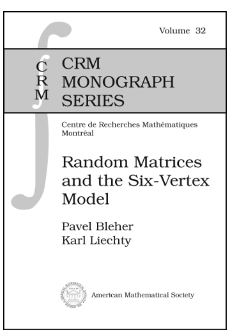
This item will also be of interest to those working in algebra and algebraic geometry and analysis.

Contents: Variants; Examples and applications; Preliminaries; Reductions; Initial approximating functions: Archimedean case; Initial approximating functions: Nonarchimedean case; The global patching construction; Local patching when $K_v \cong \mathbb{C}$; Local patching when $K_v \cong \mathbb{R}$; Local patching for nonarchimedean RL-domains; Local patching for nonarchimedean K_v-simple sets; $(\mathfrak{X}, \vec{s})$-Potential theory; The construction of oscillating pseudopolynomials; The universal function; The local action of the Jacobian; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 193

January 2014, approximately 448 pages, Hardcover, ISBN: 978-1-4704-0980-7, LC 2013034694, 2010 *Mathematics Subject Classification:* 11G30, 14G40, 14G05; 31C15, **AMS members US$95.20**, List US$119, Order code SURV/193

Probability and Statistics



Random Matrices and the Six-Vertex Model

Pavel Bleher, *Indiana University-Purdue University Indianapolis, IN*, and **Karl Liechty**, *University of Michigan, Ann Arbor, MI*

This book provides a detailed description of the Riemann-Hilbert approach (RH approach) to the asymptotic analysis of both continuous and discrete orthogonal polynomials, and applications to random matrix models as well as to the six-vertex model. The RH approach was an important ingredient in the proofs of universality in unitary matrix models. This book gives an introduction to the unitary matrix models and discusses bulk and edge universality. The six-vertex model is an exactly solvable two-dimensional model in statistical physics, and thanks to the Izergin-Korepin formula for the model with domain wall boundary conditions, its partition function matches that of a unitary matrix model with nonpolynomial interaction. The authors introduce in this book the six-vertex model and include a proof of the Izergin-Korepin formula. Using the RH approach, they explicitly calculate the leading and subleading terms in the thermodynamic asymptotic behavior of the partition function of the six-vertex model with domain wall boundary conditions in all the three phases: disordered, ferroelectric, and antiferroelectric.

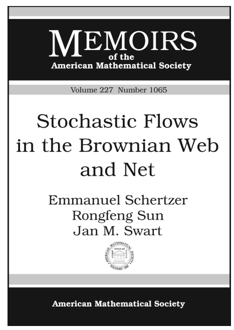
This item will also be of interest to those working in mathematical physics.

Titles in this series are co-published with the Centre de Recherches Mathématiques.

Contents: Unitary matrix ensembles; The Riemann-Hilbert problem for orthogonal polynomials; Discrete orthogonal polynomials on an infinite lattice; Introduction to the six-vertex model; The Izergin-Korepin formula; Disordered phase; Antiferroelectric phase; Ferroelectric phase; Between the phases; Bibliography.

CRM Monograph Series, Volume 32

December 2013, 224 pages, Hardcover, ISBN: 978-1-4704-0961-6, LC 2013032106, 2010 *Mathematics Subject Classification:* 60B20; 82B23, **AMS members US$78.40**, List US$98, Order code CRMM/32



Stochastic Flows in the Brownian Web and Net

Emmanuel Schertzer, *Université Pierre et Marie Curie, Paris, France*, **Rongfeng Sun**, *National University of Singapore, Singapore*, and **Jan M. Swart**, *Academy of Sciences of the Czech Republic, Praha, Czech Republic*

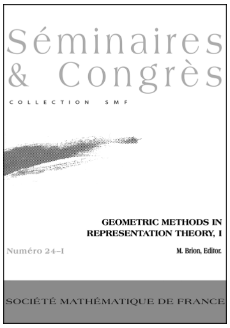
This item will also be of interest to those working in mathematical physics.

Contents: Introduction; Results for Howitt-Warren flows; Construction of Howitt-Warren flows in the Brownian web; Construction of Howitt-Warren flows in the Brownian net; Outline of the proofs; Coupling of the Brownian web and net; Construction and convergence of Howitt-Warren flows; Support properties; Atomic or non-atomic; Infinite starting mass and discrete approximation; Ergodic properties; Appendix A. The Howitt-Warren martingale problem; Appendix B. The Hausdorff topology; Appendix C. Some measurability issues; Appendix D. Thinning and Poissonization; Appendix E. A one-sided version of Kolmogorov's moment criterion; References; Index.

Memoirs of the American Mathematical Society, Volume 227, Number 1065

January 2014, 160 pages, Softcover, ISBN: 978-0-8218-9088-2, LC 2013035390, 2010 *Mathematics Subject Classification:* 82C21; 60K35, 60K37, 60D05, **Individual member US$51.60**, List US$86, Institutional member US$68.80, Order code MEMO/227/1065

New AMS-Distributed Publications



Geometric Methods in Representation Theory I

Michel Brion, *Université Grenoble I, St. Martin d'Heres, France*, Editor

This volume contains the expanded versions of lecture notes and of some seminar talks presented at the 2008 Summer School, Geometric Methods in Representation Theory, which was held in Grenoble, France, from June 16–July 4, 2008. They give an overview of representation theory of quivers, chiefly from a geometric perspective. The methods and results cover a wide range of topics in algebraic geometry (punctual Hilbert schemes, geometric invariant theory, symplectic geometry), representation theory (Hall algebras, Kac-Moody algebras, quantum groups), homological methods (intersection cohomology, equivariant cohomology, derived categories of coherent sheaves).

The lecture notes include introductory texts to fundamental aspects of the domain: quiver representations, punctual Hilbert schemes, Hall algebras, as well as more specialized texts on Nakajima varieties, Haiman's work, moment graphs and representations, canonical and crystal bases of Hall algebras, and representations in Fock spaces. The ten articles cover recent advances in various directions. In view of the diverseness of the topics, the reader is invited to consult the introductions of the texts for detailed overviews of their respective contents.

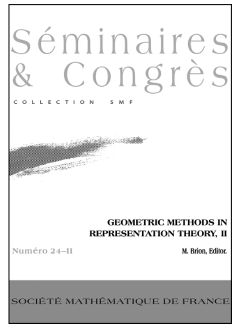
A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: J. Bertin, The punctual Hilbert scheme: An introduction; **M. Brion**, Representations of quivers; **V. Ginzburg**, Lectures on Nakajima's quiver varieties; **I. Gordon**, Haiman's work on the n! theorem, and beyond; **J. C. Jantzen**, Moment graphs and representations; **B. Leclerc**, Fock space representations of $U_q(\widehat{\mathfrak{sl}}_n)$.

Séminaires et Congrès, Number 24

April 2013, 361 pages, Softcover, ISBN: 978-2-85629-356-0, 2010 *Mathematics Subject Classification:* 14E16, 14L24, 16G20, 17B63, 17B67, 53D20, **AMS members US$84**, List US$105, Order code SECO/24.1

Algebra and Algebraic Geometry



Geometric Methods in Representation Theory II

Michel Brion, *Université Grenoble I, St. Martin d'Heres, France*, Editor

This second volume contains expanded versions of lecture notes for O. Schiffman's course, as well as ten research or survey articles, presented at the 2008 Summer School, Geometric Methods in Representation Theory (Grenoble, France, June 16–July 4, 2008).

These texts give an overview of the representation theory of quivers, chiefly from a geometric perspective. The methods and results cover a wide range of mathematical domains: algebra and representation theory (Hall algebras, canonical and crystal bases, cluster categories, modular representations), algebraic geometry (flag varieties, moduli spaces, symplectic singularities), and homological methods (perverse sheaves, exceptional collections). In view of the diverseness of the topics, the reader is invited to consult the introductions of the texts for detailed overviews of their respective contents.

This item will also be of interest to those working in discrete mathematics and combinatorics.

A publication of the Société Mathématique de France, Marseilles (SMF), distributed by the AMS in the U.S., Canada, and Mexico. Orders from other countries should be sent to the SMF. Members of the SMF receive a 30% discount from list.

Contents: O. Schiffmann, Lectures on Hall algebras; **O. Schiffmann**, Lectures on canonical and crystal bases of Hall algebras; **K. Baur**, Cluster categories, m-cluster categories and diagonals in polygons; **A. Boralevi**, On simplicity and stability of the tangent bundle of rational homogeneous varieties; **L. Evain**, Intersection theory on punctual Hilbert schemes and graded Hilbert schemes; **D. Juteau**, **C. Mautner**, and **G. Williamson**, Perverse sheaves and modular representation theory; **I. Losev**, On the structure of the category $\mathcal{O}$ for W-algebras; **M. Perling**, Examples for exceptional sequences of invertible sheaves on rational surfaces; **O. Serman**, Orthogonal and symplectic bundles on curves and quiver representations; **D. A. Shmelkin**, Some remarks on Nakajima's quiver varieties of type A; **M. Lehn** and **C. Sorger**, A symplectic resolution for the binary tetrahedral group; **F. Vaccarino**, Moduli of linear representations, symmetric products and the non commutative Hilbert scheme.

Séminaires et Congrès, Number 24

July 2013, 456 pages, Softcover, ISBN: 978-2-85629-361-4, 2010 *Mathematics Subject Classification:* 05E15, 13C60, 13P10, 14A15, 14B05, 14C05, 14C17, 14D20, 14D23, 14D24, 14E15, 14F05, 14F43, 14H60, 14J26, 14L30, 14M17, 14M25, 16G20, 16G99, 17B35, 17B37, 17B67, 18E30, 20C20, 20G05, 53D55, 55N33, **AMS members US$84**, List US$105, Order code SECO/24.2

Analysis

Recent Trends in Analysis

Proceedings of the Conference in Honor of Nikolai Nikolski, Bordeaux, 2011

Alexander Borichev, *University of Marseille, France*, **Kenneth R. Davidson**, *University of Waterloo, Canada*, **Stanislas Kupin**, *University of Bordeaux, France*, **Gilles Pisier**, *Pierre and Marie Curie University, Paris, France*, **Florian-Horia Vasilescu**, *University of Lille, France*, and **Vasily Vasyunin**, *Steklov Institute of Mathematics, St. Petersburg, Russia*, Editors

The volume contains the proceedings of the conference held in Bordeaux in 2011 to honor the 70th birthday of Nikolai Nikolski. It gathers some of the most relevant contributions presented, written by first-rate analysts. Below is a list of the main subjects covered:

- function spaces and reproducing kernels
- Toeplitz and Hankel operators
- spectral synthesis
- spectral theory
- semigroups of operators
- singular integral operators
- functional models
- rational and meromorphic approximations
- Fourier analysis

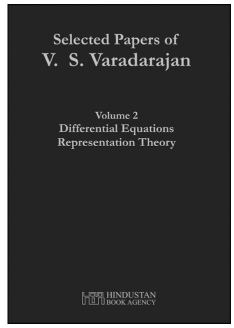
A publication of the Theta Foundation. Distributed worldwide, except in Romania, by the AMS.

Contents: **V. Adamyan** and **B. Pavlov**, Modified analytic perturbation procedure and chain rule for scattering matrices; **A. Baranov**, **Y. Belov**, **A. Borichev**, and **D. Yakubovich**, Recent developments in spectral synthesis for exponential systems and for non-self-adjoint operators; **A. Baranov** and **D. Sarason**, Quotient representations of inner functions; **L. Baratchart**, Rational approximation, meromorphic approximation, extremal domains, weak asymptotics, non-Hermitian orthogonality; **A. Böttcher**, Best constants for Markov type inequalities in Hilbert space norms; **A. Brudnyi**, Stein-like theory for Banach-valued holomorphic functions on the maximal ideal space of H^∞ and the operator corona problem of Sz.-Nagy; **S. A. Denisov**, Multidimensional L^2 conjecture: A survey; **L. Golinskii** and **S. Kupin**, On discrete spectrum of complex perturbations of finite band Schrödinger operators; **M. Haase**, The functional calculus approach to operator cosine functions; **Y. I. Lyubarskii** and **E. Malinnikova**, Composition operators on model spaces; **H. Queffélec**, Approximation numbers of classes of symbolic operators; **F. Shamoyan**, On the Fourier coefficients of functions of bounded type on the unit torus; **S. Treil**, Sharp A_2 estimates of Haar shifts via Bellman function; **M. Veraar**, Embedding results for γ-spaces; **A. Volberg** and **B. D. Wick**, Bergman-type singular integral operators on metric spaces.

International Book Series of Mathematical Texts

August 2013, 244 pages, Hardcover, ISBN: 978-606-8443-02-7, 2010 *Mathematics Subject Classification:* 00B25, 30-06, 46-06, 47-06, **AMS members US$54.40**, List US$68, Order code THETA/19

General Interest



Selected Papers of V. S. Varadarajan

Volumes 2 and 3

Donald G. Babbitt and **Ramesh Gangolli**; **K. R. Parthasarathy**, *Indian Statistical Institute, New Delhi, India*, **Enrico G. Beltrametti** and **Gianni Cassinelli**, *University of Genova, Italy*, **Rita Fioresi**, *Università di Bologna, Italy*, and **Anatoly N. Kochubei**, *National Academy of Sciences of Ukraine, Kiev, Ukraine*, Editors

Volume 2: *Differential Equations and Representation Theory*, edited by Donald G. Babbitt, Ramesh Gangolli, and K. R. Parthasarathy; 648 pages

Volume 3: *Physics, Analysis, and Reflections and Reviews*, edited by Enrico G. Beltrametti, Gianni Cassinelli, Rita Fioresi, Anatoly N. Kochubei, and K. R. Parthasarathy; 718 pages

These two volumes constitute a selection of papers of V. S. Varadarajan. An earlier volume of Selected Papers was published by the American Mathematical Society and International Press in 1998.

The papers reproduced in these two volumes include not only the articles published since 1998 but also some important papers published earlier which were not included in the original Selected Papers for reasons of space and other limitations.

The current volumes contain the papers on fundamental questions of individual and families of meromorphic differential equations that are treated by a new group theoretic and functional approach; papers on representation theory of Lie groups; papers on foundations of physics, supersymmetry, and P-adic aspects of quantum physical theories; papers on analysis, especially oscillatory integrals, on semi-simple lie groups, their conjugacy classes, and their flag manifolds; and finally, several review articles, both personal and mathematical, on a number of the above topics.

The volumes are divided into sections by topics and in each section the editors have included a brief summary of the contents of the section, put the papers in their historical context and, in the process, raised interesting new problems.

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Contents: For the table of contents, go to the AMS Bookstore at `http://www.ams.org/bookstore`.

Hindustan Book Agency

November 2013, 1366 pages, Hardcover, ISBN: 978-93-80250-57-1, 2010 *Mathematics Subject Classification:* 01A75; 35P20, 41A60, 34A20, 32G34, 81P10, 81Q99, 81T99, 60B05, 60G15, 28D15, 17B37, 22E70, **AMS members US$132**, List US$165, Order code HIN/65

Co-Sponsored Conferences

A Focus on Mathematics and Data Privacy at the 2014 AAAS Meeting

The American Association for the Advancement of Science (AAAS), founded in 1848, is the world's largest general scientific society, and it is the publisher of *Science*. The AAAS is divided into twenty-four disciplinary-based sections, including Section A (Mathematics). The 2014 annual meeting of the AAAS will be held in Chicago on February 13–17. The theme of this year's meeting is "Meeting Global Challenges: Discovery and Innovation", and this year's meeting features sessions that explore the connections between data, privacy, and mathematics.

The AAAS Annual Meeting is organized into symposia which have three or more speakers, and often a discussant who reflects on the talks that are given. Section A is sponsoring four symposia this year, featuring outstanding expository talks by prominent mathematicians and scientists. The four symposia sponsored by Section A this year are:

- Your Genome: To Share or Not to Share?, organized by Yaniv Erlich, Whitehead Institute for Biomedical Research. (Scheduled speakers: Yaniv Erlich, Kristin Lauter, and John Wilbanks.)
- Re-Identification Risk of De-Identified Data Sets in the Era of Big Data, organized by Leslie Taylor, VA Puget Sound Health Care System. (Scheduled speakers: LaTanya Sweeney, Bradley Malin, Eran Halperin, Daniel Barth-Jones, and Xiao Hua Andrew Zhou.)
- The Importance of Recreational Mathematics in Solving Practical Problems, organized by Laura Taalman and Jason Rosenhouse, James Madison University. (Scheduled speakers: Francis Su, Jason Rosenhouse, and Gary McGuire.)
- Elections through the Lens of Mathematics, organized by D. Marc Kilgour, Wilfrid Laurier University. (Scheduled speakers: Sam Merrill, Vik Amar, and Judy Goldsmith.)

Other symposia that will be of interest to the mathematical community include:

- People and Computing: On Human-Computer Collaborations for Tackling Hard Problems
- Transplant Organ Shortage: Informing National Policies Using Management Sciences
- New Modeling Approaches to Inform Climate Change Understanding and Decision Making
- Better Understanding the Science Needed for Sustainable Urban Development
- How Big Data Supports Biomedical Discovery
- A New Era for Urban Research: Open Data and Big Computation
- Data Availability: Making Sure the Gift Keeps Giving
- STEM Education Policies and Policymaking: Pushing in the Same Direction
- Analogical Processes in STEM Learning
- Unlocking the Power of Big Data by Integrating Physical, Engineering, and Life Sciences
- Statistical Methods for Large Environmental Datasets

The above symposia are only a few of the more than 150 AAAS symposia this year in the physical, life, social, and biological sciences. For further information, including the schedule of talks, go to `www.aaas.org/meetings.` Section A acknowledges the generous contributions of the American Mathematical Society for travel support for speakers this year, continuing a multi-decade commitment to the mathematics program at the AAAS.

The AAAS Annual Meeting is the showcase of American science, with about 10,000 people attending some part of the meeting each year. The AAAS Program Committee is genuinely interested in offering symposia on topics in pure and applied mathematics. In recent years there have been symposia on subjects such as compressive sensing, multi-scale modeling of cancer, quantum computing, and the changing nature of mathematical proof.

The 2015 meeting will be February 12–15, 2015, in San Jose, CA, and the Steering Committee for Section A seeks organizers and speakers who can present substantial new material in an accessible manner to a large scientific audience. All are invited to attend the Section A Committee business meeting in Chicago on Friday, February 14, 2014, at 7:00 PM, where we will brainstorm ideas for symposia. In addition, I invite you to send me, and encourage your colleagues to send me, ideas for future AAAS annual meeting symposia.

The following are the members of the Steering Committee for Section A from February 2013 to February 2014:

Chair: Juan Meza (University of California, Merced)
Chair-Elect: David M. Bressoud (Macalester College)
Retiring Chair: Jill Mesirov (Broad Institute of MIT and Harvard)
Secretary: Edward Aboufadel (Grand Valley State University)
Members at Large:
Mary Ellen Bock (Purdue University)
Joceline Lega (University of Arizona)
Sheldon Katz (University of Illinois, Urbana-Champaign)
Susan Friedlander (University of Southern California)

—*Edward Aboufadel, Secretary of Section A of the AAAS*
aboufade@gvsu.edu

Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices*. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See `http://www.ams.org/meetings/`. Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL and in an electronic issue of the *Notices* as noted below for each meeting.

Baltimore, Maryland

Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner Harbor Hotel

January 15–18, 2014

Wednesday – Saturday

Meeting #1096

Joint Mathematics Meetings, including the 120th Annual Meeting of the AMS, 97th 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), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: October 2013
Program first available on AMS website: November 1, 2013
Program issue of electronic *Notices*: January 2013
Issue of *Abstracts*: Volume 35, Issue 1

Deadlines

For organizers: Expired
For abstracts: Expired

Program Updates

Please see the complete announcement in the October issue for more information about several of these events and many others. You can also visit the JMM website at `http://jointmathematicsmeetings.org/meetings/national/jmm2014/2160_intro`.

Additions to the scientific program:

AMS Program

The leaders of the *Department Chairs Workshop* on Tuesday are **William H. Jaco**, Oklahoma State University; **Alex Smith**, University of Wisconsin-Eau Claire; **Michel Smith**, Auburn University; and **Judy Walker**, University of Nebraska-Lincoln.

The Online Courses: Benefits and Pitfalls panel discussion on Wednesday afternoon will be moderated by **Abigail Thompson**, University of California, Davis. Panelists include **Tina Garrett**, St. Olaf College; **Robert Ghrist**, University of Pennsylvania; **William E. Kirwan**, University System of Maryland, and **Randy McCarthy**, University of Illinois at Urbana-Champaign.

The Conversation on Nonacademic Employment session on Thursday morning will be moderated by **C. Allen Butler**, Daniel H. Wagner Associates, Inc.

The Public Face of Mathematics session on Friday afternoon will be moderated by **Arthur Benjamin**, Harvey Mudd College. Panelists include **Keith Devlin**, Stanford University; **Cathy O'Neill**, Johnson Research Labs; **Tom Siegfried**, freelance journalist; and **Steve Strogatz**, Cornell University.

MAA Program

Mathematics Awareness Month 2014, presented by **Eve Torrence**, Randolph-Macon College; **Bruce Torrence**, Randolph-Macon College; and **Colm Mulcahy**, Spelman College and American University; Thursday, 8:30 a.m.–8:50 a.m. The theme for Mathematics Awareness Month for 2014 is "Mathematics, Magic, and Mystery". The program organizers have planned a full month of engaging topics, culled from some of our profession's best expositors. Each day in April a new topic will be unveiled on `mathaware.org` with an attention-grabbing video that demonstrates a mathematical magic trick, illusion, or mystery. The underlying mathematics for each topic will be briefly discussed in these videos. Additional information at varying levels of mathematical sophistication will be available for enjoyment by students, mathematicians, and the general public—anyone who seeks a deeper understanding of that day's topic. The MAM 2014 poster will be unveiled on Thursday at 11:30 a.m. at the MAA Pavilion in the exhibit hall.

Birds of a Feather: CUPM Discussion Sessions, organized by **Carol Schumacher**, Kenyon College, and **Martha Siegel**, Towson University; Thursday and Friday, 7:30 p.m.–9:00 p.m. The MAA Committee on the Undergraduate Program in Mathematics (CUPM) invites JMM attendees to gather with colleagues to discuss recommendations for the 2015 CUPM Curriculum Guide for Majors in the Mathematical Sciences; members of the writing teams will lead the discussions. Choose your passion!

We are looking for program area recommendations (concentrations, double majors, minors and integrated minors) on the following topics: Teacher Education, Biomathematics and Environmental Science, Operations Research and Engineering; Financial Mathematics and Actuarial Science, Statistics, Computing, and Mathematical Programming and Applied Mathematics.

We are also looking for specific course area recommendations (broad umbrella definitions) on the following topics: Abstract Algebra, Geometry, Transitions to Proofs, Probability and Statistics; Linear Algebra, Differential Equations, Real and Complex Analysis, and Mathematical Modeling.

CUPM welcomes your contributions and questions. The url for pertinent materials will be announced on the MAA website.

Demonstration Math Circles, organized by **Paul Zeitz**, University of San Francisco, and **Tatiana Shubin**, San Jose State University; Saturday, 9:00 a.m.–9:50 a.m. (session 1) and Saturday, 1:00 p.m.–1:50 p.m. (session 2). A math circle is an enrichment experience that brings mathematics professionals in direct contact with precollege students and/or their teachers. Circles foster passion and excitement for deep mathematics. These two demonstration sessions, each directed by an experienced math circle leader, offer the opportunity for JMM 2014 attendees to observe and take part in math circle experiences, and to enjoy the organic and creative process of learning that circles offer. The first is directed towards professional mathematicians as participants, the second towards precollege students as participants. Both are for all to witness. Sponsored by the SIGMAA on Math Circles for Students and Teachers (MCST).

Math Wrangle, organized by **Steve Dunbar**, American Mathematics Competitions, and **Tatiana Shubin**, San Jose State University; Saturday, 2:00 p.m.–3:00 p.m. This Math Wrangle will pit teams of students against each other, the clock, and a slate of great math problems. The format of a Math Wrangle is designed to engage students in mathematical problem solving, promote effective teamwork, provide a venue for oral presentations, and develop critical listening skills. A Math Wrangle incorporates elements of team sports and debate, with a dose of strategy tossed in for good measure. The intention of the Math Wrangle demonstration at the JMM is to show how teachers, schools, circles, clubs, and honoraries can get students started in this exciting combination of mathematical problem solving, public speaking, strategy and rebuttal. Sponsored by the MAA American Mathematics Competitions and SIGMAA MCST.

Summer Research Programs, organized by **William Hawkins Jr.**, MAA and University of the District of Columbia; **Robert Megginson**, University of Michigan; and **Lloyd Douglas**, University of North Carolina at Greensboro; Thursday, 10:35 a.m.–11:55 a.m. The MAA has sponsored Summer Research Programs with funding from NSF and NSA since 2003. Each program consists of a small research group of at least four minority undergraduates mentored by a faculty member. About 111 sites have been funded as of summer 2013. Panelists **Noureen Khan**, University of North Texas at Dallas, and **Aprillya Lanz**, Norfolk State University will discuss their programs. There will be ample time for questions and discussion. It is expected that funding will be available for summer 2014. Additional information can be found on the NREUP website at `www.maa.org/nreup`. Sponsored by the MAA Committee on Minority Participation in Mathematics and the Office of Minority Participation.

Weird Ways to Work with Pi: An Accessible and Interactive Workshop for Middle- and High-School Educators, presented by **James Tanton**, St. Mark's School; Saturday, 10:00 a.m.–10:50 a.m. Many a mathematical scholar has contemplated the meaning and mystery of the number pi: The ratio of the circumference of a circle to its diameter. But I ask, who said the concept of pi should apply only to circles? What is pi for a square? What is pi for a right triangle? What interesting noncircular problems can be solved with non-circular pi-values?

Let's get weird and quirky and let pi loose on all kinds of wild shapes! Let's strengthen our understanding of geometry by pushing concepts to the edge. Be sure to bring pencil and paper: You won't be able to resist jotting down thoughts, working through some curious ideas, and doing some weird calculations. Bring your students too! Sponsored by the MAA Council on Outreach and SIGMAA MCST.

Social Events

Backgammon! organized by **Arthur Benjamin**, Harvey Mudd College; Thursday, 8:00 p.m.–10:00 p.m. Learn to play backgammon from expert players. It's a fun and exciting game where players with a good mathematics background have a decisive advantage. Boards and free lessons will be provided by members of the U.S. Backgammon Federation. Stop by anytime on Thursday evening.

University of Chicago Mathematics Alumni Reception, Thursday, 6:00 p.m.–7:00 p.m.

Claremont Colleges Reception, Thursday, 7:00 p.m.–9:00 p.m. All alumni, students, faculty, and friends are invited to join us for our annual reception. Drinks and hors d'oeuvres will be served, and guests are welcome.

MAA Maryland-Washington DC-Virginia Section Reception, Friday, 6:00 p.m.–7:00 p.m. Reconnect with old friends from the section, or come and make some new ones!

University of Maryland Mathematics Department Reception, Friday, 5:30 p.m.–7:30 p.m. All alumni and friends are invited.

Summer Program and Outreach Meet and Greet, Friday, 6:00 p.m.–7:00 p.m. Join experienced leaders of middle and high school mathematical outreach programs to find out how to get involved or learn some new strategies for your work. This will be an opportunity to share stories and ideas, and to more deeply connect with the community. Groups will leave for dinner from the reception.

Knoxville, Tennessee

University of Tennessee, Knoxville

March 21–23, 2014

Friday – Sunday

Meeting #1097

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: January 2014
Program first available on AMS website: February 6, 2014
Program issue of electronic *Notices*: March 2014
Issue of *Abstracts*: Volume 35, Issue 2

Deadlines

For organizers: Expired
For abstracts: January 28, 2014

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Maria Chudnovsky, Columbia University, *Title to be announced* (Erdős Memorial Lecture).

Ilse Ipsen, North Carolina State University, *Title to be announced.*

Daniel Krashen, University of Georgia, *Title to be announced.*

Suresh Venapally, Emory University, *Title to be announced.*

Special Sessions

Algebraic Methods in Graph Theory and Combinatorics (Code: SS 7A), **Felix Lazebnik**, University of Delaware, **Andrew Woldar**, Villanova University, and **Bangteng Xu**, Eastern Kentucky University.

Arithmetic of Algebraic Curves (Code: SS 9A), **Lubjana Beshaj**, Oakland University, **Caleb Shor**, Western New England University, and **Andreas Malmendier**, Colby College.

Commutative Ring Theory (in honor of the retirement of David E. Dobbs) (Code: SS 1A), **David Anderson**, University of Tennessee, Knoxville, and **Jay Shapiro**, George Mason University.

Completely Integrable Systems and Dispersive Nonlinear Equations (Code: SS 12A), **Robert Buckingham**, University of Cincinnati, and **Peter Perry**, University of Kentucky.

Complex Analysis, Probability, and Metric Geometry (Code: SS 11A), **Matthew Badger**, Stony Brook University, **Jim Gill**, St. Louis University, and **Joan Lind**, University of Tennessee, Knoxville.

Discontinuous Galerkin Finite Element Methods for Partial Differential Equations (Code: SS 18A), **Xiaobing Feng** and **Ohannes Karakashian**, University of Tennessee, Knoxville, and **Yulong Xing**, University of Tennessee, Knoxville, and Oak Ridge National Laboratory.

Diversity of Modeling and Optimal Control: A Celebration of Suzanne Lenhart's 60th Birthday (Code: SS 3A), **Wandi Ding**, Middle Tennessee State University, and **Renee Fister**, Murrray State University.

Fractal Geometry and Ergodic Theory (Code: SS 2A), **Mrinal Kanti Roychowdhury**, University of Texas Pan American.

Galois Cohomology and the Brauer Group (Code: SS 26A), **Ben Antieau**, University of Washington, **Daniel Krashen**, University of Georgia, and **Suresh Venapally**, Emory University.

Geometric Topology (Code: SS 21A), **Craig Guilbault**, University of Wisconsin-Milwaukee, and **Steve Ferry**, Rutgers University.

Geometric Topology and Number Theory (Code: SS 22A), **Eriko Hironaka** and **Kathleen Petersen**, Florida State University.

Geometric and Algebraic Combinatorics (Code: SS 16A), **Benjamin Braun** and **Carl Lee**, University of Kentucky.

Geometric and Combinatorial Methods in Lie Theory (Code: SS 15A), **Amber Russell** and **William Graham**, University of Georgia.

Graph Theory (Code: SS 8A), **Chris Stevens**, **Dong Ye**, and **Xiaoya Zha**, Middle Tennessee State University.

Harmonic Analysis and Nonlinear Partial Differential Equations (Code: SS 5A), **J. Denzler**, **M. Frazier**, **Tuoc Phan**, and **T. Todorova**, University of Tennessee, Knoxville.

Invariant Subspaces of Function Spaces (Code: SS 6A), **Catherine Beneteau**, University of South Florida, **Alberto A. Condori**, Florida Gulf Coast University, **Constanze Liaw**, Baylor University, and **Bill Ross**, University of Richmond.

Mathematical Modeling of the Within-and Between-Host Dynamics of Infectious Diseases (Code: SS 25A), **Megan Powell**, University of St. Francis, and **Judy Day** and **Vitaly Ganusov**, University of Tennessee, Knoxville.

Mathematical Physics and Spectral Theory (Code: SS 10A), **Roger Nichols**, The University of Tennessee at Chattanooga, and **Günter Stolz**, University of Alabama at Burmingham.

Metric Geometry and Topology (Code: SS 23A), **Catherine Searle**, Oregon State University, **Jay Wilkins**, University of Connecticut, and **Conrad Plaut**, University of Tennessee, Knoxville.

Nonlinear Partial Differential Equations in the Applied Sciences (Code: SS 19A), **Lorena Bociu**, North Carolina State University, **Ciprian Gal**, Florida International University, and **Daniel Toundykov**, University of Nebraska-Lincoln.

Randomized Numerical Linear Algebra (Code: SS 4A), **Ilse Ipsen**, North Carolina State University.

Recent Development on Hyperbolic Conservation Laws (Code: SS 20A), **Geng Chen**, **Ronghua Pan**, and **Weizhe Zhang**, Georgia Tech.

Scientific Computing, Numerical Analysis, and Mathematical Modeling (Code: SS 17A), **Vasilios Alexiades**, **Xiaobing Feng**, and **Steven Wise**, University of Tennessee, Knoxville.

Singularities and Physics (Code: SS 13A), **Mboyo Esole**, Harvard University, and **Paolo Aluffi**, Florida State University.

Stochastic Processes and Related Topics (Code: SS 14A), **Jan Rosinski** and **Jie Xiong**, University of Tennessee, Knoxville.

von Neumann Algebras and Free Probability (Code: SS 24A), **Remus Nicoara**, University of Tennessee, Knoxville, and **Arnaud Brothier**, Vanderbilt University.

Baltimore, Maryland

University of Maryland, Baltimore County

March 29–30, 2014

Saturday – Sunday

Meeting #1098

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2014
Program first available on AMS website: February 26, 2014
Program issue of electronic *Notices*: March 2014
Issue of *Abstracts*: Volume 35, Issue 2

Deadlines

For organizers: Expired
For abstracts: January 28, 2014

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Maria Gordina, University of Connecticut, *Stochastic analysis and geometric functional inequalities.*

L. Mahadevan, Harvard University, *Shape: Mathematics, physics and biology.*

Nimish Shah, Ohio State University, *Dynamics of subgroup actions on homogeneous spaces and its interaction with number theory.*

Dani Wise, McGill University, *Cube complexes.*

Special Sessions

Difference Equations and Applications (Code: SS 8A), **Michael Radin**, Rochester Institute of Technology.

Harmonic Analysis and Its Applications (Code: SS 10A), **Susanna Dann**, University of Missouri, **Azita Mayeli**, Queensborough College, City University of New York, and **Gestur Olafsson**, Louisana State University.

Invariants in Low-Dimensional Topology (Code: SS 1A), **Jennifer Hom**, Columbia University, and **Tye Lidman**, University of Texas at Austin.

Knots and Applications (Code: SS 3A), **Louis Kauffman**, University of Illinois at Chicago, **Samuel Lomonaco**, University of Maryland, Baltimore County, and **Jozef Przytycki**, George Washington University.

Mathematical Biology (Code: SS 6A), **Jonathan Bell** and **Brad Peercy**, University of Maryland Baltimore County.

Mathematical Finance (Code: SS 2A), **Agostino Capponi**, John Hopkins University.

Mechanics and Control (Code: SS 9A), **Jinglai Shen**, University of Maryland Baltimore County, and **Dmitry Zenkov**, North Carolina State University.

Novel Developments in Tomography and Applications (Code: SS 4A), **Alexander Katsevich**, **Alexandru Tamasan**, and **Alexander Tovbis**, University of Central Florida.

Open Problems in Stochastic Analysis and Related Fields (Code: SS 7A), **Masha Gordina**, University of Connecticut, and **Tai Melcher**, University of Virginia.

Optimization and Related Topics (Code: SS 11A), **M. Seetharama Gowda**, **Osman Guler**, **Florian Potra**, and **Jinlai Shen**, University of Maryland at Baltimore County.

Theory and Applications of Differential Equations on Graphs (Code: SS 5A), **Jonathan Bell**, University of Maryland Baltimore County, and **Sergei Avdonin**, University of Alaska Fairbanks.

Albuquerque, New Mexico

University of New Mexico

April 5–6, 2014

Saturday – Sunday

Meeting #1099

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: January 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: April 2014
Issue of *Abstracts*: Volume 35, Issue 2

Deadlines

For organizers: Expired
For abstracts: February 11, 2014

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Anton Gorodetski, University of California, Irvine, *To be announced*.

Fan Chung Graham, University of California, San Diego, *Some problems and results in spectral graph theory*.

Adrian Ioana, University of California, San Diego, *To be announced*.

Karen Smith, University of Michigan, Ann Harbor, *To be announced*.

Special Sessions

Analysis and Topology in Special Geometries (Code: SS 14A), **Charles Boyer**, **Daniele Grandini**, and **Dimiter Vassilev**, University of New Mexico.

Arithmetic and Differential Algebraic Geometry (Code: SS 17A), **Alexandru Buium**, University of New Mexico, **Taylor Dupuy**, University of California, Los Angeles, and **Lance Edward Miller**, University of Arkansas.

Commutative Algebra (Code: SS 7A), **Daniel J. Hernandez**, University of Utah, **Karen E. Smith**, University of Michigan, and **Emily E. Witt**, University of Minnesota.

Descriptive Set Theory and its Applications (Code: SS 6A), **Alexander Kechris**, California Institute of Technology, and **Christian Rosendal**, University of Illinois, Chicago.

Flat Dynamics (Code: SS 8A), **Jayadev Athreya**, University of Illinois, Urbana-Champaign, **Robert Niemeyer**, University of New Mexico, Albuquerque, **Richard E. Schwartz**, Brown University, and **Sergei Tabachnikov**, The Pennsylvania State University.

Harmonic Analysis and Dispersive Equations (Code: SS 11A), **Matthew Blair**, University of New Mexico, and **Jason Metcalfe**, University of North Carolina.

Harmonic Analysis and Its Applications (Code: SS 19A), **Jens Gerlach Christensen**, Colgate University, and **Joseph Lakey** and **Nicholas Michalowski**, New Mexico State University.

Harmonic Analysis and Operator Theory: In memory of Cora Sadosky (Code: SS 18A), **Laura De Carli**, Florida International University, **Alex Stokolos**, Georgia Southern University, and **Wilfredo Urbina**, Roosevelt University.

Interactions in Commutative Algebra (Code: SS 4A), **Louiza Fouli** and **Bruce Olberding**, New Mexico State University, and **Janet Vassilev**, University of New Mexico.

Modeling Complex Social Processes Within and Across Levels of Analysis (Code: SS 15A), **Simon DeDeo**, Indiana University, and **Richard Niemeyer**, University of Colorado, Denver.

Partial Differential Equations in Materials Science (Code: SS 10A), **Lia Bronsard**, McMaster University, and **Tiziana Giorgi**, New Mexico State University.

Physical Knots, honoring the retirement of Jonathan K. Simon (Code: SS 13A), **Greg Buck**, St. Anselm College, and **Eric Rawdon**, University of St. Thomas.

Progress in Noncommutative Analysis (Code: SS 2A), **Anna Skripka**, University of New Mexico, and **Tao Mei**, Wayne State University.

Spectral Theory (Code: SS 12A), **Milivoje Lukic**, Rice University, and **Maxim Zinchenko**, University of New Mexico.

Stochastic Processes in Noncommutative Probability (Code: SS 20A), **Michael Anshelevich**, Texas A&M University, and **Todd Kemp**, University of California San Diego.

Stochastics and PDEs (Code: SS 5A), **Juraj Földes**, Institute for Mathematics and Its Applications, **Nathan Glatt-Holtz**, Institute for Mathematics and Its Applications and Virginia Tech, and **Geordie Richards**, Institute for Mathematics and Its Applications and University of Rochester.

The Common Core and University Mathematics Instruction (Code: SS 16A), **Justin Boyle**, **Michael Nakamaye**, and **Kristin Umland**, University of New Mexico.

The Inverse Problem and Other Mathematical Methods Applied in Physics and Related Sciences (Code: SS 1A), **Hanna Makaruk**, Los Alamos National Laboratory, and **Robert Owczarek**, University of New Mexico and Enfitek, Inc.

Topics in Spectral Geometry and Global Analysis (Code: SS 3A), **Ivan Avramidi**, New Mexico Institute of Mining and Technology, and **Klaus Kirsten**, Baylor University.

Weighted Norm Inequalities and Related Topics (Code: SS 9A), **Oleksandra Beznosova**, Baylor University, **David Cruz-Uribe**, Trinity College, and **Cristina Pereyra**, University of New Mexico.

Lubbock, Texas

Texas Tech University

April 11–13, 2014

Friday – Sunday

Meeting #1100

Central Section
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: February 2014
Program first available on AMS website: February 27, 2014
Program issue of electronic *Notices*: April 2014
Issue of *Abstracts*: Volume 35, Issue 2

Deadlines

For organizers: Expired
For abstracts: February 10, 2014

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Nir Avni, Northwestern University, *To be announced*.

Alessio Figalli, University of Texas, *To be announced*.

Jean-Luc Thiffeault, University of Wisconsin-Madison, *To be announced*.

Rachel Ward, University of Texas at Austin, *To be announced*.

Special Sessions

Algebraic Geometry (Code: SS 9A), **David Weinberg**, Texas Tech University.

Analysis and Applications of Dynamic Equations on Time Scales (Code: SS 2A), **Heidi Berger**, Simpson College, and **Raegan Higgins**, Texas Tech University.

Applications of Special Functions in Combinatorics and Analysis (Code: SS 12A), **Atul Dixit**, Tulane University, and **Timothy Huber**, University of Texas Pan American.

Approximation Theory in Signal Processing (Code: SS 17A), **Rachel Ward**, University of Texas at Austin, and **Rayan Saab**, University of California San Diego.

Complex Function Theory and Special Functions (Code: SS 7A), **Roger W. Barnard** and **Kent Pearce**, Texas Tech University, **Kendall Richards**, Southwestern University, and **Alex Solynin** and **Brock Williams**, Texas Tech University.

Developments from PASI 2012: Commutative Algebra and Interactions with Related Disciplines (Code: SS 26A), **Kenneth Chan**, University of Washington, and **Jack Jeffries**, University of Utah (AMS-AAAS).

Differential Algebra and Galois Theory (Code: SS 23A), **Lourdes Juan** and **Arne Ledet**, Texas Tech University, **Andy R. Magid**, University of Oklahoma, and **Michael F. Singer**, North Carolina State University (AMS-AAAS).

Fractal Geometry and Dynamical Systems (Code: SS 3A), **Mrinal Kanti Roychowdhury**, The University of Texas-Pan American.

Geometry and Geometric Analysis (Code: SS 25A), **Lance Drager** and **Jeffrey M. Lee**, Texas Tech University (AMS-AAAS).

Homological Methods in Algebra (Code: SS 8A), **Lars W. Christensen**, Texas Tech University, **Hamid Rahmati**, Miami University, and **Janet Striuli**, Fairfield University.

Hysteresis and Multi-rate Processes (Code: SS 19A), **Ram Iyer**, Texas Tech University.

Interactions between Commutative Algebra and Algebraic Geometry (Code: SS 11A), **Brian Harbourne** and **Alexandra Seceleanu**, University of Nebraska-Lincoln.

Issues Regarding the Recruitment and Retention of Women and Minorities in Mathematics (Code: SS 5A), **James Valles, Jr.**, Prairie View A&M University, and **Doug Scheib**, Saint Mary-of-the-Woods College.

Lie Groups (Code: SS 13A), **Benjamin Harris**, **Hongyu He**, and **Gestur Ólafsson**, Louisiana State University.

Linear Operators in Representation Theory and in Applications (Code: SS 20A), **Markus Schmidmeier**, Florida Atlantic University, and **Gordana Todorov**, Northeastern University.

Mathematical Models of Infectious Diseases in Plants, Animals and Humans (Code: SS 21A), **Linda Allen**, Texas Tech University, and **Vrushal Bokil**, Oregon State University (AMS-AAAS).

Navier-Stokes Equations and Fluid Dynamics (Code: SS 14A), **Radu Dascaliuc**, Oregon State University, and **Luan Hoang**, Texas Tech University.

Noncommutative Algebra, Deformations, and Hochschild Cohomology (Code: SS 10A), **Anne Shepler**, University of North Texas, and **Sarah Witherspoon**, Texas A&M University.

Numerical Methods for Systems of Partial Differential Equations (Code: SS 27A), **JaEun Ku**, Oklahoma State Universtity, and **Young Ju Lee**, Texas State University (AMS-AAAS).

Optimal Control Problems from Neuron Ensembles, Genomics and Mechanics (Code: SS 24A), **Bijoy K. Ghosh** and **Clyde F. Martin**, Texas Tech University (AMS-AAAS).

Qualitative Theory for Non-linear Parabolic and Elliptic Equations (Code: SS 6A), **Akif Ibragimov**, Texas Tech University, and **Peter Polacik**, University of Minnesota.

Recent Advancements in Differential Geometry and Integrable PDEs, and Their Applications to Cell Biology and Mechanical Systems (Code: SS 4A), **Giorgio Bornia**, **Akif Ibragimov**, and **Magdalena Toda**, Texas Tech University.

Recent Advances in the Applications of Nonstandard Finite Difference Schemes (Code: SS 15A), **Ronald E. Mickens**, Clark Atlanta University, and **Lih-Ing W. Roeger**, Texas Tech University.

Recent Developments in Number Theory (Code: SS 18A), **Dermot McCarthy** and **Chris Monico**, Texas Tech University.

Statistics on Manifolds (Code: SS 22A), **Leif Ellingson**, Texas Tech University (AMS-AAAS).

Topology and Physics (Code: SS 1A), **Razvan Gelca** and **Alastair Hamilton**, Texas Tech University.

Undergraduate Research (Code: SS 16A), **Jerry Dwyer**, **Levi Johnson**, **Jessica Spott**, and **Brock Williams**, Texas Tech University.

Tel Aviv, Israel

Bar-Ilan University, Ramat-Gan and Tel-Aviv University, Ramat-Aviv

June 16–19, 2014

Monday – Thursday

Meeting #1101

The Second Joint International Meeting between the AMS and the Israel Mathematical Union.

Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: January 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/internmtgs.html`.

Special Sessions

Mirror Symmetry and Representation Theory, **David Kazhdan**, Hebrew University, and **Roman Bezrukavnikov**, Massachusetts Institute of Technology.

Nonlinear Analysis and Optimization, **Boris Mordukhovich**, Wayne State University, and **Simeon Reich** and **Alexander Zaslavski**, The Technion-Israel Institute of Technology.

Qualitative and Analytic Theory of ODE's, **Yosef Yomdin**, Weizmann Institute.

Eau Claire, Wisconsin

University of Wisconsin-Eau Claire

September 20–21, 2014

Saturday – Sunday

Meeting #1102

Central Section
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: June 2014
Program first available on AMS website: August 7, 2014
Program issue of electronic *Notices*: September 2014
Issue of *Abstracts*: Volume 35, Issue 3

Deadlines

For organizers: March 20, 2014
For abstracts: July 29, 2014

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Matthew Kahle, Ohio State University, *To be announced*.

Markus Keel, University of Minnesota, *To be announced*.

Svitlana Mayboroda, University of Minnesota, *To be announced*.

Dylan Thurston, Indiana University, *To be announced*.

Special Sessions

Directions in Commutative Algebra: Past, Present and Future (Code: SS 1A), **Joseph P. Brennan**, University of Central Florida, and **Robert M. Fossum**, University of Illinois at Urbana-Champaign.

Von Neumann Algebras and Related Fields (Code: SS 2A), **Stephen Avsec** and **Ken Dykema**, Texas A&M University.

Halifax, Canada

Dalhousie University

October 18–19, 2014

Saturday – Sunday

Meeting #1103

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: August 2014
Program first available on AMS website: September 5, 2014
Program issue of electronic *Notices*: October 2014
Issue of *Abstracts*: Volume 35, Issue 3

Deadlines

For organizers: March 18, 2014
For abstracts: August 19, 2014

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

François Bergeron, Université du Québec à Montréal, *Title to be announced*.

Sourav Chatterjee, New York University, *Title to be announced*.

William M. Goldman, University of Maryland, *Title to be announced*.

Sujatha Ramdorai, University of British Columbia, *Title to be announced*.

Special Sessions

p-adic Methods in Arithmetic. (Code: SS 1A), **Henri Darmon**, McGill University, **Adrian Iovita**, Concordia University, and **Sujatha Ramdorai**, University of British Columbia.

San Francisco, California

San Francisco State University

October 25–26, 2014

Saturday – Sunday

Meeting #1104

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2014
Program first available on AMS website: September 11, 2014
Program issue of electronic *Notices*: October 2014
Issue of *Abstracts*: Volume 35, Issue 4

Deadlines

For organizers: March 25, 2014
For abstracts: September 3, 2014

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Kai Behrend, University of British Columbia, Vancouver, Canada, *Title to be announced*.

Kiran S. Kedlaya, University of California, San Diego, *Title to be announced*.

Julia Pevtsova, University of Washington, Seattle, *Title to be announced*.

Burt Totaro, University of California, Los Angeles, *Title to be announced*.

Special Sessions

Algebraic Geometry (Code: SS 1A), **Renzo Cavalieri**, Colorado State University, **Noah Giansiracusa**, University of California, Berkeley, and **Burt Totaro**, University of California, Los Angeles.

Geometry of Submanifolds (Code: SS 3A), **Yun Myung Oh**, Andrews University, **Bogdan D. Suceava**, California State University, Fullerton, and **Mihaela B. Vajiac**, Chapman University.

Polyhedral Number Theory (Code: SS 2A), **Matthias Beck**, San Francisco State University, and **Martin Henk**, Universität Magdeburg.

Greensboro, North Carolina

University of North Carolina, Greensboro

November 8–9, 2014

Saturday – Sunday

Meeting #1105

Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: August 2014
Program first available on AMS website: September 25, 2014
Program issue of electronic *Notices*: November 2014
Issue of *Abstracts*: Volume 35, Issue 4

Deadlines

For organizers: April 8, 2014
For abstracts: September 16, 2014

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Susanne Brenner, Louisiana State Unviersity, *Title to be announced*.

Skip Garibaldi, Emory University, *Title to be announced*.

Stavros Garoufaldis, Georgia Institute of Technology, *Title to be announced*.

James Sneyd, University of Auckland, *Title to be announced* (AMS-NZMS Maclaurin Lecture).

San Antonio, Texas

Henry B. Gonzalez Convention Center and Grand Hyatt San Antonio

January 10–13, 2015

Saturday – Tuesday

Meeting #1106

Joint Mathematics Meetings, including the 121st Annual Meeting of the AMS, 98th 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 of Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: October 2014
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2015
Issue of *Abstracts*: Volume 36, Issue 1

Deadlines

For organizers: April 1, 2014
For abstracts: To be announced

Washington, District of Columbia

Georgetown University

March 7–8, 2015

Saturday – Sunday
Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 7, 2014
For abstracts: To be announced

Huntsville, Alabama

University of Alabama in Huntsville

March 27–29, 2015
Friday – Sunday
Southeastern Section
Associate secretary: Brian D. Boe
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: August 20, 2014
For abstracts: To be announced

Las Vegas, Nevada

University of Nevada, Las Vegas

April 18–19, 2015
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: September 18, 2014
For abstracts: To be announced

Porto, Portugal

University of Porto

June 11–14, 2015
Thursday – Sunday
First Joint International Meeting involving the American Mathematical Socieтy (AMS), the European Mathematical Society (EMS), and the Sociedade de Portuguesa Matematica (SPM).
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Not applicable

Deadlines
For organizers: To be announced
For abstracts: To be announced

Chicago, Illinois

Loyola University Chicago

October 3–4, 2015
Saturday – Sunday
Central Section
Associate secretary: Georgia M. Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2015
Issue of *Abstracts*: To be announced

Deadlines
For organizers: March 10, 2015
For abstracts: To be announced

Fullerton, California

California State University, Fullerton

October 24–25, 2015
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*: October 2015
Issue of *Abstracts*: To be announced

Deadlines
For organizers: March 27, 2015
For abstracts: To be announced

Seattle, Washington

Washington State Convention Center and the Sheraton Seattle Hotel

January 6–9, 2016
Wednesday – Saturday
Joint Mathematics Meetings, including the 122nd Annual Meeting of the AMS, 99th Annual Meeting of the Mathematical Association of America (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 of 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 2015
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2016
Issue of *Abstracts*: Volume 37, Issue 1

Deadlines
For organizers: April 1, 2015
For abstracts: To be announced

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Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Central Section: **Georgia Benkart**, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388; e-mail: `benkart@math.wisc.edu`; telephone: 608-263-4283.

Eastern Section: **Steven H. Weintraub**, Department of Mathematics, Lehigh University, Bethlehem, PA 18105-3174; e-mail: `steve.weintraub@lehigh.edu`; telephone: 610-758-3717.

Southeastern Section: **Brian D. Boe,** Department of Mathematics, University of Georgia, 220 D W Brooks Drive, Athens, GA 30602-7403, e-mail: `brian@math.uga.edu`; telephone: 706-542-2547.

Western Section: Michel L. Lapidus, Department of Mathematics, University of California, Surge Bldg., Riverside, CA 92521-0135; e-mail: `lapidus@math.ucr.edu`; telephone: 951-827-5910.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information can be found at** `www.ams.org/meetings/`**.**

Meetings:

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 274 in the the February 2013 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarily coded material (such as accent marks in text) must be typeset in LaTeX. Visit `http://www.ams.org/cgi-bin/abstracts/abstract.pl`. Questions about abstracts may be sent to `abs-info@ams.org`. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences in Cooperation with the AMS: (see `http://www.ams.org/meetings/` for the most up-to-date information on these conferences.)

February 13–17, 2014: 2014 Annual Meeting of AAAS, Chicago, Illinois.

2014 Joint Mathematics Meetings Advance Registration/Housing Form

JOINT MATHEMATICS MEETINGS
BALTIMORE • JAN 15-18, 2014
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA

Name ____________________
(please write name as you would like it to appear on your badge)

Mailing Address ____________________

____

Telephone ____________________ Fax: ____________________

In case of emergency (for you) at the meeting, call: Day #____________ Evening #:____________

Email Address ____________________ Additional email address for receipt ____________

Acknowledgment of this registration and any hotel reservations will be sent to the email address(es) given here. **Check this box for a copy in U.S. Mail:** ☐

Affiliation for badge ____________________ (company/university) Nonmathematician guest badge name: ____________ (Note fee of US$15)

☐ **I DO NOT want my program and badge to be mailed to me on 12/13/13. (Materials will be mailed to the address listed above unless you check this box.)**

Registration Fees

Membership please ✓ that apply. First row is eligible to register as a JMM member.
☐ AMS ☐ MAA ☐ ASL ☐ CMS ☐ SIAM
☐ ASA ☐ AWM ☐ NAM ☐ YMN

Joint Meetings	**by Dec 24**	**at mtg**	**Subtotal**
☐ Member AMS, MAA, ASL, CMS, SIAM	US$ 240	US$ 315	
☐ Nonmember	US$ 374	US$ 486	
☐ Graduate Student (Mem. of AMS or MAA)	US$ 53	US$ 63	
☐ Graduate Student (Nonmember)	US$ 82	US$ 93	
☐ Undergraduate Student	US$ 53	US$ 63	
☐ High School Student	US$ 5	US$ 10	
☐ Unemployed	US$ 53	US$ 63	
☐ Temporarily Employed	US$ 195	US$ 224	
☐ Developing Countries Special Rate	US$ 53	US$ 63	
☐ Emeritus Member of AMS or MAA	US$ 53	US$ 63	
☐ High School Teacher	US$ 53	US$ 63	
☐ Librarian	US$ 53	US$ 63	
☐ Press	US$ 0	US$ 0	
☐ Nonmathematician Guest	US$ 15	US$ 15	
			$ ________

AMS Short Course: *Geometry and Topology in Statistical Inference (1/13–1/14)*

☐ Member of AMS or MAA	US$ 106	US$ 140	
☐ Nonmember	US$ 155	US$ 185	
☐ Student, Unemployed, Emeritus	US$ 54	US$ 75	
			$ ________

MAA Short Course: *Reading, Writing and Doing the History of Mathematics: Learning the Methods of Historical Research (1/13–1/14)*

☐ Member of MAA or AMS	US$ 159	US$ 169	
☐ Nonmember	US$ 234	US$ 244	
☐ Student, Unemployed, Emeritus	US$ 81	US$ 91	
			$ ________

MAA Minicourses (see listing in text)
I would like to attend: ☐ One Minicourse ☐ Two Minicourses
Please enroll me in MAA Minicourse(s) #______ and/or #______
In order of preference, my alternatives are: #______ and/or #______
Price: US$80 for each minicourse.
(For more than 2 minicourses, call or email the MMSB.) $ ________

Graduate School Fair
☐ Graduate Program Table US$ 75 US$ 75
(includes table, posterboard & electricity) $ ________

MAA Workshops
☐ Introductory Proposal Writing Workshop for Grant Applications to the NSF Div. of Undergraduate Education (1/16) (no charge)
☐ Advanced Proposal Writing Workshop for Grant Applications to the NSF Div. of Undergraduate Education (1/17) (no charge)

Receptions & Banquets
☐ Graduate Student/First Time Attendee Reception (1/15) (no charge)
☐ NAM Banquet (1/17) US$ 62 #___Chicken #___Fish #___Kosher #___Vegan
☐ AMS Dinner (1/18) US$ 62
(Additional fees may apply for Kosher meals.) $ ________

Total for Registrations and Events $ ________

Registration for the Joint Meetings is not required for the short courses but it is required for the minicourses and the Employment Center. To register for the Employment Center, go to www.ams.org/profession/employment-services/employment-center.

Payment

Registration & Event Total (total from column on left) $ ____________
Hotel Deposit (only if paying by check) $ ____________

Total Amount To Be Paid $ ____________
(Note: A US$5 processing fee will be charged for each returned check or invalid credit card. Debit cards cannot be accepted.)

Method of Payment
☐ **Check**. Make checks payable to the AMS. Checks drawn on foreign banks must be in equivalent foreign currency at current exchange rates. For all check payments, please keep a copy of this form for your records.

☐ **Credit Card**. All major credit cards accepted. For your security, we do not accept credit card numbers by postal mail, email or fax. If the MMSB receives your registration form by fax or postal mail, it will contact you at the phone number provided on this form. For questions, contact the MMSB at mmsb@ams.org.

Signature: ____________________

☐ **Purchase Order #**____________ (please enclose copy)

Other Information

Mathematical Reviews field of interest #____________
How did you hear about this meeting? Check one:
☐ Colleague(s) ☐ Internet ☐ *Notices* ☐ *Focus* ☐ Other________
☐ This is my first Joint Mathematics Meetings.
☐ I am a mathematics department chair.
☐ For planning purposes for the MAA Two-year College Reception, please check if you are a faculty member at a two-year college.
☐ I would like to receive promotions for future JMM meetings.
☐ Please do not include my name on any promotional mailing lists.
☐ Please do not include my name on any list of participants distributed or displayed at any time.
☐ Please ✓ this box if you have a disability requiring special services.

Mailing Address/Contact:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887 Fax: 401-455-4004; **Email:** mmsb@ams.org
Telephone: 401-455-4144 or 1-800-321-4267 x4144 or x4137

Deadlines

To be eligible for the complimentary room drawing:	**Nov. 4, 2013**
For receiving badges/programs in the mail:	**Nov. 19, 2013**
For housing changes/cancellations through MMSB:	**Dec. 13, 2013**
For advance registration for the Joint Meetings, short courses, minicourses, and tickets:	**Dec. 24, 2013**
For 50% refund on banquets, cancel by:	**Jan. 7, 2014***
For 50% refund on advance registration, minicourses & short courses, cancel by:	**Jan. 10, 2014***

***no refunds issued after this date**

2014 Joint Mathematics Meetings Hotel Reservations – Baltimore, Maryland

(Please see the hotel page in the announcement or on the web for detailed information on each hotel.) To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc. in the column on the left and by circling the requested bed confirguration. If your requested hotel and room type is no longer available, you will be assigned a room at the next available comparable rate. Please call the MMSB for details on suite configurations, sizes, availability, etc. All reservations, including suite reservations, must be made through the MMSB to receive the JMM rates. Reservations made directly with the hotels before **December 13, 2013** may be changed to a higher rate. All rates are subject to a 15.5% sales/occupancy tax. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee.**

☐ **Deposit enclosed (see front of form)**

☐ **Hold with my credit card. For your security, we do not accept credit card numbers by postal mail, email or fax.** If the MMSB receives your registration form by postal mail or fax, we will contact you at the phone number provided on the reverse of this form.

Date and Time of Arrival ______________ **Date and Time of Departure** ______________ **Number of adult guests in room** ______________

Name of Other Adult Room Occupant ______________ **Arrival Date** ______________ **Departure Date** ______________

Name of Other Adult Room Occupant ______________ **Arrival Date** ______________ **Departure Date** ______________

Name of Other Adult Room Occupant ______________ **Arrival Date** ______________ **Departure Date** ______________

Housing Requests:.(example: rollaway cot, crib, nonsmoking room, low floor) ______________

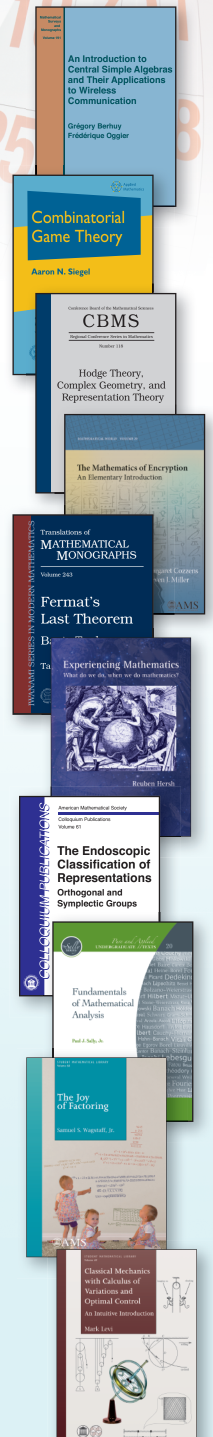
☐ I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are: ______________

☐ I am a member of a hotel frequent-travel club and would like to receive appropriate credit. The hotel chain and card number are: ______________

☐ I am not reserving a room. I am sharing with______________ , who is making the reservation.

Order of choice	Hotel	Bed configuration (please circle preference)	Single/Double Rate	Additional Adult (More than 2 adults; Max: 4)	Rollaway Cot Fee (add to special requests)
	Hilton Baltimore (htqrs)	King bed or 2 double beds	US$ 159	US$ 20 per person	US$ 25.00 (one time)
	Student Rate	King bed or 2 double beds	US$ 127	US$ 20 per person	US$ 25.00 (one time)
	Baltimore Marriott Inner Harbor (htqrs)	King bed or 2 double beds	US$ 149	US$ 20 per person	No charge
	Student Rate	King bed or 2 double beds	US$ 115	US$ 20 per person	No charge
	Sheraton Inner Harbor	King bed or 2 double beds	US$ 149	US$ 20 per person	US$ 20.00 (per day)
	Student Rate	King bed or 2 double beds	US$ 139	US$ 20 per person	US$ 20.00 (per day)
	Hyatt Regency Baltimore	King, Queen or 2 double beds	US$ 145	US$ 25 per person	US$ 25.00 (one time)
	Student Rate	King, Queen or 2 double beds	US$ 135	US$ 25 per person	US$ 25.00 (one time)
	Renaissance Baltimore Harborplace	King, Queen or 2 double beds	US$ 135	US$ 20 per person	US$ 20.00 (per day)
	Student Rate	King, Queen or 2 double beds	US$ 115	US$ 20 per person	US$ 20.00 (per day)
	Baltimore Marriott Waterfront	King bed or 2 double beds	US$ 135	US$ 20 per person	No charge
	Student Rate	King bed or 2 double beds	US$ 115	US$ 20 per person	No charge
	Royal Sonesta Harbor Court	King bed or 2 double beds	US$ 125	US$ 20 per person	US$ 25.00 (per day, king bed room only)
	Student Rate	King bed or 2 double beds	US$ 99	US$ 20 per person	US$ 25.00 (per day, king bed room only)
	Days Inn Baltimore Inner Harbor	King, Queen or 2 double beds	US$ 119	No charge	US$ 10.00 (per day, king bed room only)
	Student Rate	King, Queen or 2 double beds	US$ 109	No charge	US$ 10.00 (per day, king bed room only)
	Holiday Inn Inner Harbor	King, Queen or 2 double beds	US$ 119	No charge	US$ 15.00 (per day, king bed room only)
	Student Rate	King, Queen or 2 double beds	US$ 99	No charge	US$ 15.00 (per day, king bed room only)
	Hotel Monaco	King, 2 Queens or 2 double beds	US$ 119	US$ 20 per person	US$ 25.00 (per day, king bed room only)
	Student Rate	King, 2 Queens or 2 double beds	US$ 109	US$ 20 per person	US$ 25.00 (per day, king bed room only)

People interested in suites should contact the MMSB directly at mmsb@ams.org or call 800-321-4267, ext. 4137 or 4144 (401-455-4137 or 401-455-4144)



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