ISSN 0002-9920

Notices

of the American Mathematical Society

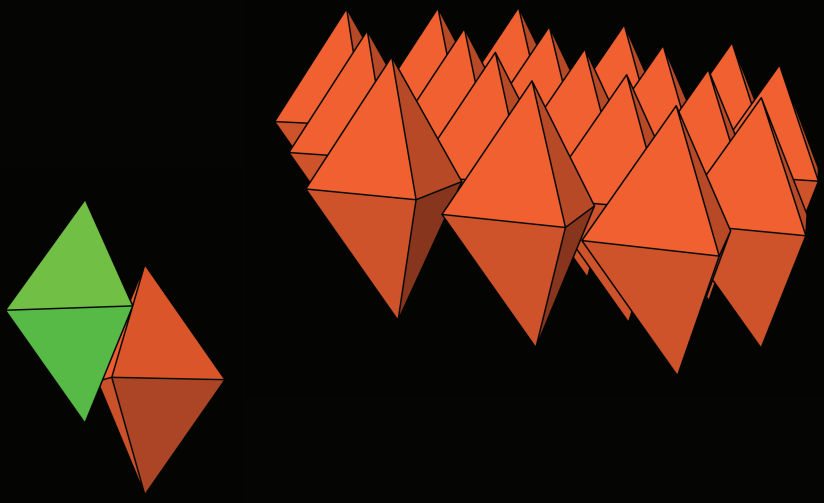
December 2012 Volume 59, Number 11

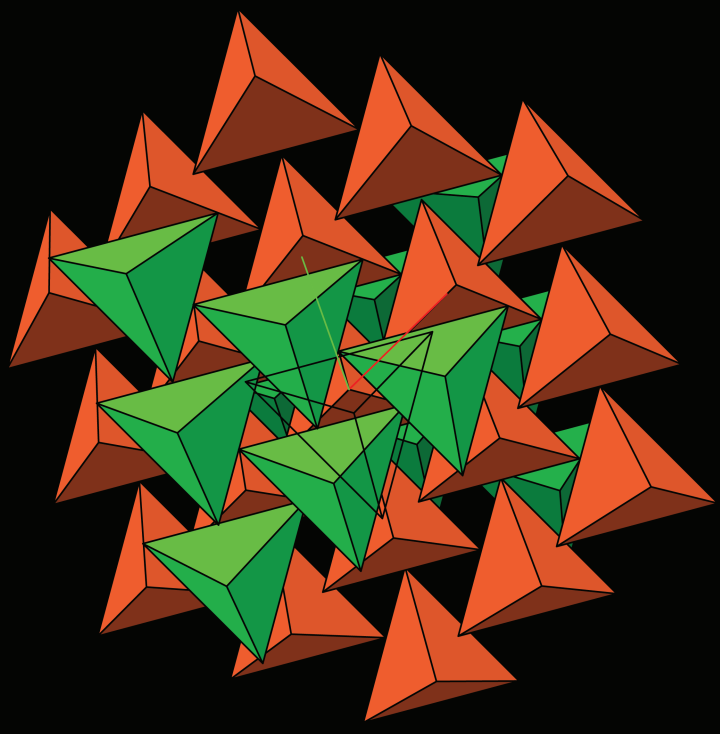
Srinivasa Ramanujan:
Going Strong at 125, Part I
page 1522

Mysteries in Packing
Regular Tetrahedra
page 1540

Leibniz's Laws of
Continuity and
Homogeneity
page 1550

Oxford Meeting
page 1614

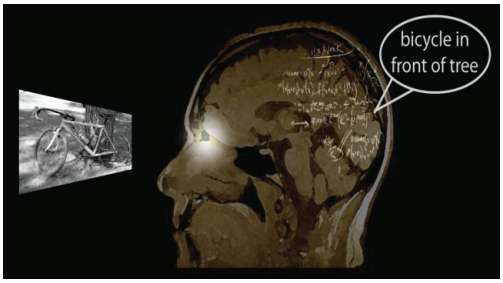




About the Cover:
"Does it get any better?"
(see page 1558)

INSTITUTE FOR PURE AND APPLIED MATHEMATICS

Los Angeles, California



IPAM Summer School on Computer Vision

July 22 – August 9, 2013

ORGANIZING COMMITTEE: Alan Yuille, Chair (UCLA), Don Geman (John Hopkins), Fei Fei Li (Stanford), Deva Ramanan (UC Irvine), Stefano Soatto (UCLA)

Scientific Overview

The summer school will involve leaders in computer vision and experts from mathematics, statistics, engineering and computer science who are interested in vision. Computer Vision is a rapidly developing interdisciplinary field with an increasing number of practical applications such as automated cars, visual surveillance, and aids for the visual impaired. Its main goal is the automatic understanding and interpreting of images and image sequences. The school will present the core techniques in Computer Vision, illustrate the large range of visual tasks they can be applied to, and describe the conceptual and theoretical foundations that underlie them. These techniques include filtering, geometry, differential equations, harmonic analysis, probabilistic methods, machine learning, and many more. The school will describe real world applications and discuss interactions with related disciplines such as image processing, machine learning, and biological vision.

Participation

IPAM's Computer Vision Summer School will provide a rare opportunity for researchers in the mathematics, statistics, computer science, and engineering sciences to learn about recent research directions and future challenges in this area. Funding is available to support graduate students and postdoctoral researchers in the early stages of their career, as well as more senior researchers interested in undertaking new research in this area. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications. The application is available online, and is due **March 31, 2013**.

www.ipam.ucla.edu/programs/gss2013

UCLA *IPAM is an NSF funded institute*

Institute for Pure & Applied Mathematics
IPAM
University of California, Los Angeles

Solve the differential equation.

$$t \ln t \frac{dr}{dt} + r = 7te^t$$

$$r = \frac{7e^t + C}{\ln t}$$

WHO HAS THE #1 HOMEWORK SYSTEM FOR CALCULUS?
THE ANSWER IS IN THE QUESTIONS.

When it comes to online calculus, you need a solution that can grade the toughest open-ended questions. And for that there is one answer: WebAssign.

Only WebAssign's patent pending grading engine can recognize multiple correct answers to the same complex question. Competitive systems, on the other hand, are forced to use multiple choice answers because, well they have no choice. And speaking of choice, only WebAssign supports every major textbook from every major publisher. With new interactive tutorials and videos offered to every student, it's not hard to see why WebAssign is the perfect answer to your online homework needs.

It's all part of the WebAssign commitment to excellence in education. Learn all about it now at webassign.net/math.

WebAssign®

The way you imagined teaching could be.™

800.955.8275 webassign.net/math

MATHEMATICAL MOMENTS

See inside
for examples of math applied to real-world problems.

MATHEMATICAL MOMENTS

Being on the Cutting Edge

Cutters of diamonds and other gemstones have a high-pressure job with conflicting demands: Flaws must be removed from rough stones to maximize brilliance but done so in a way that yields the greatest weight possible. Because diamonds are often cut to a standard shape, cutting them is far less complex than cutting other gemstones, such as rubies or sapphires, which can have hundreds of different shapes. By coupling geometry and multivariable calculus with optimization techniques, mathematicians have been able to devise algorithms that automatically generate precise cutting plans that maximize brilliance and yield.

AMS American Mathematical Society — *The Mathematical Moments program promotes appreciation and understanding of the role mathematics plays in science, nature, technology, and human culture.*

www.ams.org/mathmoments

MM1994

MATHEMATICAL MOMENTS

Getting a Handle on Obesity

Once a problem only in the developed world, obesity is now a worldwide epidemic. The overwhelming cause of the epidemic is a dramatic increase in the food supply and in food consumption—not a surprise. Yet there are still many mysteries about weight change that can't be answered either inside the lab, because of the impracticality of keeping people isolated for long periods of time, or outside, because of the unreliability of dietary diaries. Mathematical models based on differential equations can help overcome this roadblock and allow detailed analysis of the relationship between food intake, metabolism, and weight change. The models' predictions fit existing data and explain such things as why it is hard to keep weight off and why obese people are more susceptible to further weight gain.

Photo: Ryan McVay

AMS American Mathematical Society — *The Mathematical Moments program promotes appreciation and understanding of the role mathematics plays in science, nature, technology, and human culture.*

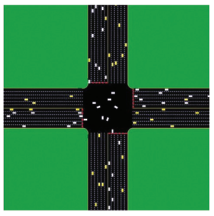
www.ams.org/mathmoments

MM1995

MATHEMATICAL MOMENTS

Putting the Auto in Automobile

It may be hard to accept but it's likely that we'd all be much safer in autonomous vehicles driven by computers, not humans. Annually more than 30,000 Americans die in car crashes, almost all due to human error. Autonomous vehicles will communicate position and speed to each other and avoid potential collisions—without the possibility of dozing off or road rage. There are still many legal (and insurance) issues to resolve, but researchers who are revving up the development of autonomous vehicles are relying on geometry for recognizing and tracking objects, probability to assess risk, and logic to prove that systems will perform as required.



Design: Kurt Dresner, Tsu-Chin Au, and Peter Stone, Department of Computer Science, UT Austin

AMS American Mathematical Society — *The Mathematical Moments program promotes appreciation and understanding of the role mathematics plays in science, nature, technology, and human culture.*

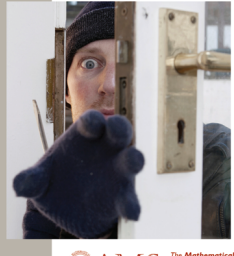
www.ams.org/mathmoments

MM1996

MATHEMATICAL MOMENTS

Forecasting Crime

No one can predict *who* will commit a crime but in some cities math is helping detect areas *where* crimes have the greatest chance of occurring. Police then increase patrols in these "hot spots" in order to prevent crime. This innovative practice, called predictive policing, is based on large amounts of data collected from previous crimes, but it involves more than just maps and push pins. Predictive policing identifies hot spots by using algorithms similar to those used to predict aftershocks after major earthquakes. Just as aftershocks are more likely near a recent earthquake's epicenter, so too are crimes, as criminals do indeed return to, or very close to, the scene of a crime.



AMS American Mathematical Society — *The Mathematical Moments program promotes appreciation and understanding of the role mathematics plays in science, nature, technology, and human culture.*

www.ams.org/mathmoments

MM1997

MATHEMATICAL MOMENTS

Catching and Releasing

There's more mathematics involved in juggling than just trying to make sure that the number of balls (or chainsaws) that hits the ground stays at zero. Subjects such as combinatorics and abstract algebra help jugglers answer important questions, such as whether a particular juggling pattern can actually be juggled. For example, can balls be juggled so that the time period that each ball stays aloft alternates between five counts and one? The answer is "Yes." Math also tells you that the number of balls needed for such a juggling pattern is the average of the counts, in this case three.

AMS American Mathematical Society — *The Mathematical Moments program promotes appreciation and understanding of the role mathematics plays in science, nature, technology, and human culture.*

www.ams.org/mathmoments

MM1998

MATHEMATICAL MOMENTS

Finding Friends

Facebook has over 700 million users with almost 70 billion connections. The hard part isn't people making friends; rather it's Facebook's computers storing and accessing relevant data, including information about friends of friends. The latter is important for recommendations to users (People You May Know). Much of this work involves computer science, but mathematics also plays a significant role. Subjects such as linear programming and graph theory help cut in half the time needed to determine a person's friends of friends and reduce network traffic on Facebook's machines by about two-thirds. What's not to like?

Image of 2010 Facebook connections by Paul Butler.

AMS American Mathematical Society — *The Mathematical Moments program promotes appreciation and understanding of the role mathematics plays in science, nature, technology, and human culture.*

www.ams.org/mathmoments

MM1999

See 100 Mathematical Moments, **hear** people talk about how they use math on the job in the modern world, and **read translations** in 13 languages at

www.ams.org/mathmoments

AMS
AMERICAN MATHEMATICAL SOCIETY
ams.org

MM2012

Notices

of the American Mathematical Society

December 2012

Communications

1560 WHAT IS...a Shimura Variety?
James S. Milne

1569 Alexander Abrosimov
Valery Beloshapka, Aleksey Kalinin, Michael Kuznetsov, Kirill Mayorov, Grigory Polotovskiy, Ivan Remizov, Yakov Sennikovskiy, George Shabat, Mikhail Tokman, Alexander Tumanov, Grigoriy Zhislin

1571 *Doceamus:* The University of California Cal Teach Program: Recruiting Highly Qualified Future Teachers of Mathematics and Science
Edward Landesman and Gretchen Andreasen

1574 *Scripta Manent: Geometry & Topology*: A Community-Based Publishing Initiative
Colin Rourke

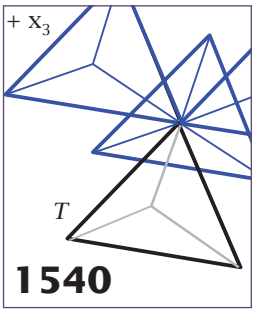
Commentary

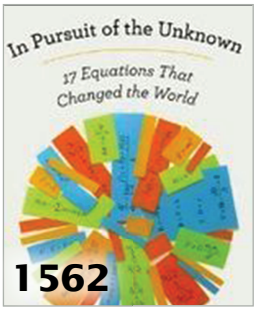
1518 Opinion: The Math Gene: A Ticket to Wealth or Nerdiness?
Ronald Lipsman

1520 Letters to the Editor, Corrections

1562 The Universe in Zero Words *and* In Pursuit of the Unknown—Review of Two Books
Reviewed by Gerald B. Folland

1565 The Mathematical Writings of Évariste Galois—A Book Review
Reviewed by Charles W. Curtis





This month we celebrate the 125th anniversary of the remarkable Srinivasa Ramanujan. To commemorate the event, there is a four-part article about different aspects of his life and ideas. We also have features about Leibniz's ideas in calculus, and about tetrahedral packing. The Opinion Column on the math gene should strike a familiar chord with many readers. As usual, we round things out with the *Doceamus* and *Scripta Manent* columns.

—Steven G. Krantz, Editor

Features

1522 Srinivasa Ramanujan: Going Strong at 125, Part I
Krishnaswami Alladi, Editor

1540 Mysteries in Packing Regular Tetrahedra
Jeffrey C. Lagarias and Chuanming Zong

1550 Leibniz's Laws of Continuity and Homogeneity
Mikhail G. Katz and David M. Sherry

Notices
of the American Mathematical Society

EDITOR: Steven G. Krantz

ASSOCIATE EDITORS:
Krishnaswami Alladi, David Bailey, Jonathan Borwein, Susanne C. Brenner, Bill Casselman (*Graphics Editor*), Robert J. Daverman, Susan Friedlander, Robion Kirby, Rafe Mazzeo, Harold Parks, Lisette de Pillis, Peter Sarnak, Mark Saul, Edward Spitznagel

SENIOR WRITER and DEPUTY EDITOR:
Allyn Jackson

MANAGING EDITOR: Sandra Frost

CONTRIBUTING WRITER: Elaine Kehoe

CONTRIBUTING EDITOR: Randi D. Ruden

EDITORIAL ASSISTANT: David M. Collins

PRODUCTION: Kyle Antonevich, Anna Hattoy, Teresa Levy, Mary Medeiros, Stephen Moye, Erin Murphy, Lori Nero, Arlene O'Sean, Karen Ouellette, Donna Salter, Deborah Smith, Peter Sykes, Patricia Zinni

ADVERTISING SALES: Anne Newcomb

SUBSCRIPTION INFORMATION: Subscription prices for Volume 60 (2013) are US$547 list; US$437.60 institutional member; US$328.20 individual member; US$492.30 corporate member. (The subscription price for members is included in the annual dues.) A late charge of 10% of the subscription price will be imposed upon orders received from nonmembers after January 1 of the subscription year. Add for postage: Surface delivery outside the United States and India—US$27; in India—US$40; expedited delivery to destinations in North America—US$35; elsewhere—US$120. Subscriptions and orders for AMS publications should be addressed to the American Mathematical Society, P.O. Box 845904, Boston, MA 02284-5904 USA. All orders must be prepaid.

ADVERTISING: *Notices* publishes situations wanted and classified advertising, and display advertising for publishers and academic or scientific organizations. Advertising material or questions may be sent to `classads@ams.org` (classified ads) or `notices-ads@ams.org` (display ads).

SUBMISSIONS: Articles and letters may be sent to the editor by email at `notices@math.wustl.edu`, by fax at 314-935-6839, or by postal mail at Department of Mathematics, Washington University in St. Louis, Campus Box 1146, One Brookings Drive, St. Louis, MO 63130. Email is preferred. Correspondence with the managing editor may be sent to `notices@ams.org`. For more information, see the section "Reference and Book List".

NOTICES ON THE AMS WEBSITE: Supported by the AMS membership, most of this publication is freely available electronically through the AMS website, the Society's resource for delivering electronic products and services. Use the URL `http://www.ams.org/notices/` to access the *Notices* on the website.

[*Notices of the American Mathematical Society* (ISSN 0002-9920) is published monthly except bimonthly in June/July by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2294 USA, GST No. 12189 2046 RT****. Periodicals postage paid at Providence, RI, and additional mailing offices. POSTMASTER: Send address change notices to *Notices of the American Mathematical Society*, P.O. Box 6248, Providence, RI 02940-6248 USA.] Publication here of the Society's street address and the other information in brackets above is a technical requirement of the U.S. Postal Service. Tel: 401-455-4000, email: `notices@ams.org`.

© Copyright 2012 by the American Mathematical Society.
All rights reserved.

Printed in the United States of America. The paper used in this journal is acid-free and falls within the guidelines established to ensure permanence and durability.

Departments

About the Cover 1558

Mathematics People 1576

Viehmann Awarded von Kaven Prize, Prizes of the Canadian Mathematical Society, Shiller Awarded 2012 CME/MSRI Prize, NDSEG Fellowships Awarded, B. H. Neumann Awards Given.

Mathematics Opportunities 1578

AWM Announces Two New Research Prizes, STaR Program for Early Career Mathematics Educators, MfA Fellowship Program, NSF Program in Computational and Data-Enabled Science and Engineering in Mathematical and Statistical Sciences, NDSEG Fellowships, News from the Bernoulli Center.

For Your Information 1580

Departments Coordinate Job Offer Deadlines, New PIMS Headquarters.

Inside the AMS 1581

2012 Trjitzinsky Memorial Awards Presented, Project NExT Fellows Chosen, MSC/SKOS—The New Implementation of the MSC as a Linked Open Dataset, Free Grant Writing Workshop Offered, Deaths of AMS Members.

Reference and Book List 1583

Mathematics Calendar 1588

New Publications Offered by the AMS 1598

Classified Advertisements 1606

2013 AAAS Meeting in Boston, MA 1613

Meetings and Conferences of the AMS 1614

2012 *Notices* Index 1626

San Diego Meeting Registration Forms 1645

Meetings and Conferences Table of Contents 1647

Opinions expressed in signed *Notices* articles are those of the authors and do not necessarily reflect opinions of the editors or policies of the American Mathematical Society.

The American Mathematical Society *announces*

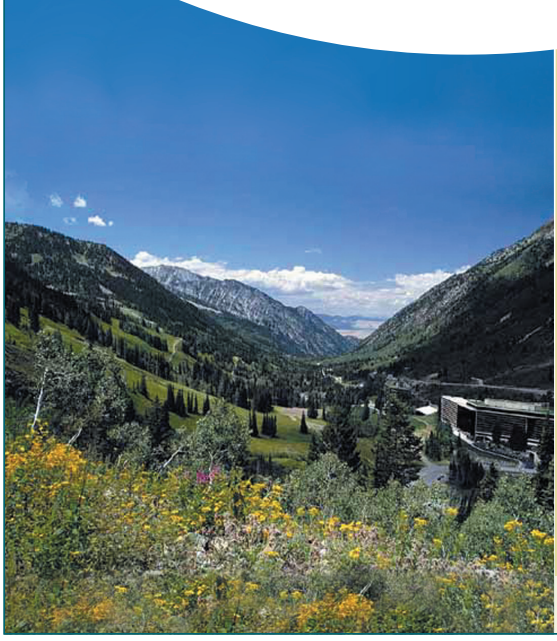
Mathematics Research Communities

The AMS invites mathematicians just beginning their research careers to become part of **Mathematics Research Communities**, a program to develop and sustain long-lasting cohorts for collaborative research projects in many areas of mathematics. Women and underrepresented minorities are especially encouraged to participate. The AMS will provide a structured program to engage and guide all participants as they start their careers. The program will include:

- One-week summer conference for each topic
- Special Sessions at the national meeting
- Discussion networks by research topic
- Longitudinal study of early career mathematicians

The summer conferences of the Mathematics Research Communities will be held in the breathtaking mountain setting of the Snowbird Resort, Utah, where participants can enjoy the natural beauty and a collegial atmosphere. **The application deadline for summer 2013 is March 1, 2013.**

This program is supported by a grant from the National Science Foundation.



Week 1a (June 9-15, 2013)
Complex Dynamics

Organizers:
Laura DeMarco (University of Illinois at Chicago)
Adam Epstein (University of Warwick)
Sarah Koch (Harvard University)

Week 1b (June 9-15, 2013)
Tropical and Nonarchimedean Analytic Geometry

Organizers:
Matt Baker (Georgia Institute of Technology)
Sam Payne (Yale University)

AMS
American Mathematical Society
ams.org

Week 2 (June 16-22, 2013)
Geometric Group Theory

Organizers:
Ruth Charney (Brandeis University)
Tullia Dymarz (University of Wisconsin, Madison)
Dan Margalit (Georgia Institute of Technology)
Kim Ruane (Tufts University)
Kevin Wortman (University of Utah)

Week 3 (June 25-July 1, 2013)
Regularity Problems for Nonlinear Partial Differential Equations Modeling Fluids and Complex Fluids

Organizers:
Peter Constantin (Princeton University)
Gautam Iyer (Carnegie Mellon University)
Igor Kukavica (University of Southern California)
Helena Nussenzveig-Lopes (Universidade Federal do Rio de Janeiro)
Jiahong Wu (Oklahoma State University)

www.ams.org/programs/research-communities/mrc

Opinion

The Math Gene: A Ticket to Wealth or Nerdiness?

To say that a person has the Math Gene[1] is to attribute to him an unusual propensity to handle numbers and the advanced algorithmic processes by which experts manipulate them. Among the people who possess these special talents, there is no biological or neurological evidence for any of it. And yet, those of us who exhibit these traits are easily identified among the general population.

My gene became evident at a young age and has remained conspicuous during all of my professional life. Throughout my journey, I have naturally and consciously surrounded myself with others like me. This is not surprising. Human beings always seek companions and colleagues who not only think and behave like they do, but inhabit a world of ideas, attitudes, and habits similar to their own.

In fact we mathematicians stand out. We don't think and behave like the vast majority of our fellow citizens. John Q. Public knows us when he sees us, and—at the risk of overgeneralization—here are some of the more striking of our singular characteristics:

- We're often socially awkward. We generally don't pay much attention to clothes, fashion, or what's in or hot or cool. Our homes, cars, and bodies are often unkempt, and we do poorly at small talk. We tend to be introverted, soft-spoken, and not terribly athletic.
- We excel at abstract thinking, but are notoriously weak at practical affairs.
- We are amazing problem solvers, especially those of the abstract or theoretical variety; but please don't ask us to change a tire or balance a checkbook.
- We sometimes find it hard to look you straight in the eye, and we are easily embarrassed when we find ourselves the center of attention.

I cannot tell you how many times in my life when, in casual conversation with someone I've just met, after I reveal that I am a mathematician, the reaction is: "Omigod, math was my worst subject in school; it was soooo hard. You must be a genius." But at the same time, the one who has just uttered the confession/paean gives a furtive look at a fellow conversant which screams: "What a nerd! I wouldn't have been like this guy for my weight in gold."

However, in recent years, I detect another partially hidden reaction—both in stolen glances as well as in meekly asked follow-up questions, such as "So do you have a software or consulting company? I bet that you do OK?"

This is a result of society's increasing fascination with technology and the seeming nerds who have pioneered its development. The names Bill Gates, Steve Jobs, Sergey Brin, and Mark Zuckerberg come to mind. Which leads to the question posed in the title: Is the Math Gene a ticket to wealth or nerdiness?

Alas, if there is a definitive answer, it is far closer to the latter than the former. Of the four names cited, only Brin can lay any claim to being a mathematician, and in fact his academic pedigree is more computer science than mathematics. Indeed, I know of only one academic mathematician—a former professor at Stony Brook University—who parlayed his math talent into a fortune. There might be others, but I doubt very many. For, generally speaking, the qualities that I have identified, which characterize mathematicians, are not those that equip a person with the skills needed to acquire great wealth.

Although the depiction of Mark Zuckerberg in the opening scene of "The Social Network" suggests some of the math nerd characteristics that I've specified, it would be a mistake to suppose that those traits helped Zuckerberg to attain the phenomenal wealth that he enjoys today. No, the traits that enabled him and the other great modern technological entrepreneurs to do the things that garnered massive wealth for them were otherwise. They certainly include: extraordinary creativity and originality—as opposed to mere problem-solving skills; a willingness, indeed eagerness, to take great risks; an aggressive, self-confident, and strong-willed personality; persistence and single-mindedness; an ability to read people and gauge their desires; and an inclination to defy convention and a lack of concern about what others think of them.

Not exactly the characteristics of your typical mathematician. But, if I might address a wider audience than just the normal *Notices*' readership: Not to despair, all ye parents and grandparents of a budding mathematician. Your progeny will not be cool, not trendy, probably not a leader of men, and almost certainly not rich. But a life of mathematics will yield: the satisfaction of cracking numerous mathematical puzzles; a professional life of honesty, fulfillment, a sense of doing something worthy, and occasional serenity; a camaraderie with others who are similarly endowed; and the respect, if not admiration, from the people one serves.

So, if your kid can swing a golf club as well as he can juggle numbers, and if you think that he would prefer riches to the contentment of a life filled with numbers, then take away his calculator and jam a putter in his hand. But, if he does have the Math Gene and you encourage it to flourish, then I promise you that he will lead a life in which he enjoys what he does for a living, often feels the joy of solving problems—even if they are theoretical and not practical—and finally, through teaching and research, he will take pride and pleasure in his role in the advancement of human knowledge.

—Ronald Lipsman
Emeritus, University of Maryland
rlipsman@umd.edu

[1]The title of this essay "The Math Gene" is the same as the title of Keith Devlin's fascinating 2001 book. But the essay takes a different point of view. Whereas Devlin's book deals with the nature of mathematical thought, the workings of the human mind, and an intricate comparison of innate mathematical ability with innate language ability, this essay deals solely with the nature and behavior of mathematicians themselves—in particular, their social manifestations and economic motivations.

DOI: http://dx.doi.org/10.1090/noti919

AMERICAN MATHEMATICAL SOCIETY

Your charitable gift to the AMS in 2012:

Thank You!

AMS
AMERICAN MATHEMATICAL SOCIETY
ams.org

For more information, visit ams.org/about-us/support-ams/

Letters to the Editor

Mathematics and Home Schooling

I read the article "Mathematics and home schooling" (*Notices*, April 2012) and would like to make some comments. I and my wife are homeschooling parents, we are evangelical Christians, and we have homeschooled five children to varying grades. The oldest (a girl) is about to graduate in mechanical engineering.

1) The Constitution starts with the words "We the People". The people delegate tasks to the government, but it was never the intention of the framers that the state would be the repository of authority and would delegate responsibility to parents. I take my responsibility as a parent very seriously, from God who gave me the children to begin with, and I do not recognize the state as delegating authority to me. The responsibility and authority are mine unless I screw up. What I do recognize is the right of the other "people" around me to take action if they see me not performing my responsibility to educate my children. Those "people" can form a government if they like, to enforce their view of what should be done as a minimum standard (and they have done so). The authors quote the Tenth Amendment, where powers not delegated to the United States by the Constitution, nor prohibited to it by the States, are reserved to the States respectively, or to the people.

2) Much is made in the article about girls and certain publications. I've never heard of them (and I've seen and heard a lot, being on homeschooling mailing lists), and I note the absence of data. What principal or school board member was ever seen going to a girls basketball game? There is ample data on gender discrimination in society, and the schools must be held accountable.

3) I do avoid the public school system out of a desire to maintain a Godly curriculum. It makes a major difference to a young person to know that God created them. Therefore others around them are special, and should be treated tenderly. The kids come home from high school talking about Maslow's "hierarchy of needs", which is accepted without any evidence. One gets only what one gives, and the giving has to come first. The focus is on giving, not on trying to fulfill one's needs first (which is selfish and is hurtful to teach).

4) Much of "teacher certification" training is in handling groups of youngsters, preparing and executing group instruction, and is not germane to a home-schooling situation.

—Thomas A. Ryan
thomas.a.ryan@thesiorg.com

(Received July 23, 2012)

A Collision with Salam

Regarding *The Infinity Puzzle*, reviewed by Brian E. Blank, in the *Notices*, September 2012. May I share a personal experience from my undergraduate days in Imperial College London in 1966? I was rushing to a class and collided with someone who almost fell over. In my haste I did not stop to apologize. Later I was told that I had almost killed a potential Nobelist. My victim was Salam, the same Nobelist discussed on p. 1107 of Mr. Blank's review.

—Frank Okoh
Wayne State University
okoh@math.wayne.edu

(Received September 6, 2012)

Severi's Last Political Creed

There is one more piece of information that could complement the interesting article "A fresh look at Francesco Severi", by Judith Goodstein and Donald Babbitt (*Notices*, September 2012). In the last years of his life Severi was the president of the "Associazione Italia-URSS", a cultural association which was financed by the Soviet Union and was very close to the Italian Communist Party. Perhaps this association could deserve the epithet of "Communist Front Organization".

—Alessandro Figà Talamanca
Sapienza University of Rome
sandroft938@gmail.com

(Received September 10, 2012)

Correction

The "Mathematics Opportunities" section of the August 2012 issue of *Notices*, carried a Call for Nominations for the Otto Neugebauer Prize, giving a deadline of December 31, 2012. In fact, the prize was awarded in July 2012, and the call for nominations is not open at present.

—Sandy Frost

Correction

The photographer for the photo in Figure 7 in "Glimpses of Benoît B. Mandelbrot (1924–2010)", *Notices*, September 2012, was incorrectly identified as Richard Bernt. The photographer was actually Bernt Wahl.

—Sandy Frost

JOINT MATHEMATICS MEETINGS
SAN DIEGO • JAN 9-12, 2013
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA

The 2013 Employment Center

Exhibit Hall A, San Diego Convention Center
San Diego, California
January 9–12, 2013

Open hours:

Wednesday, January 9, 8:00 a.m. – 6:00 p.m.
Thursday, January 10, 8:00 a.m. – 6:00 p.m.
Friday, January 11, 8:00 a.m. – 6:00 p.m.
Saturday, January 12, 9:00 a.m. – noon

Visit www.ams.org/emp-reg for registration instructions.

AMS
American Mathematical Society
www.ams.org

Srinivasa Ramanujan: Going Strong at 125, Part I

Krishnaswami Alladi, Editor

The 125th anniversary of the birth of the Indian mathematical genius Srinivasa Ramanujan falls on December 22, 2012. To mark this occasion, the Notices *offers the following feature article, which appears in two installments. The article contains an introductory piece describing various major developments in the world of Ramanujan since his centennial in 1987, followed by seven pieces describing important research advances in several areas of mathematics influenced by him. The first installment in the present issue of the* Notices *contains the introductory piece by Krishnaswami Alladi, plus pieces by George Andrews, Bruce Berndt, and Jonathan Borwein. Pieces by Ken Ono, K. Soundararajan, R. C. Vaughan, and S. Ole Warnaar will appear in the second installment in the January 2013 issue of the* Notices.

Krishnaswami Alladi

Ramanujan's Thriving Legacy

Srinivasa Ramanujan is one of the greatest mathematicians in history and one of the most romantic figures in the mathematical world as well. Born on December 22, 1887, to a poor Hindu brahmin family in Erode in the state of Tamil Nadu in South India, Ramanujan was a self-taught genius who discovered a variety of bewildering identities starting from his school days. There is a legend that the Hindu goddess Namagiri in the neighboring town of Namakkal used to come in his dreams and give him these formulae. Unable to find individuals in India to understand and evaluate his findings, Ramanujan wrote two letters in 1913 to G. H. Hardy of Cambridge University, England, listing several of his most appealing formulae. The depth and startling beauty of these identities convinced Hardy that Ramanujan was on a par with Euler and Jacobi in sheer manipulative ability. At Hardy's invitation, Ramanujan went to Cambridge in 1914. The rest is history. In the five years he was in England, Ramanujan published several important papers, some of which stemmed from his discoveries in India; he collaborated with G. H. Hardy and wrote two very influential papers with him. For his pathbreaking contributions, Ramanujan was honored by being elected Fellow of Trinity College, Cambridge, and Fellow of the Royal Society (FRS) even though he did not have a college degree! The rigors of life in England during the First World War, combined with his own peculiar habits, led to a rapid decline in his health. Ramanujan returned to Madras, India, in 1919 a very sick man and died shortly after on April 20, 1920. Even during his last days, his mathematical creativity remained undiminished. He wrote one last letter to Hardy in January 1920 outlining his discovery of the mock theta functions, considered to be among his deepest contributions. In the decades after Ramanujan's death, we have come to realize the depth, breadth, and significance of his many discoveries. Ramanujan's work has had a major influence on several branches of mathematics, most notably in number theory and classical analysis, and even in some areas of physics.

During the Ramanujan Centennial in 1987, eminent mathematicians from around the world gathered in India to pay homage to this singular genius. It was an appropriate time to reflect on his legacy and consider the directions in which his work would have influence in the future. In this quarter century since the centennial, many significant developments have taken place in the world of Ramanujan: (i) there have been major research advances in recent years that have widened the arena of impact of Ramanujan's work; (ii) books on Ramanujan's work, of interest to students

Krishnaswami Alladi is professor of mathematics at the University of Florida, Gainesville. His email address is alladik@ufl.edu.

DOI: http://dx.doi.org/10.1090/noti917

and researchers alike, and books on Ramanujan's life with appeal to the general public have been published; (iii) journals bearing Ramanujan's name have been established, one of which is devoted to all areas of research influenced by him; (iv) annual conferences devoted to various aspects of Ramanujan's work are being held in his hometown in India; (v) international prizes bearing his name and encouraging young mathematicians have been created; and (vi) movies and plays about Ramanujan inspired by his remarkable life have also appeared or are in production.

This feature in the *Notices of the AMS* is devoted to describing some of the significant developments in the world of Ramanujan since the centennial. My opening article will broadly address the developments listed under (i)–(vi). This will be followed by articles by leading mathematicians on various aspects of research related to Ramanujan's work.

Some Major Research Advances

I focus here on certain aspects of the theory of partitions and q-hypergeometric series with which I am most familiar and provide just a sample of some very important recent results. Research relating to Ramanujan's work in many other areas has been very significant, and some of these ideas will be described by others in the following articles.

Ramanujan's mock theta functions are mysterious, and the identities he communicated to Hardy about them are deep. Since George Andrews unearthed the *Lost Notebook of Ramanujan* at Trinity College Library in Cambridge University in 1976, he has been analyzing the identities contained therein, especially those on the mock theta functions. We owe much to Andrews for explaining the mock theta function identities in the context of the theory partitions (see for instance [12]). In Andrews-Garvan [21] the mock theta conjectures are formulated. These relate the q-hypergeometric mock theta function identities to partition identities; the mock theta conjectures were proved by Hickerson [40] around the time of the centennial.

In spite of their resemblance to the classical theta functions, the exact relationship between the mock theta functions and theta functions remained unclear. In the last decade, dramatic progress on this matter has been achieved by Ken Ono and his coworkers, most notably Kathrin Bringmann, in establishing the links between mock theta functions and Maass forms, thereby providing the key to unlock this mystery [32], [33], [34].

Ramanujan's congruences for the partition function modulo the primes 5, 7, and 11 and their powers are among his most significant discoveries. More specifically, Ramanujan discovered that $p(5n+4)$ is a multiple of 5, $p(7n+5)$ is a multiple of 7, and $p(11n+6)$ is a multiple of 11, where $p(n)$ is the number of partitions of n. In the ensuing decades, this led to a fruitful study of congruences satisfied by coefficients of modular forms. Yet it was unclear whether the partition function itself satisfied congruences with respect to other primes. Oliver Atkin [22] was the first to discover congruences for the partition function of the type $p(An+b) \equiv C \pmod{p}$ with a prime modulus $p > 11$, but unlike the Ramanujan congruences, we have A not equal to p. In recent years Scott Ahlgren [1] and Ken Ono [44] have discovered partition congruences to larger prime moduli and have shown that there are indeed infinitely many such congruences.

Ramanujan (see [46]) wrote down two spectacular identities for the generating functions of $p(5n+4)$ and $p(7n+5)$, from which his congruences modulo 5 and 7 follow. Proofs of Ramanujan's partition congruences were given by Atkin using the theory of modular forms. In 1944, Freeman Dyson [35] gave a combinatorial explanation of Ramanujan's partition congruences mod 5 and 7 using the now famous statistic he called the *rank*. He then conjectured the existence of a statistic

Photo courtesy of Krishnaswami Alladi.

The bust of Ramanujan now stands in the central hall of his home in Kumbakonam. The bust was added after SASTRA University purchased Ramanujan's home. In the background is a replica of his famous passport photograph.

he dubbed the *crank* that would explain the mod 11 congruence. A combinatorial explanation of Ramanujan's partition congruence modulo 11 was first given in the Ph.D. thesis of Frank Garvan [36] using vector partitions and a vector crank. This was then converted to ordinary partitions by Andrews and Garvan [20] when they got together at the Ramanujan Centennial Conference at the University of Illinois, Urbana, in the summer of 1987, and so finally the crank conjectured by Dyson was found. Perhaps the Goddess of Namakkal made sure that the solution to this problem should actually happen during the Ramanujan Centennial! Since 1987 there has been an enormous amount of work on the rank and on cranks for various partition statistics by several mathematicians: Garvan, Kim, and Stanton [37] found cranks for t-cores; Mahlburg [43] found cranks for the partition congruences to moduli larger than 11; and Andrews [16] has noticed new connections with Durfee symbols of partitions. In the last decade, Richard Stanley [49] introduced a refinement of Dyson's rank, and this has led to important refinements and extensions of Ramanujan's partition congruences (see for instance Andrews [15] and Berkovich-Garvan [24]).

In the entire theory of partitions and q-hypergeometric series, the Rogers-Ramanujan identities are unmatched in simplicity of form, elegance, and depth. This pair of identities connects partitions into parts that differ by at least two with partitions into parts congruent to $\pm i \pmod 5$, for $i = 1, 2$. Nowadays, by a Rogers-Ramanujan (R-R) type identity, we mean an identity which in its analytic form equates a q-hypergeometric series to a product, where the series represents the generating function of partitions whose parts satisfy gap conditions and the product is the generating function of partitions whose parts satisfy congruence conditions. This subject has blossomed into an active area of research thanks to systematic analysis of R-R type identities, primarily by Andrews ([11], Chapter 7). In the 1980s the Australian physicist Rodney Baxter showed how certain R-R type identities arise as solutions of some models in statistical mechanics (see Andrews [13], Chapter 8). Soon after, Andrews, Baxter, and Forrester [18] determined the class of R-R type identities that arise in such models in statistical mechanics. For this work Baxter was recognized with the Boltzmann Medal of the American Statistical Society.

Subsequently there has been significant work on q-hypergeometric identities and integrable models in conformal field theory in physics. The leader in this effort is Barry McCoy, who in the 1990s, with his collaborators Alexander Berkovich, Anne Schilling, and Ole Warnaar [25], [26], [27], [28], discovered new R-R type identities from the study of integrable models in conformal field theory. For this work McCoy was recognized with the Heineman Prize in Mathematical Physics and an invited talk at the ICM in Berlin in 1998.

My own work in the theory of partitions and q-hypergeometric series has been in the study of R-R type identities and their refinements [4], especially on a partition theorem of Göllnitz, one of the deepest R-R type identities. In collaboration with Basil Gordon, George Andrews, and Alexander Berkovich, I was able to obtain generalizations and refinements of Göllnitz's partition theorem in 1995 [9] and later, in 2003, a much deeper four-parameter extension of the Göllnitz theorem [10].

Books on Ramanujan's Life and Work

Hardy's twelve lectures on Ramanujan [39] are a classic in exposition. For several decades after Ramanujan's death, this book and the *Collected Papers* [46] of Ramanujan were the primary sources for students and young researchers aspiring to enter the Ramanujan mathematical garden. In 1987, *The Lost Notebook of Ramanujan* was published [48]. Students today are very fortunate, because Bruce Berndt has edited the original three notebooks of Ramanujan and published this material in five volumes [29]. In these volumes one can find proofs of Ramanujan's theorems and how they are related to past and contemporary research. For this monumental contribution, Berndt was recognized with the AMS Steele Prize. In the past five years, Bruce Berndt and George Andrews have joined forces to edit Ramanujan's *Lost Notebook*. This is expected to also require five volumes, of which three have already appeared [19].

Ramanujan is now making an impact beyond mathematics into society in general around the world. Throughout India, Ramanujan's life story is well known, and Ramanujan is a hero to every Indian student. But with the publication of Robert Kanigel's book *The Man Who Knew Infinity* [41], Ramanujan's life story has reached the world over. The impact of this book cannot be underestimated (see [2]). Subsequently, Bruce Berndt and Robert Rankin have published two wonderful books. The first one, called *Ramanujan—Letters and Commentary* [30], collects various letters written to, from, and about Ramanujan and makes detailed commentaries on each letter. For instance, if a letter contains a mathematical statement, there is an explanation of the mathematics with appropriate references. If there is a statement about Ramanujan being elected Fellow of the Royal Society, there is a description about the procedures and practices for such an election (see review [3]). The second book, *Ramanujan—Essays and Surveys* [31], is a collection of excellent articles by various

experts on Ramanujan's life and work and about various individuals who played a major role in Ramanujan's life (see review [5]). This book also contains an article by the great mathematician Atle Selberg, who describes how he was inspired by Ramanujan's mathematical discoveries. Most recently, David Leavitt has published a book [42] entitled *The Indian Clerk* which focuses on the close relationship between Ramanujan and Hardy (see review [38]). All of these books will not only appeal to mathematicians but to students and lay persons as well.

Since the Ramanujan Centennial, I have written articles annually comparing Ramanujan's life and mathematics with those of several great mathematicians in history, such as Euler, Jacobi, Galois, Abel, and others. These articles, which were written to appeal to the general public, appeared in *The Hindu*, India's national newspaper, each year around Ramanujan's birthday in December. The collection of all these articles, along with my book reviews and other Ramanujan-related articles, has just appeared as a book [8] for Ramanujan's 125th anniversary.

There are many other books on Ramanujan that have been published, and my list above is certainly not exhaustive. However, I must add to this list the comprehensive CD on Ramanujan that Srinivasa Rao brought out in India a few years ago. In this CD we have scanned images of Ramanujan's notebooks, his papers, several articles about Ramanujan, many important letters, etc.

Journals Bearing Ramanujan's Name

Inspired by what I saw and heard during the Ramanujan Centennial, I wanted to create something that would be a permanent and continuing memorial to Ramanujan, namely, *The Ramanujan Journal*, devoted to all areas of mathematics influenced by Ramanujan. This idea received enthusiastic support from mathematicians worldwide, many of whom have served, or are serving, on the editorial board. The journal was launched in 1997 by Kluwer Academic Publishers, which published four issues of one hundred pages per year in one volume. Now the journal is published by Springer, which publishes nine issues per year of one hundred fifty pages each in three volumes. The rapid growth of this journal is a further testimony to the fact that Ramanujan's work is continuing to have major influence on various branches of mathematics.

There is another journal bearing Ramanujan's name: *The Journal of the Ramanujan Mathematical Society*, which is distributed by the AMS and is devoted to all areas of mathematics. It bears Ramanujan's name since he is India's most illustrious mathematician.

Photo courtesy of Krishnaswami Alladi.

Left to right: Krishnaswami Alladi, George Andrews (Pennsylvania State University), and SASTRA Vice-chancellor R. Sethuraman in front of a bust of Srinivasa Ramanujan at SASTRA University, Kumbakonam—December 22, 2003.

Prior to these two journals, in the 1970s Professor K. Ramachandra (now deceased) founded *The Hardy-Ramanujan Journal*, devoted to elementary and classical analytic number theory, and published it privately in India.

Annual Conferences in Ramanujan's Hometown

A recent major event in the world of Ramanujan is the acquisition in 2003 of Ramanujan's home in Kumbakonam, South India, by SASTRA University. This private university, founded about twenty years ago, has grown by leaps and bounds. Since the university has purchased Ramanujan's home, we have the active involvement of administrators, academicians, and students in the preservation of Ramanujan's legacy. To mark the occasion of the purchase of Ramanujan's home, SASTRA University conducted an international conference at its Kumbakonam campus December 20–22, 2003, and had it inaugurated by Dr. Abdul Kalam, president of India. I was invited to bring a team of mathematicians to this conference. George Andrews gave the opening lecture of this conference as well as the concluding Ramanujan Commemoration Lecture on December 22, Ramanujan's birthday. At the conclusion of the conference, the participants suggested that SASTRA should conduct conferences annually in Kumbakonam on various areas of mathematics influenced by Ramanujan. I have helped SASTRA organize these annual conferences. Each year several leading researchers visit SASTRA in December to speak at these conferences, and by participating in them, I have had the pleasure of spending Ramanujan's birthday, December 22, every year in Ramanujan's hometown (see [6]).

Prizes Bearing Ramanujan's Name

At the inauguration of the second Ramanujan conference at SASTRA University in December 2004, Vice Chancellor Professor R. Sethuraman graciously offered to set apart US$10,000 annually to recognize pathbreaking research by young mathematicians.

In response to his offer of such support, I suggested that an annual prize be launched the next year to be given to mathematicians not exceeding the age of thirty-two for outstanding contributions to areas influenced by Ramanujan. The age limit was set at thirty-two because Ramanujan achieved so much in his brief life of thirty-two years. Thus the SASTRA Ramanujan Prize was born. In 2005, the year the prize was launched, the prize committee felt that two brilliant mathematicians, Manjul Bhargava (Princeton) and Kannan Soundararajan (then at Michigan, now at Stanford), both deserved the prize for spectacular contributions to algebraic and analytic number theory respectively. The vice chancellor generously informed the prize committee that there would be two full prizes that year, and it would not be split. The prestige of any prize is determined by the caliber of the winners. The SASTRA Ramanujan Prize could not have had a better start (see [7], [45]). The prize is now one of the most prestigious and coveted. The subsequent winners are: Terence Tao (UCLA) in 2006, Ben Green (Cambridge University) in 2007, Akshay Venkatesh (Stanford) in 2008, Kathrin Bringmann (Cologne) in 2009, Wei Zhang (Harvard) in 2010, Roman Holowinsky (Ohio State) in 2011, and Zhiwei Yun (MIT and Stanford) in 2012. This prize has been given in December each year in Ramanujan's hometown, Kumbakonam, during the SASTRA Ramanujan Conference.

There is another very prestigious prize with Ramanujan's name attached, namely, the ICTP Ramanujan Prize. The International Centre for Theoretical Physics (ICTP) in Trieste, Italy, was created in the sixties by the great physicist Abdus Salam with a particular commitment to encourage scientists from developing countries. Keeping this vision of Salam, the ICTP Ramanujan Prize launched in 2003 is a US$10,000 annual prize for mathematicians under the age of forty-five from developing countries for outstanding research in any branch of mathematics. Whereas the SASTRA Ramanujan Prize is open to mathematicians the world over but focuses on areas influenced by Ramanujan, the ICTP Ramanujan Prize is open to all areas of mathematics but focuses on candidates from developing countries. The ICTP Prize has Ramanujan's name because Ramanujan is the greatest mathematician to emerge from a developing country. The ICTP Ramanujan Prize is given in cooperation with the Abel Foundation.

Finally, there is the Srinivasa Ramanujan Medal given by the Indian National Science Academy for outstanding contributions to mathematical sciences. There is no age limit for this medal. Since its launch in 1962, the medal has been given fourteen times.

Movies and Plays about Ramanujan

Ramanujan's life story is so awe inspiring that movies and plays about him have been and are being produced. The first was a superb documentary about Ramanujan in the famous *Nova* series of the Public Broadcasting System (PBS) on television, which described some of his most appealing mathematical contributions in lay terms and some of the most startling aspects of his life, such as the episode of the taxi cab number 1729. This documentary was produced before the Ramanujan Centennial but after Andrews's discovery of the *Lost Notebook*.

Since the Ramanujan Centennial, there have been many stage productions, including the *Opera Ramanujan*, which was performed in Munich in 1998. In 2005 I had the pleasure of seeing the play *Partition* at the Aurora Theater in Berkeley along with George Andrews. In this and other stage productions, there is usually a "playwright's fancy", namely, a modification of the true life story of Ramanujan for a special effect. The producer of *Partition*, Ira Hauptman, focuses on Ramanujan's monumental work with Hardy on the asymptotic formula for the partition function, but for a special effect describes Ramanujan's attempts to solve Fermat's Last Theorem and Ramanujan's conversation with the Goddess of Namakkal regarding this matter. As far as we know, Ramanujan never worked on Fermat's Last Theorem, but this digression for a special effect is acceptable artist's fancy (see [8], article 23).

In 2006 Andrews and I served on a panel to critique a script entitled *A First Class Man* which had received support from the Sloan Foundation. The reading of the script was done at the Tribeca Film Institute in New York when the distinguished writer David Freeman was present. Andrews and I helped in clearing up certain mathematical misconceptions in the script and also noted that the script had changed the Ramanujan life story in certain ways that were not appropriate. Regardless of how the life of Ramanujan is portrayed in these stage productions, they have had the positive effect of drawing the attention of the public around the world to the life of this unique figure in history.

In 2007 a play entitled *A Disappearing Number* was conceived and directed by the English playwright Simon McBurney for the Theatre Complicite Company. It first played at the Theater Royal in Plymouth, England, and won three very

prestigious awards in England in 2007. This play was performed at the International Congress of Mathematicians in Hyderabad, India, in August 2010.

The latest theatrical production is a movie that is now being produced in India based on Kanigel's book *The Man Who Knew Infinity* and featuring one of the most popular actors in the Tamil cinema world as Ramanujan.

Events in 2011–12

Since December 2012 is the 125th anniversary of Ramanujan's birth, the entire year starting from December 22, 2011, was declared as the Year of Mathematics by the prime minister of India at a public function in Madras on December 26, 2011. On that day, a stamp of Ramanujan was released and Robert Kanigel was given a special award for his biography of Ramanujan. Also, the Tata Institute released a reprinting of the *Notebooks* of Ramanujan in the form of a collector's edition [47]. The mathematics year has featured several conferences and public lectures on Ramanujan throughout India.

The Ramanujan Journal is bringing out a special volume for the 125th birth anniversary in December 2012. The 125th anniversary celebrations will conclude in 2012 with an International Conference on the Works of Ramanujan at the University of Mysore, India, December 12–13; an International Conference on the Legacy of Ramanujan at SASTRA University in Kumbakonam during December 14–16; and an International Conference on Ramanujan's Legacy in India's capital New Delhi during December 17–22. In 2012 only, the SASTRA Ramanujan Prize will be given outside of Kumbakonam, namely, at the New Delhi conference.

Just as there was a Ramanujan Centennial Conference at the University of Illinois, Urbana, in the summer of 1987 before the centennial celebrations in India that December, there was a Ramanujan 125 Conference at the University of Florida, Gainesville, in November 2012, one month before the 125th anniversary celebrations in India. Finally, at the Joint Annual Meetings of the AMS and MAA in January 2013 in San Diego, there will be a Special Session on Ramanujan's mathematics to mark his 125th birth anniversary.

We have much to be proud of regarding what has happened in the quarter century after the Ramanujan Centennial. The articles in this *Notices* feature convince us that the world of Ramanujan's mathematics is continuing to grow, and so we have much to look forward to in the next quarter century.

References

[1] S. Ahlgren and K. Ono, Congruence properties for the partition function, *Proc. Nat. Acad. Sci. USA* **98** (2001), 12882–12884.

[2] K. Alladi, The discovery and rediscovery of mathematical genius, Book Review of *The Man Who Knew Infinity* (by Robert Kanigel), *The American Scientist* **80** (1992), 388–389.

[3] ———, Book Review of *Ramanujan: Letters and Commentary* (by Bruce C. Berndt and Robert A. Rankin), *The American Math. Monthly* **103** (1996), 708–713.

[4] ———, *Refinements of Rogers-Ramanujan type identities*, in Proc. Fields Inst. Conf. on Special Functions, q-Series and Related Topics, Fields Inst. Communications, 14, Amer. Math. Soc., Providence, RI, 1997, pp. 1–35.

[5] ———, Book Review of *Ramanujan: Essays and Surveys* (by Bruce C. Berndt and Robert A. Rankin), *American Math. Monthly* **110** (2003), 861–865.

[6] ———, A pilgrimage to Ramanujan's hometown, *MAA Focus* **26** (2006), 4–6.

[7] ———, The first SASTRA Ramanujan prizes, *MAA Focus* **26** (2006), 7.

[8] ———, *Ramanujan's Place in the World of Mathematics*, Springer, New Delhi, 2012, 180 pp.

[9] K. Alladi, G. E. Andrews, and B. Gordon, Generalizations and refinements of a partition theorem of Göllnitz, *J. Reine Angew. Math.* **460** (1995), 165–188.

[10] K. Alladi, G. E. Andrews, and A. Berkovich, A new four parameter q-series identity and its partition implications, *Invent. Math.* **153** (2003), 231–260.

[11] G. E. Andrews, *The theory of partitions*, in Encyl. Math., 2, Addison-Wesley, Reading, MA 1976.

[12] ———, An introduction to Ramanujan's lost notebook, *Amer. Math. Monthly* **86** (1979), 89–108.

[13] ———, *q-Series: Their Development and Applications in Analysis, Number Theory, Combinatorics, Physics, and Computer Algebra*, CBMS Regional Conf. Ser. in Math., 66, Amer. Math. Soc., Providence, RI, 1986.

[14] ———, The hard-hexagon model and the Rogers-Ramanujan identities, *Proc. Nat. Acad. Sci. USA* **78** (1981), 5290–5292.

[15] ———, On a partition function of Richard Stanley, Stanley Festschrift, *Elec. J. Comb.* **11** (2004/06).

[16] ———, Partitions, Durfee symbols, and the Atkin-Garvan moments of ranks, *Invent. Math.* **169** (2007), 37–73.

[17] ———, The meaning of Ramanujan, now and for the future, *Ramanujan J.* **20** (2009), 257–273.

[18] G. E. Andrews, R. J. Baxter, and P. J. Forrester, Eight-vertex SOS model and generalized Rogers-Ramanujan type identities, *J. Stat. Phys.* **35** (1984), 193–266.

[19] G. E. Andrews and B. C. Berndt, *Ramanujan's Lost Notebook, Parts I–V*, Springer, New York, 2005, 2009, 2012, to appear.

[20] G. E. Andrews and F. Garvan, Dyson's crank of a partition, *Bull. Amer. Math. Soc. (N.S.)* **18** (1988), 167–171.

[21] ———, Ramanujan's "lost" notebook, VI: The mock theta conjectures, *Adv. in Math.* **73** (1989), 242–255.

[22] A. O. L. Atkin, Multiplicative congruence properties and density problems for $p(n)$, *Proc. London Math. Soc.* **18** (1968), 563–576.

[23] A. O. L. Atkin and F. Garvan, Relations between the ranks and cranks of partitions, *Ramanujan J.* **7** (2003), 343–366.
[24] A. Berkovich and F. Garvan, On the Andrews-Stanley refinement of Ramanujan's partition congruence modulo 5 and generalizations, *Trans. Amer. Math. Soc.* **358** (2006), 703–726.
[25] A. Berkovich and B. McCoy, Continued fractions and Fermionic representations for characters of $M(p,p')$ minimal models, *Lett. Math. Phys.* **37** (1996), 49–66.
[26] ———, *Rogers-Ramanujan identities: A century of progress from mathematics to physics*, Doc. Math. 1998 Extra Vol. III ICM, 163–172.
[27] A. Berkovich, B. McCoy, A. Schilling, and O. Warnaar, Bailey flows and Bose-Fermi identities for conformal coset models $(A_1^{(1)})_N \times (A_1^{(1)})_{N'} / (A_1^{(1)})_{N+N'}$, *Nucl. Phys. B* **499** (1997), 621–649.
[28] A. Berkovich, B. McCoy, and A. Schilling, Rogers-Schur-Ramanujan type identities for $M(p,p')$ models of conformal field theory, *Comm. Math. Phys.* **191** (1998), 325–395.
[29] Bruce C. Berndt, *Ramanujan's Notebooks, Parts I–V*, Springer, New York, 1985, 1989, 1991, 1994, 1998.
[30] Bruce C. Berndt and Robert A. Rankin, *Ramanujan: Letters and Commentary*, Amer. Math. Soc., Providence, RI, and LMS, London, 1995.
[31] ———, *Ramanujan: Essays and Surveys*, Amer. Math. Soc., Providence, RI, and LMS, London, 2001.
[32] K. Bringmann and K. Ono, The $f(q)$ mock theta function conjecture and partition ranks, *Invent. Math.* **165** (2006), 243–266.
[33] ———, Dyson's rank and Maass forms, *Annals of Math.* **171** (2010), 419–449.
[34] J. K. Bruinier and K. Ono, Heegner divisors, L-functions, and harmonic weak Maass forms, *Annals of Math.* **172** (2010), 2135–2181.
[35] F. J. Dyson, Some guesses in the theory of partitions, *Eureka* (Cambridge) **8** (1944), 10–15.
[36] Francis Gerard Garvan, *Generalizations of Dyson's rank*, Ph.D. Thesis, The Pennsylvania State University (1986), 136 pp.
[37] Frank Garvan, Dongsu Kim, and Dennis Stanton, Cranks and t-cores, *Invent. Math.* **101** (1990), 1–17.
[38] H. Halberstam, Review of *The Indian Clerk* (by David Leavitt), *Notices Amer. Math. Soc.* **55** (2008), 952–956.
[39] G. H. Hardy, *Ramanujan—Twelve Lectures on his Life and Work*, Cambridge University Press, Cambridge, 1940.
[40] D. Hickerson, A proof of the mock theta conjectures, *Invent. Math.* **94** (1988), 639–660.
[41] Robert Kanigel, *The Man Who Knew Infinity: A Life of the Genius Ramanujan*, Charles Scribner's, New York, 1991.
[42] David Leavitt, *The Indian Clerk*, Bloomsbury, New York, 2007.
[43] Karl Mahlburg, Partition congruences and the Andrews-Garvan-Dyson crank, *Proc. Nat. Acad. Sci. USA* **102** (2005), 15373–15376.
[44] K. Ono, Distribution of the partition function modulo m, *Annals of Math.* **151** (2000), 293–307.
[45] ———, Honoring a gift from Kumbakonam, *Notices Amer. Math. Soc.* **53** (2006), 640–651.
[46] S. Ramanujan, *Collected Papers*, Cambridge University Press, Cambridge, 1927.
[47] ———, *Notebooks* (2 volumes), Tata Institute of Fundamental Research, Bombay, 1957 (reprinted as Collector's Edition in 2011).
[48] ———, *The Lost Notebook and Other Unpublished Papers*, Narosa, New Delhi, 1987.
[49] R. Stanley, Problem 10969, *Amer. Math. Monthly* **109** (2000), 760.

George E. Andrews

Partitions and the Rogers-Ramanujan Identities

In his first letter to G. H. Hardy [19, p. xxvii], Ramanujan asserts:

"The coefficient of x^n in $\dfrac{1}{1-2x+2x^4-2x^9+2x^{16}-\cdots}$

$$= \text{the nearest integer to } \frac{1}{4n}\left\{\cosh(\pi\sqrt{n}) - \frac{\sinh(\pi\sqrt{n})}{\pi\sqrt{n}}\right\},\text{"} \tag{1}$$

and, in a footnote, Hardy states, "This is quite untrue. But the formula is extremely interesting for a variety of reasons." Perhaps one of the most important justifications for calling it "extremely interesting" is that it eventually led to the Hardy-Ramanujan formula for $p(n)$.

Each positive integer can be partitioned into unordered sums of positive integers. For example, there are seven partitions of the number 5: 1+1+1+1+1, 1+1+1+2, 1+2+2, 1+1+3, 2+3, 1+4, 5. We denote by $p(n)$ the number of partitions on n, so $p(5) = 7$.

Inspired by (1), Hardy and Ramanujan eventually proved [13] the following:

Theorem 1. *Suppose that*

$$\phi_q(n) = \frac{\sqrt{q}}{2\pi\sqrt{2}}\frac{d}{dn}\left(e^{C\lambda_n/q}/\lambda_n\right),$$

where C and λ_n are defined by $C = \frac{2\pi}{\sqrt{6}}$ and $\lambda_n = \sqrt{n-\frac{1}{24}}$, and for all positive integral values of q; that p is a positive integer less than and prime to q; that $\omega_{p,q}$ is a $24q$-th root of unity, defined when p is odd by the formula

$$\omega_{p,q} = \left(\frac{-q}{p}\right)\exp\left[-\left\{\frac{1}{4}(2-pq-p) + \frac{1}{12}\left(q-\frac{1}{q}\right)(2p-p'+p^2p')\right\}\pi i\right]$$

and when q is odd by the formula

$$\omega_{p,q} = \left(\frac{-p}{q}\right)\exp\left[-\left\{\frac{1}{4}(q-1) + \frac{1}{12}\left(q-\frac{1}{q}\right)(2p-p'+p^2p')\right\}\pi i\right],$$

George E. Andrews is Evan Pugh Professor of Mathematics at The Pennsylvania State University. His email address is andrews@math.psu.edu.

Photo courtesy of Krishnaswami Alladi.

Krishnaswami Alladi and George Andrews in front of Srinivasa Ramanujan's home, Sarangapani Sannidhi Street, Kumbakonam, December 20, 2003.

where (a/b) is the symbol of Legendre and Jacobi and p' is any positive integer such that $1 + pp'$ is divisible by q; that

$$A_q(n) = \sum_{(p)} \omega_{p,q} e^{-2np\pi i/q};$$

and that α is any positive constant; and ν, the integer part of $\alpha\sqrt{n}$.

Then

$$p(n) = \sum_{1}^{\nu} A_q \phi_q + O(n^{-\frac{1}{4}}),$$

so that $p(n)$ is, for all sufficiently large values of n, the integer nearest to

$$\sum_{1}^{\nu} A_q \phi_q.$$

In 1937 Rademacher was preparing lecture notes on this amazing theorem. To simplify things a bit, he replaced $\frac{1}{2}e^{C\lambda_n/q}$ by $\sinh(C\lambda_n/q)$ in the definition of $\phi_q(n)$ [17, p. 699]. To his amazement, he was now able to prove that, in fact,

$$p(n) = \sum_{q=1}^{\infty} A_q \phi_q.$$

In the celebrations surrounding the one hundredth anniversary of Ramanujan's birth, Atle Selberg [22] notes a further major surprise:

> If one looks at Ramanujan's first letter to Hardy, there is a statement there [ed: i.e., (1) above] which has some relation to his later work on the partition function, namely about the coefficient of the reciprocal of a certain theta series (a power series with square exponents and alternating signs as coefficients). It gives the leading term in what he claims as an approximate expression for the coefficient. If one looks at that expression, one sees that this is the exact analogue of the leading term in the Rademacher formula for $p(n)$ which shows that Ramanujan, in whatever way he had obtained this, had been led to the correct term of that expression.
>
> In the work on the partition function, studying the paper, it seems clear to me that it must have been, in a way, Hardy who did not fully trust Ramanujan's insight and intuition, when he chose the other form of the terms in their expression, for a purely technical reason, which one analyses as not very relevant. I think that if Hardy had trusted Ramanujan more, they should have inevitably ended with the Rademacher series. There is little doubt about that.

The subsequent impact of the "circle method" introduced by Hardy and Ramanujan (cf. [25]) is discussed by Vaughan. Further amazing formulas for $p(n)$ have been found by Folsom, Kent, and Ono [10], along with spectacular results on the divisibility of $p(n)$; these aspects will be discussed by Ono.

The Rogers-Ramanujan identities also form an intriguing and surprising component of Ramanujan's career. In 1916 P. A. MacMahon began Chapter III, Section VII, of his monumental *Combinatory Analysis* [16, p. 33] as follows:

> RAMANUJAN IDENTITIES
>
> Mr Ramanujan of Trinity College, Cambridge, has suggested a large number of formulae which have applications to the partition of numbers. Two of the most interesting of these concern partitions whose parts have a definite relation to the modulus five. Theorem I gives the relation

$$\begin{aligned} 1 + \frac{x}{1-x} &+ \frac{x^4}{(1-x)(1-x^2)} \\ &+ \frac{x^9}{(1-x)(1-x^2)(1-x^3)} + \cdots \\ &+ \frac{x^{i^2}}{(1-x)(1-x^2)\dots(1-x^i)} + \cdots \\ &= \frac{1}{(1-x)(1-x^6)(1-x^{11})\dots(1-x^{5m+1})\dots} \\ &\times \frac{1}{(1-x^4)(1-x^9)(1-x^{14})\dots(1-x^{5m+4})\dots}, \end{aligned}$$

> where on the right-hand side the exponents of x are the numbers given by the congruences $\equiv 1 \mod 5, \equiv 4 \mod 5$.
>
> This most remarkable theorem has been verified as far as the coefficient of x^{89} by actual expansion so that there is practically no reason to doubt its truth; but it has not yet been established.

MacMahon then notes that this identity implies the following assertion about partitions:

> The theorem asserts that the partitions, whose parts are limited to be of the forms $5m+1, 5m+4$, are equi-numerous with those which involve neither repetitions nor sequences.

Subsequently, MacMahon notes that, in the second identity,

$$1+\frac{x^2}{1-x}+\frac{x^6}{(1-x)(1-x^2)}+\frac{x^{12}}{(1-x)(1-x^2)(1-x^3)}+\cdots + \frac{x^{i^2+i}}{(1-x)(1-x^2)\dots(1-x^i)}+\cdots = \frac{1}{(1-x^2)(1-x^7)(1-x^{12})\dots(1-x^{5m+2})} \times \frac{1}{(1-x^3)(1-x^8)(1-x^{13})\dots(1-x^{5m+3})\dots},$$

the exponents of x on the right-hand side are of the form $5m+2$ and $5m+3$.

This relation has also been verified by actual expansion to a high power of x, but it has not been established. As with the first identity, MacMahon notes the implications for partitions:

> states that of any given number such partitions are equi-numerous with those whose parts are all of the forms $5m+2, 5m+3$.

So here in 1916 was an immensely appealing unsolved problem. As Hardy remarks [14, p. 91]:

> Ramanujan rediscovered the formulae sometime before 1913. He had then no proof (and knew that he had none), and none of the mathematicians to whom I communicated the formulae could find one. They are therefore stated without proof in the second volume of MacMahon's Combinatory Analysis.
>
> The mystery was solved, trebly, in 1917. In that year Ramanujan, looking through old volumes of the *Proceedings of the London Mathematical Society,* came accidentally across Rogers' paper. I can remember very well his surprise, and the admiration which he expressed for Rogers' work. A correspondence followed in the course of which Rogers was led to a considerable simplification of his original proof. About the same time I. Schur, who was then cut off from England by the war, rediscovered the identities again.

In his account of Ramanujan's notebooks, Berndt [9, pp. 77–79] gives a detailed history of subsequent work on the Rogers-Ramanujan identities.

Surprisingly, this aspect of the theory of partitions languished for the next forty years. W. N. Bailey [8], [7] and his student Lucy Slater [24], [23] did generalize the series-product identities, but D. H. Lehmer [15] and H. L. Alder [1] published papers suggesting that there were no generalizations of an obvious sort. Even Hans Rademacher [18, p. 73] asserted that "It can be shown there can be no corresponding identities for moduli higher than 5."

It turned out that Lehmer and Alder had shown only that the wrong generalization is the wrong generalization. The subject truly opened up with B. Gordon's magnificent partition-theoretic generalization [12] in 1961.

Theorem 2. *Let $B_{k,i}(n)$ denote the number of partitions of n of the form $b_1+b_2+\cdots+b_s$, where $b_j \geq b_{j+1}, b_j - b_{j+k-1} \geq 2$ and at most $i-1$ of the $b_j = 1$. Let $A_{k,i}(n)$ denote the number of partitions of n into parts $\not\equiv 0, \pm i \pmod{2k+1}$. Then $A_{k,i}(n) = B_{k,i}(n)$, for $1 \leq i \leq k$.*

The cases $k=2$, $i=1,2$ are the partition theoretic consequences of the original identities as stated by MacMahon.

The question of analogous identities remained open until 1974, when the following result appeared [15].

Theorem 3. *For $1 \leq i \leq k$,*

$$\sum_{n_1,\dots,n_{k-1}\geq 0} \frac{q^{N_1^2+\cdots+N_{k-1}^2+N_i+N_{i+1}+\cdots+N_{k-1}}}{(q)_{n_1}(q)_{n_2}\cdots(q)_{n_{k-1}}} = \prod_{\substack{n=1 \\ n\not\equiv 0,\pm i \pmod{2k+1}}}^{\infty} \frac{1}{1-q^n},$$

where $N_j = n_j + n_{j+1} + \cdots + n_{k-1}$, and $(q)_n = (1-q)(1-q^2)\cdots(1-q^n)$.

Since the 1970s there has been a cornucopia of Rogers–Ramanujan-type results pouring forth. As mentioned earlier, Berndt [9, p. 77] gives many references to recent work.

It should be added that Schur (mentioned in Hardy's brief history given above) had a strong influence on the combinatorial/arithmetical aspects of Rogers-Ramanujan theory. Both his independent discovery of the Rogers-Ramanujan identities [20] and his modulus 6 theorem of 1926 [21] greatly impacted subsequent developments. These include the Ph.D. thesis of H. Göllnitz [11] and the "weighted words" method of Alladi and Gordon [2], the latter culminating in a generalization of Göllnitz's deep modulus 12 theorem by Alladi, Andrews, and Berkovich [3].

The analytic side of the study was greatly assisted by the discovery of "Bailey chains" in 1984 [6]. Further accounts of this part of the Rogers-Ramanujan identities are provided in S. O. Warnaar's survey [26] "50 Years of Bailey's lemma" and in Chapter 3 of the *Selected Works of George E. Andrews* [4].

The Rogers-Ramanujan identities also lead directly to a study of a related continued fraction, a topic dealt with at lenghth in [9].

References

[1] HENRY L. ALDER, The nonexistence of certain identities in the theory of partitions and compositions, *Bull. Amer. Math. Soc.*, 54:712–722, 1948.

[2] KRISHNASWAMI ALLADI, The method of weighted words and applications to partitions. In *Number Theory (Paris, 1992–1993)*, volume 215 of London Math. Soc. Lecture Note Ser., pages 1–36, Cambridge Univ. Press, Cambridge, 1995.

[3] KRISHNASWAMI ALLADI, GEORGE E. ANDREWS, and ALEXANDER BERKOVICH, A new four parameter q-series identity and its partition implications, *Invent. Math.*, 153(2):231–260, 2003.

[4] G. E. ANDREWS and A. V. SILLS, *Selected Works of George E. Andrews: With Commentary*, Imperial College Press, 2012.

[5] GEORGE E. ANDREWS, An analytic generalization of the Rogers-Ramanujan identities for odd moduli, *Proc. Nat. Acad. Sci. U.S.A.*, 71:4082–4085, 1974.

[6] ———, Multiple series Rogers-Ramanujan type identities, *Pacific J. Math.*, 114(2):267–283, 1984.

[7] W. N. BAILEY, Some identities in combinatory analysis, *Proc. London Math. Soc. (2)*, 49:421–425, 1947.

[8] ———, Identities of the Rogers-Ramanujan type, *Proc. London Math. Soc. (2)*, 50:1–10, 1948.

[9] BRUCE C. BERNDT, *Ramanujan's Notebooks. Part III*, Springer-Verlag, New York, 1991.

[10] AMANDA FOLSOM, ZACHARY A. KENT, and KEN ONO, l-adic properties of the partition function, *Advances in Mathematics*, 229(3):1586–1609, 2012.

[11] H. GÖLLNITZ, Partitionen mit Differenzenbedingungen, *J. Reine Angew. Math.*, 225:154–190, 1967.

[12] BASIL GORDON, A combinatorial generalization of the Rogers-Ramanujan identities. *Amer. J. Math.*, 83:393–399, 1961.

[13] G. H. HARDY and S. RAMANUJAN, Asymptotic formulæ in combinatory analysis [Proc. London Math. Soc. (2) **17** (1918), 75–115], in *Collected Papers of Srinivasa Ramanujan*, pages 276–309, AMS Chelsea Publ., Amer. Math. Soc., Providence, RI, 2000.

[14] G. H. HARDY, *Ramanujan: Twelve Lectures on Subjects Suggested by His Life and Work*, AMS Chelsea Publishing Series, Amer. Math. Soc., Providence, RI, 1999.

[15] D. H. LEHMER, Two nonexistence theorems on partitions, *Bull. Amer. Math. Soc.*, 52:538–544, 1946.

[16] PERCY A. MACMAHON, *Combinatory Analysis. Vols. I, II (bound in one volume)*, Dover Phoenix Editions, Dover Publications Inc., Mineola, NY, 2004. Reprint of *An Introduction to Combinatory Analysis* (1920) and *Combinatory Analysis. Vols. I, II* (1915, 1916).

[17] H. RADEMACHER, On the partition function $p(n)$, *Proc. London Math. Soc.*, 43(2):241–254, 1937.

[18] ———, *Lectures on Elementary Number Theory*, Tata Institute of Fundamental Research, Bombay. Lectures on mathematics and physics. Mathematics. Tata Institute of Fundamental Research, 1963.

[19] SRINIVASA RAMANUJAN, *Collected Papers of Srinivasa Ramanujan*, AMS Chelsea Publishing, Amer. Math. Soc., Providence, RI, 2000, edited by G. H. Hardy, P. V. Seshu Aiyar, and B. M. Wilson, third printing of the 1927 original, with a new preface and commentary by Bruce C. Berndt.

[20] I. SCHUR, Ein Beitrag zur additiven Zahlentheorie und zur Theorie der Kettenbrüche, *S.-B. Preuss. Akad. Wiss. Phys.-Math. Kl.*, pages 302–321, 1917. Reprinted in *Gesammelte Abhandlungen*. Springer-Verlag, 1973.

[21] ———, Zur additiven Zahlentheorie, *S.-B. Preuss. Akad. Wiss. Phys.-Math. Kl.*, pages 488–495, 1926. Reprinted in *Gesammelte Abhandlungen*, Springer-Verlag, 1973.

[22] A. SELBERG, *Collected Papers, Vol. I*, Springer-Verlag, 1989.

[23] L. J. SLATER, A new proof of Rogers's transformations of infinite series, *Proc. London Math. Soc. (2)*, 53:460–475, 1951.

[24] ———, Further identities of the Rogers-Ramanujan type, *Proc. London Math. Soc. (2)*, 54:147–167, 1952.

[25] R. C. VAUGHAN, *The Hardy-Littlewood Method*, Cambridge Tracts in Mathematics, vol. 80, Cambridge University Press, Cambridge, 1981.

[26] S. OLE WARNAAR, 50 years of Bailey's lemma, in *Algebraic Combinatorics and Applications (Gößweinstein, 1999)*, pages 333–347, Springer, Berlin, 2001.

Photo courtesy of Krishnaswami Alladi.

The only cot at the humble home of Ramanujan in Kumbakonam. As a young boy, Ramanujan used to sit on the windowsill and do his "sums", watching the passersby on the street.

Bruce C. Berndt

Ramanujan's Earlier Notebooks and His Lost Notebook

Since the centenary of Ramanujan's birth, a large amount of Ramanujan's mathematics that had been ensconced in his earlier notebooks and in his lost notebook has been brought to light. In particular, in 1987 only one book had been written on Ramanujan's notebooks [2], but now several have appeared [2], [1]. We now have a larger portion of Ramanujan's mathematics to appreciate, evaluate, analyze, and challenge. The *challenge* is to ascertain Ramanujan's thinking and motivation and to properly place his work within contemporary mathematics. Since other writers in this series of articles are focusing on Ramanujan's

Bruce C. Berndt is professor of mathematics at the University of Illinois, Urbana-Champaign. His email address is berndt@illinois.edu.

lost notebook, we give more concentration in this paper on his earlier notebooks.

For most of his life, both in Kumbakonam and later in Madras, Ramanujan worked on a slate. Paper was expensive for him, and so he recorded only his final results in notebooks. Writing down his proofs in notebooks would have taken precious time; Ramanujan was clearly anxious to get on with his next ideas. Moreover, if someone had asked him how to prove a certain claim in his notebooks, he undoubtedly was confident that he could reproduce his argument. We do not know precisely when Ramanujan began to record his mathematical discoveries in notebooks, but it was likely around the time that he entered the Government College in Kumbakonam in 1904. Except for possibly a few entries, he evidently stopped recording his theorems in notebooks after he boarded a passenger ship for England on March 17, 1914. That Ramanujan no longer concentrated on logging entries in his notebooks is evident from two letters that he wrote to friends in Madras during his first year in England [5, pp. 112–113; 123–125]. In a letter of November 13, 1914, to his friend R. Krishna Rao, Ramanujan confided, "I have changed my plan of publishing my results. I am not going to publish any of the old results in my notebooks till the war is over." And in a letter of January 7, 1915, to S. M. Subramanian, Ramanujan admitted, "I am doing my work very slowly. My notebook is sleeping in a corner for these four or five months. I am publishing only my present researches as I have not yet proved the results in my notebooks rigorously."

Prior to his journey to England in 1914, Ramanujan prepared an enlarged edition of his first notebook; this augmented edition is the second notebook. A third notebook contains only thirty-three pages. G. N. Watson, in his delightful account of the notebooks [16], relates that Sir Gilbert Walker, head of the Indian Meteorological Observatory and a strong supporter of Ramanujan, told him that in April 1912 he observed that Ramanujan possessed four or five notebooks, each with a black cover and each about an inch thick. We surmise that these notebooks were either a forerunner of the first notebook or that the first notebook is an amalgam of these earlier black-covered notebooks.

When Ramanujan returned to India on March 13, 1919, he took with him only his second and third notebooks. The first notebook was left with G. H. Hardy, who used it to write a paper [9] on a chapter in the notebook devoted to hypergeometric series. Hardy's paper [9] was read on February 5, 1923, and published later during that year. He begins by writing, "I have in my possession a manuscript note-book which Ramanujan left with me when he returned to India in 1919." It was not until March 1925 that Hardy returned the first notebook to the University of Madras through its librarian, S. R. Rangathanan [15, pp. 56, 57]. A handwritten copy was subsequently made and sent to Hardy in August 1925.

Meanwhile, Hardy had originally wanted to bring Ramanujan's published papers, his notebooks, and any other unpublished manuscripts together for publication. To that end, in a letter to Hardy dated August 30, 1923, Francis Dewsbury, registrar at the University of Madras, wrote, "I have the honour to advise despatch to-day to your address per registered and insured parcel post of the four manuscript note-books referred to in my letter No. 6796 of the 2nd idem. I also forward a packet of miscellaneous papers which have not been copied. It is left to you to decide whether any or all of them should find a place in the proposed memorial volume. Kindly preserve them for ultimate return to this office." The "four manuscript notebooks" were handwritten copies of the second and third notebooks, and the packet of miscellaneous papers evidently included the "lost notebook", which Hardy passed on to Watson and which was later rediscovered by George Andrews in the Trinity College Library in March 1976. Note that, in contradistinction to Dewsbury's request, Hardy never returned the miscellaneous papers.

As it transpired, only Ramanujan's published papers were collected for publication. However, published with the *Collected Papers* [12] were the first two letters that Ramanujan had written to Hardy, which contained approximately one hundred twenty mathematical claims. Upon their publication, these letters generated considerable interest, with the further publication of several papers establishing proofs of these claims. Consequently, either in 1928 or 1929, at the strong suggestion of Hardy, Watson and B. M. Wilson, one of the three editors of [12], agreed to edit the notebooks. The word "edit" should be interpreted in a broader sense than usual. If a proof of a claim can be found in the literature, then it is sufficient to simply cite sources where proofs can be found; if a proof cannot be found in the literature, then the task of the editors is to provide one. In an address [16] to the London Mathematical Society on February 5, 1931, Watson cautioned (in retrospect, far too optimistically), "We anticipate that it, together with the kindred task of investigating the work of other writers to ascertain which of his results had been discovered previously, may take us five years." Wilson died prematurely in 1935, and although Watson wrote approximately thirty papers on Ramanujan's work, his interest evidently flagged in the late 1930s, and so the editing was not completed.

Photo courtesy of Krishnaswami Alladi.

The majestic gopuram (entrance tower) of the Sarangapani Temple as seen from the front of Ramanujan's home on Sarangapani Sannidhi Street.

Altogether, the notebooks contain over three thousand claims, almost all without proof. Hardy surmised that over two-thirds of these results were rediscoveries. This estimate is much too high; on the contrary, at least two-thirds of Ramanujan's claims were new at the time that he wrote them, and two-thirds more likely should be replaced by a larger fraction. Almost all of the results are correct; perhaps no more than five to ten claims are incorrect. The topics examined by Ramanujan in his notebooks fall primarily under the purview of analysis, number theory, and elliptic functions, with much of his work in analysis being associated with number theory and with some of his discoveries also having connections with enumerative combinatorics and modular forms. Chapter 16 in the second notebook represents a turning point, since in this chapter he begins to examine q-series for the first time and also to begin an enormous devotion to theta functions. Chapters 16–21 and considerable material in the unorganized pages that follow focus on Ramanujan's distinctive theory of elliptic functions, in particular, on theta functions. Especially in the years 1912–1914 and 1917–1920, Ramanujan's concentration on number theory was through q-series and elliptic functions.

Finally, in 1957, the notebooks were made available to the public when the Tata Institute of Fundamental Research in Bombay published a photocopy edition [13], but no editing was undertaken. The notebooks were set in two volumes, with the first containing the first notebook and with the second comprising the second and third notebooks. The reproduction is quite faithful, with even Ramanujan's scratch work photographed. Buttressed by vastly improved technology, a new, much clearer, edition was published in 2011 to commemorate the 125th anniversary of Ramanujan's birth.

In February 1974, while reading two papers by Emil Grosswald [7], [8] in which some formulas from the notebooks were proved, we observed that we could prove these formulas by using a transformation formula for a general class of Eisenstein series that we had proved two years earlier. We found a few more formulas in the notebooks that could be proved using our methods, but a few thousand further assertions that we could not prove. In May 1977 the author began to devote all of his attention to proving all of Ramanujan's claims in the notebooks. With the help of a copy of the notes from Watson and Wilson's earlier attempt at editing the notebooks and with the help of several other mathematicians, the task was completed in five volumes [2] in slightly over twenty years.

In this series of articles for the *Notices*, George Andrews, Ken Ono, and Ole Warnaar, in particular, write about Ramanujan's discoveries in his lost notebook, which is dominated by q-series. However, published with the lost notebook [14] are several partial manuscripts and fragments of manuscripts on other topics that provide valuable insight into Ramanujan's interests and ideas. We first mention two topics that we have examined with Sun Kim and Alexandru Zaharescu in two series of papers, with [3] and [4] being examples of the two series. First, Ramanujan had a strong interest in the *circle problem* and *Dirichlet divisor problem*, with two deep formulas in the lost notebook clearly aimed at attacking these problems. Second, [14] contains three very rough, partial manuscripts on diophantine approximation. In one of these, Ramanujan derives the best diophantine approximation to $e^{2/a}$, where a is a nonzero integer, a result not established in the literature until 1978 [6]. Also appearing in [14] are fragments of material that were originally intended for portions of published papers, for example, [10] and [11]. It is then natural to ask why Ramanujan chose not to include these results in his papers. In at least two instances, the discarded material depends on the use of complex analysis, a subject that Ramanujan occasionally employed but not always correctly. In particular, in the cases at hand, Ramanujan did not have a firm knowledge of the Mittag-Leffler Theorem for developing partial fraction decompositions. The fragments and incomplete manuscripts will be examined in the fourth book

that the author is writing with Andrews on the lost notebook [1].

We conclude with a few remarks about Ramanujan's methods. It has been suggested that he discovered his results by "intuition" or by making deductions from numerical calculations or by inspiration from Goddess Namagiri. Indeed, like most mathematicians, Ramanujan evidently made extensive calculations that provided guidance. However, Hardy and this writer firmly believe that Ramanujan created mathematics as any other mathematician would and that his thinking can be explained like that of other mathematicians. However, because Ramanujan did not leave us any proofs for the vast number of results found in his earlier notebooks and in his lost notebook, we often do not know Ramanujan's reasoning. As Ramanujan himself was aware, some of his arguments were not rigorous by then-contemporary standards. Nonetheless, despite his lack of rigor at times, Ramanujan doubtless thought and devised proofs as would any other mathematician.

References

[1] G. E. Andrews and B. C. Berndt, *Ramanujan's Lost Notebook*, Parts I–V, Springer, New York, 2005, 2009, 2012, to appear.

[2] B. C. Berndt, *Ramanujan's Notebooks, Parts I–V*, Springer-Verlag, New York, 1985, 1989, 1991, 1994, 1998.

[3] B. C. Berndt, S. Kim, and A. Zaharescu, *Circle and divisor problems, and double series of Bessel functions*, *Adv. Math*, to appear.

[4] ———, *Diophantine approximation of the exponential function, and a conjecture of Sondow*, submitted for publication.

[5] B. C. Berndt and R. A. Rankin, *Ramanujan: Letters and Commentary*, American Mathematical Society, Providence, RI, 1995; London Mathematical Society, London, 1995.

[6] C. S. Davis, Rational approximation to *e*, *J. Austral. Math. Soc.* **25** (1978), 497–502.

[7] E. Grosswald, Die Werte der Riemannschen Zetafunktion an ungeraden Argumentstellen, *Nachr. Akad. Wiss. Göttingen Math.-Phys. Kl. II* **1970** (1970), 9–13.

[8] ———, Comments on some formulae of Ramanujan, *Acta Arith.* **21** (1972), 25–34.

[9] G. H. Hardy, A chapter from Ramanujan's note-book, *Proc. Cambridge Philos. Soc.* **21** (1923), 492–503.

[10] S. Ramanujan, Some formulae in the analytic theory of numbers, *Mess. Math.* **45** (1916), 81–84.

[11] ———, On certain trigonometric sums and their applications in the theory of numbers, *Trans. Cambridge Philos. Soc.* **22** (1918), 259–276.

[12] ———, *Collected Papers*, Cambridge University Press, Cambridge, 1927; reprinted by Chelsea, New York, 1962; reprinted by the American Mathematical Society, Providence, RI, 2000.

[13] ———, *Notebooks* (2 volumes), Tata Institute of Fundamental Research, Bombay, 1957; second edition, Tata Institute of Fundamental Research, Mumbai, 2011.

[14] ———, *The Lost Notebook and Other Unpublished Papers*, Narosa, New Delhi, 1988.

[15] S. R. Ranganathan, *Ramanujan: The Man and the Mathematician*, Asia Publishing House, Bombay, 1967.

[16] G. N. Watson, Ramanujan's notebooks, *J. London Math. Soc.* **6** (1931), 137–153.

Jonathan M. Borwein

Ramanujan and Pi

Since Ramanujan's 1987 centennial, much new mathematics has been stimulated by uncanny formulas in Ramanujan's *Notebooks* (lost and found). In illustration, I mention the exposition by Moll and his colleagues [1] which illustrates various neat applications of Ramanujan's Master Theorem, which extrapolates the Taylor coefficients of a function, and relates them to methods of integration used in particle physics. I also note lovely work on the modular functions behind Apéry and Domb numbers by Chan and others [6], and finally I mention my own work with Crandall on Ramanujan's arithmetic-geometric continued fraction [12].

For reasons of space, I now discuss only work related directly to pi, and so continue a story started in [9], [11]. Truly novel series for $1/\pi$, based on elliptic integrals, were found by Ramanujan around 1910 [19], [5], [7], [21]. One is

$$(1)\qquad \frac{1}{\pi} = \frac{2\sqrt{2}}{9801}\sum_{k=0}^{\infty}\frac{(4k)!\,(1103+26390k)}{(k!)^4 396^{4k}}.$$

Each term of (1) adds eight correct digits. Though then unproven, Gosper used (1) for the computation of a then-record 17 million digits of π in 1985, thereby completing the first proof of (1) [7, Ch. 3]. Soon after, David and Gregory Chudnovsky found the following variant, which relies on the quadratic number field $Q(\sqrt{-163})$ rather than $Q(\sqrt{58})$, as is implicit in (1):

$$(2)\quad \frac{1}{\pi} = 12\sum_{k=0}^{\infty}\frac{(-1)^k\,(6k)!\,(13591409+545140134k)}{(3k)!\,(k!)^3\,640320^{3k+3/2}}.$$

Each term of (2) adds fourteen correct digits. (Were a larger imaginary quadratic field to exist with class number one, there would be an even more extravagant rational series for some surd divided by π [10].) The brothers used this formula several times, culminating in a 1994 calculation of π to over four billion decimal digits. Their remarkable story was told in a prize-winning *New Yorker* article [18]. Remarkably, (2) was used again in 2010 and 2011 for the current record computations of π to five and ten trillion decimal digits respectively.

Jonathan M. Borwein is Laureate Professor in the School of Mathematical and Physical Sciences at the University of Newcastle (NSW), Australia. His email address is jon.borwein@gmail.com.

Quartic Algorithm for π

The record for computation of π has gone from 29.37 *million* decimal digits in 1986 to ten *trillion* digits in 2011. Since the algorithm below, which found its inspiration in Ramanujan's 1914 paper, was used as part of computations both then and as late as 2009, it is interesting to compare the performance in each case: Set $a_0 := 6 - 4\sqrt{2}$ and $y_0 := \sqrt{2} - 1$; then iterate

$$y_{k+1} = \frac{1 - (1 - y_k^4)^{1/4}}{1 + (1 - y_k^4)^{1/4}},$$

(3)

$$a_{k+1} = a_k(1 + y_{k+1})^4 - 2^{2k+3} y_{k+1}(1 + y_{k+1} + y_{k+1}^2).$$

Then a_k converges *quartically* to $1/\pi$; each iteration quadruples the number of correct digits. Twenty-one iterations produce an algebraic number that coincides with π to well over six trillion places.

This scheme and the 1976 Salamin–Brent scheme [7, Ch. 3] have been employed frequently over the past quarter century. Here is a highly abbreviated chronology (based on `http://en.wikipedia.org/wiki/Chronology_of_computation_of_pi`):

- 1986: David Bailey used (3) to compute 29.4 million digits of π. This required 28 hours on one CPU of the new Cray-2 at NASA Ames Research Center. Confirmation using the Salamin-Brent scheme took another 40 hours. This computation uncovered hardware and software errors on the Cray-2.
- January 2009: Takahashi used (3) to compute 1.649 trillion digits (nearly 60,000 times the 1986 computation), requiring 73.5 hours on 1,024 cores (and 6.348 Tbyte memory) of the Appro Xtreme-X3 system. Confirmation via the Salamin-Brent scheme took 64.2 hours and 6.732 Tbyte of main memory.
- April 2009: Takahashi computed 2.576 trillion digits.
- December 2009: Bellard computed nearly 2.7 trillion decimal digits (first in binary) using (2). This took 131 days, but he used only a single four-core workstation with lots of disk storage and even more human intelligence!
- August 2010: Kondo and Yee computed 5 trillion decimal digits, again using equation (2). This was done in binary, then converted to decimal. The binary digits were confirmed by computing 32 hexadecimal digits of π ending with position 4,152,410,118,610 using BBP-type formulas for π due to Bellard and Plouffe [7, Chapter 3]. Additional details are given at `http://www.numberworld.org/misc_runs/pi-5t/announce_en.html`. See also [4], in which analysis showing these digits appear to be "very normal" is made.

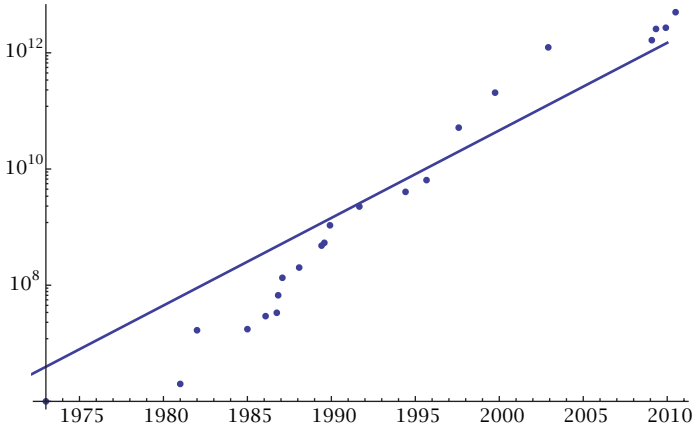


Figure 1. Plot of π calculations in digits (dots) compared with the long-term slope of Moore's Law (line).

Daniel Shanks, who in 1961 computed π to over 100,000 digits, once told Phil Davis that a billion-digit computation would be "forever impossible". But both Kanada and the Chudnovskys achieved that in 1989. Similarly, the intuitionists Brouwer and Heyting asserted the "impossibility" of ever knowing whether the sequence 0123456789 appears in the decimal expansion of π; yet it was found in 1997 by Kanada, beginning at position 17387594880. As late as 1989, Roger Penrose ventured, in the first edition of his book *The Emperor's New Mind*, that we likely will never know if a string of ten consecutive 7s occurs in the decimal expansion of π. This string was found in 1997 by Kanada, beginning at position 22869046249.

Figure 6 shows the progress of π calculations since 1970, superimposed with a line that charts the long-term trend of Moore's Law. It is worth noting that whereas progress in computing π exceeded Moore's Law in the 1990s, it has lagged a bit in the past decade. Most of this progress is still in mathematical debt to Ramanujan.

As noted, one billion decimal digits were first computed in 1989, and the ten (actually fifty) billion digit mark was first passed in 1997. Fifteen years later one can explore, in real time, multibillion step walks on the hex digits of π at `http://carmaweb.newcastle.edu.au/piwalk.shtml`, as drawn by Fran Aragon.

Formulas for $1/\pi^2$ and More

About ten years ago Jésus Guillera found various Ramanujan-like identities for $1/\pi^N$ using integer

relation methods. The three most basic—and entirely rational—identities are

(4)
$$\frac{4}{\pi^2} = \sum_{n=0}^{\infty} (-1)^n r(n)^5 (13+180n+820n^2) \left(\frac{1}{32}\right)^{2n+1},$$

(5)
$$\frac{2}{\pi^2} = \sum_{n=0}^{\infty} (-1)^n r(n)^5 (1+8n+20n^2) \left(\frac{1}{2}\right)^{2n+1},$$

(6)
$$\frac{4}{\pi^3} \stackrel{?}{=} \sum_{n=0}^{\infty} r(n)^7 (1+14n+76n^2+168n^3) \left(\frac{1}{8}\right)^{2n+1},$$

where $r(n) := (1/2 \cdot 3/2 \cdot \cdots \cdot (2n-1)/2)/n!$.

Guillera proved (4) and (5) in tandem by very ingeniously using the Wilf-Zeilberger algorithm [20], [17] for formally proving hypergeometric-like identities [7], [15], [21]. No other proof is known. The third, (6), is almost certainly true. Guillera ascribes (6) to Gourevich, who found it using integer relation methods in 2001.

There are other sporadic and unexplained examples based on other symbols, most impressively a 2010 discovery by Cullen:

(7)
$$\frac{2^{11}}{\pi^4} \stackrel{?}{=} \sum_{n=0}^{\infty} \frac{(\frac{1}{4})_n (\frac{1}{2})_n^7 (\frac{3}{4})_n}{(1)_n^9} \times (21+466n+4340n^2+20632n^3+43680n^4) \left(\frac{1}{2}\right)^{12n}.$$

We shall revisit this formula below.

Formulae for π^2

In 2008 Guillera [15] produced another lovely, if numerically inefficient, pair of third-millennium identities—discovered with integer relation methods and proved with creative telescoping—this time for π^2 rather than its reciprocal. They are based on:

$$(8) \quad \sum_{n=0}^{\infty} \frac{1}{2^{2n}} \frac{\left(x+\frac{1}{2}\right)_n^3}{(x+1)_n^3} (6(n+x)+1) = 8x \sum_{n=0}^{\infty} \frac{\left(\frac{1}{2}\right)_n^2}{(x+1)_n^2},$$

and

(9)
$$\sum_{n=0}^{\infty} \frac{1}{2^{6n}} \frac{\left(x+\frac{1}{2}\right)_n^3}{(x+1)_n^3} (42(n+x)+5) = 32x \sum_{n=0}^{\infty} \frac{\left(x+\frac{1}{2}\right)_n^2}{(2x+1)_n^2}.$$

Here $(a)_n = a(a+1)\cdots(a+n-1)$ is the *rising factorial*. Substituting $x = 1/2$ in (8) and (9), he obtained respectively the formulae

$$(10) \qquad \sum_{n=0}^{\infty} \frac{1}{2^{2n}} \frac{(1)_n^3}{\left(\frac{3}{2}\right)_n^3} (3n+2) = \frac{\pi^2}{4},$$
$$\sum_{n=0}^{\infty} \frac{1}{2^{6n}} \frac{(1)_n^3}{\left(\frac{3}{2}\right)_n^3} (21n+13) = 4\frac{\pi^2}{3}.$$

Calabi-Yau Equations and Supercongruences

Motivated by the theory of Calabi-Yau differential equations [2], Almkvist and Guillera have discovered many new identities. One of the most pleasing is

$$(11) \quad \frac{1}{\pi^2} \stackrel{?}{=} \frac{32}{3} \sum_{n=0}^{\infty} \frac{(6n)!}{(n!)^6} \frac{(532n^2+126n+9)}{10^{6n+3}}.$$

This is yet one more case where mysterious connections have been found between disparate parts of mathematics and Ramanujan's work [21], [13], [14].

As a final example, we mention the existence of *supercongruences* of the type described in [3], [16], [23]. These are based on the empirical observation that a Ramanujan series for $1/\pi^N$, if truncated after $p-1$ terms for a prime p, seems always to produce congruences to a higher power of p. The formulas below are taken from [22]:

(12)
$$\sum_{n=0}^{p-1} \frac{(\frac{1}{4})_n (\frac{1}{2})_n^3 (\frac{3}{4})_n}{2^{4n} (1)_n^5} \left(3+34n+120n^2\right) \equiv 3p^2 \pmod{p^5},$$

(13)
$$\sum_{n=0}^{p-1} \frac{(\frac{1}{4})_n (\frac{1}{2})_n^7 (\frac{3}{4})_n}{2^{12n} (1)_n^9} \left(21+466n+4340n^2+20632n^3+43680n^4\right) \stackrel{?}{\equiv} 21p^4 \pmod{p^9}.$$

We note that (13) is the supercongruence corresponding to (6), while for (12) the corresponding infinite series sums to $32/\pi^4$. We conclude by reminding the reader that all identities marked with '$\stackrel{?}{=}$' are assuredly true but remain to be proved. Ramanujan might well be pleased.

References

[1] T. Amdeberhan, O. Espinosa, I. Gonzalez, M. Harrison, V. Moll, and A. Straub, Ramanujan's Master Theorem, *Ramanujan J.* **29** (2012, to appear).

[2] G. Almkvist, Ramanujan-like formulas for $1/\pi^2$ à la Guillera and Zudilin and Calabi-Yau differential equations, *Computer Science Journal of Moldova* **17**, no. 1 (49) (2009), 100–120.

[3] G. Almkvist and A. Meurman, Jesus Guillera's formula for $1/\pi^2$ and supercongruences (Swedish), *Normat* **58**, no. 2 (2010), 49–62.

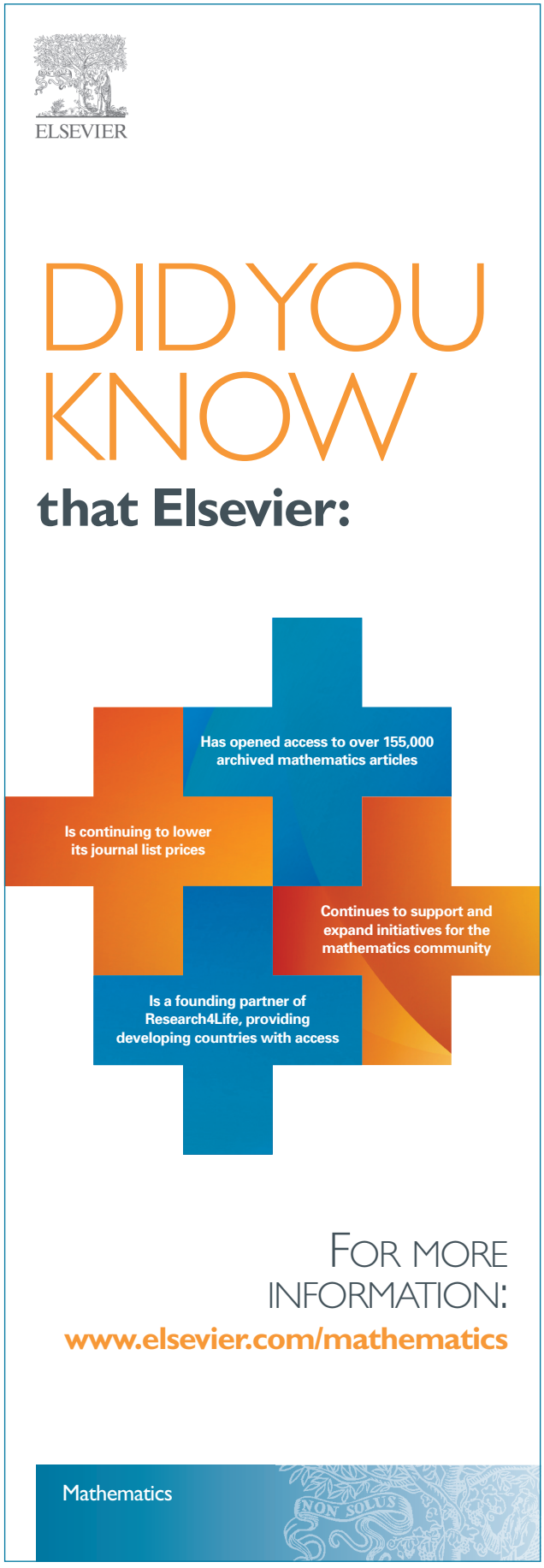
[4] D. H. Bailey, J. M. Borwein, C. S. Calude, M. J. Dinneen, M. Dumitrescu, and A. Yee, An empirical approach to the normality of pi, *Experimental Mathematics*. Accepted February 2012.

[5] N. D. Baruah, B. C. Berndt, and H. H. Chan, Ramanujan's series for $1/\pi$: A survey, *Amer. Math. Monthly* **116** (2009), 567–587.

[6] B. C. Berndt, H. H. Chan, and S. S. Huang, Incomplete elliptic integrals in Ramanujan's lost notebook, pp. 79–126 in *q-series from a Contemporary Perspective*, Contemp. Math., 254, Amer. Math. Soc., Providence, RI, 2000.

[7] J. M. Borwein and D. H. Bailey, *Mathematics by Experiment: Plausible Reasoning in the 21st Century*, 2nd ed., A K Peters, Natick, MA, 2008.
[8] J. M. Borwein, D. H. Bailey, and R. Girgensohn, *Experimentation in Mathematics: Computational Roads to Discovery*, A K Peters, 2004.
[9] J. M. Borwein and P. B. Borwein, Ramanujan and pi, *Scientific American*, February 1988, 112–117. Reprinted in *Ramanujan: Essays and Surveys*, B. C. Berndt and R. A. Rankin, eds., AMS-LMS History of Mathematics, vol. 22, 2001, pp. 187–199.
[10] _____, Class number three Ramanujan type series for $1/\pi$, *Journal of Computational and Applied Math. (Special Issue)* **46** (1993), 281–290.
[11] J. M. Borwein, P. B. Borwein, and D. A. Bailey, Ramanujan, modular equations and pi or how to compute a billion digits of pi, *MAA Monthly* **96** (1989), 201–219. Reprinted on `http://www.cecm.sfu.ca/organics`, 1996.
[12] J. M. Borwein and R. E. Crandall, On the Ramanujan AGM fraction, Part II: The complex-parameter case, *Experimental Mathematics* **13** (2004), 287–296.
[13] H. H. Chan, J. Wan, and W. Zudilin, Legendre polynomials and Ramanujan-type series for $1/\pi$, *Israel J. Math.*, in press, 2012.
[14] _____, Complex series for $1/\pi$, *Ramanujan J.*, in press, 2012.
[15] J. Guillera, Hypergeometric identities for 10 extended Ramanujan-type series, *Ramanujan J.* **15** (2008), 219–234.
[16] J. Guillera and W. Zudilin, "Divergent" Ramanujan-type supercongruences, *Proc. Amer. Math. Soc.* **140** (2012), 765–777.
[17] M. Petkovsek, H. S. Wilf, and D. Zeilberger, $A = B$, A K Peters, 1996.
[18] R. Preston, The Mountains of Pi, *New Yorker*, March 2, 1992, `http://www.newyorker.com/archive/content/articles/050411fr_archive01`.
[19] S. Ramanujan, Modular equations and approximations to pi, *Quart. J. Math.* **45** (1913–14), 350–372.
[20] H. S. Wilf and D. Zeilberger, Rational functions certify combinatorial identities, *Journal of the AMS* **3** (1990), 147–158.
[21] W. Zudilin, Ramanujan-type formulae for $1/\pi$: a second wind? Modular forms and string duality, in Fields Inst. Commun., 5, Amer. Math. Soc., Providence, RI, 2008, pp. 179–188.
[22] _____, Arithmetic hypergeometric series, *Russian Math. Surveys* **66**:2 (2011), 1–51.
[23] _____, Ramanujan-type supercongruences, *J. Number Theory* **129** (2009), 1848–1857.

The second installment of this article—with pieces by Ken Ono, K. Soundararajan, R. C. Vaughan, and S. Ole Warnaar—will appear in the January 2013 issue of the Notices.



Celebrating

125 YEARS OF ADVANCING MATHEMATICS

125th Anniversary
AMS
American Mathematical Society
www.ams.org

In 2013, the American Mathematical Society will celebrate its 125th anniversary. Founded in 1888 to further the interests of mathematics research and scholarship, the AMS continues to serve the national and international community through its meetings, publications, advocacy, and other programs.

Join us at the Joint Mathematics Meetings in San Diego (January 9-12, 2013), where there will be special events and promotions honoring the AMS 125th anniversary.

THE AMS 125TH ANNIVERSARY GALA

SATURDAY, JANUARY 12: Reception at 6pm followed by program and dinner at 7pm

To launch the year-long festivities, the AMS invites its members and friends to a celebratory dinner. Gourmet food stations and music will complement the special program. The gala will be held this year in place of the traditional banquet. Tickets are US$62 including tax and gratuity. Advance purchase required (contact mmsb@ams.org).

JMM
JOINT MATHEMATICS MEETINGS
SAN DIEGO • JAN 9-12, 2013
AMERICAN MATHEMATICAL SOCIETY
MATHEMATICAL ASSOCIATION OF AMERICA
jointmathematicsmeetings.org/jmm

SPECIALS AT THE AMS BOOK EXHIBIT BOOTH

Stop by the AMS booth in aisle 800 and enter the $125 AMS Bookstore gift certificate giveaway. Winners will be announced daily.

Free limited-edition AMS 125th anniversary canvas bag with $125 purchase. Quantities are limited, so be sure to stop by early.

AMS 125th anniversary t-shirts. Show your AMS pride with this special t-shirt, available for purchase at the AMS book booth.

A CELEBRATION AT THE AMS MEMBERSHIP BOOTH

THURSDAY, JANUARY 10 at 3pm

Anniversary cake will be served in the membership booth in the exhibit hall (aisle 800). Come join the celebration!

A special anniversary pin will be given to any AMS member who visits the membership booth any time during exhibit hours.

THROUGHOUT 2013

Look for announcements of other special events and sales throughout 2013 on ams.org, Facebook (amermathsoc), and Twitter (#AMS125).

FOR MORE INFORMATION, VISIT: ams.org/about-us/ams-125th

125th Anniversary

AMS

AMERICAN MATHEMATICAL SOCIETY

Advancing mathematics since 1888

Mysteries in Packing Regular Tetrahedra

Jeffrey C. Lagarias and Chuanming Zong

The regular tetrahedron is the simplest Platonic solid. Nevertheless, in studying its packing properties, several renowned scholars have made mistakes, and many questions about it remain unsolved. Currently no one knows the density of its densest packings, the density of its densest translative packings, or the exact value of its congruent kissing number. In this paper we recount historical developments on packing regular tetrahedra, report new results on its translative packing density and congruent kissing number, and formulate several unsolved problems.

Aristotle's Error

In the history of mathematics, one of the earliest recorded mistakes was made by Aristotle. More than 2,300 years ago, Aristotle (384–322 BCE) taught that the regular tetrahedra fill space. In *De Caelo* (*On the Heavens*) Book III.8 he says (in translation): "Among surfaces it is agreed that there are three figures which fill the place that contain them—the triangle, the square and the hexagon: among solids only two, the pyramid and the cube" [3, 306b, p. 319]. Here "pyramid" refers to the regular tetrahedron, a Platonic solid. Thus Aristotle's assertion can be taken to mean: space can be tiled by congruent regular tetrahedra.

Jeffrey C. Lagarias is professor of mathematics at the University of Michigan. His email address is lagarias@umich.edu.

Chuanming Zong is professor of mathematics at Peking University. His email address is cmzong@math.pku.edu.cn.

DOI: http://dx.doi.org/10.1090/noti918

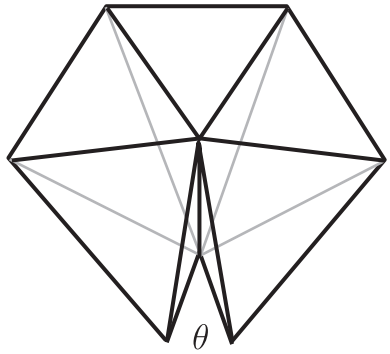


Figure 1. Five regular tetrahedra that share an edge.

Such a tiling is impossible. Let T denote a regular tetrahedron with unit edges and let α denote one of its dihedral angles. By a routine computation one can deduce that

$$\alpha = \arccos(1/3) \approx 70^\circ 32'.$$

If five tetrahedra are fitted around an edge (see Figure 1), then there is a small gap whose angular measure θ satisfies

$$0 < \theta = 2\pi - 5\alpha \approx 7^\circ 21' < \alpha,$$

and we conclude that regular tetrahedra cannot fill the space when arranged face-to-face. In any other tiling arrangement, along an edge a dihedral angle of $\pi - \alpha$ is created, which also cannot be filled by regular tetrahedra.

Of course, at the time of Aristotle, methods of geometric measurement and computation were more limited and computers were not available!

Eighteen Hundred Years to a Corrigendum

It took 1,800 years for Aristotle's error to be resolved. Much of the following history was uncovered by Struik [51].

Simplicius and Averroës

Aristotle's early commentators considered regular tetrahedral packing around a point and in so doing introduced a new mistake.

In the sixth century, to clarify Aristotle's assertion, the commentator Simplicius stated that twelve regular tetrahedra (locally) fill space about a point [33, p. 650, lines 27–28], [51]. Such an arrangement of regular tetrahedra, if it existed, would have twelve tetrahedra touch at a point and fill the solid angle. (But twelve tetrahedra do not fill the solid angle.)

In the twelfth century Averroës (Abu al-Walid Mohammad ibn Ahmad al Rushd (1126–1198)), in Cordoba, wrote thousands of pages of commentary on Aristotle, basing his work on Arabic translations of the Greek. Concerning Aristotle's assertion in *De Caelo*, he formulated a (mistaken) analysis of trihedral angles as sums of three dihedral angles and, based on this, inferred that twelve tetrahedra fill the same solid angle as eight cubes (they don't). He then concluded that twelve regular tetrahedra (locally) fill space around a point [4, Comm. 66, pp. 628–631].

Michael Scot

The Arabic commentaries of Averroës reached Christian Europe through Latin translations, many done by the Toledo school of translators. Gerard of Cremona (c. 1114–1187) translated many books, including Ptolemy's *Almagest* and Euclid's *Elements*. The translation of the commentaries of Averroës on *De Caelo* is attributed to Michael Scotus (Michael Scot (1175–c. 1234)) [19, p. 27], [54, pp. 23–25]. In 1217, in Toledo, Scot translated from Arabic the astronomical treatise of Alpetragius (al-Biṭrûjî (died c. 1204)), a non-Ptolemaic astronomical system for describing planetary motion [7]. He also translated works of Aristotle and Avicenna on animals. He later joined the service of the Holy Roman Emperor Frederick II as astrologer and wrote several works covering topics on astrology, meteorology, and other subjects [32]. His request to Leonardo of Pisa (Fibonacci) for a copy of *Liber Abaci* led Fibonacci to prepare his 1228 revised edition, which he dedicated to Scot [50, pp. 15–16]. Scot's knowledge of alchemy and other esoteric subjects (e.g., using the astrolabe to invoke evil spirits but recommending against it) led to his acquiring a reputation as a magician [54, Chap 12]. He appears in Dante's *Inferno*, condemned to the second lowest circle of Hell [1, Canto XX, v. 115–116]. He is also mentioned in Boccaccio's *Decameron*, as a necromancer [8, Eighth Day, Story 9].

Scholastic Philosophers: Roger Bacon, Peter of Auvergne, and Thomas Bradwardine

In 1266–1267 Roger Bacon (c. 1214–1294) wrote a series of essays on natural science at the request of Pope Clement II. According to Struik [51], Bacon writes in "Opus Tertium" [5, Chap. XL, pp. 135–140] that there is a fool in Paris who says that Averroës was incorrect and that twenty pyramids fill space (around a point). Bacon defends the assertion of Averroës that twelve pyramids fill space around a point but concludes that one cannot have complete certainty on these things without constructing the bodies as in Euclid's Book 13.[1]

Thomas Aquinas (c. 1225–1274), best known for his lectures on theology, commented on Aristotle using new, more literal, translations of Aristotle made by William of Moerbeke[2] (1215–c. 1286). In Naples in 1272–1273 he wrote lectures on Aristotle's *De Caelo*. These remained incomplete at his death, and the lectures of *De Caelo*, covering Books III and IV, were completed by Peter of Auvergne (d. 1304) [2, p. 222, bottom]. Peter criticizes Averroës's commentary, saying the assertion of Averroës that twelve tetrahedra fill space (at a point) is contrary to both sense perception and reason and that his assertion on solid angles is not intelligible [2, Book III, Lectio XII, pp. 234–238]. Concerning sense perception, Peter says he saw it for himself.[3]

A perceptive observation was made by Bradwardinus (Thomas Bradwardine (c. 1290–1349)), a scholastic philosopher who late in life became Archbishop of Canterbury. In *Geometria Speculativa* he stated that there are differing opinions whether the assertion of Averroës that twelve tetrahedra fill space is correct, that others assert that twenty regular tetrahedra (locally) fill space. He observed that a regular icosahedron can be subdivided around its centroid into twenty congruent tetrahedra. But he could not decide if the tetrahedra in this subdivision were regular tetrahedra [44,

[1] *The culminating Book 13 of* The Elements *proves existence and uniqueness of the five regular solids and constructs them, in each case inscribed in a sphere.*

[2] *William of Moerbeke translated part of* De Caelo *by 1260, the full text by 1265, and later the Greek commentary of Simplicius, finishing on June 15, 1271* [19, pp. 29 and 48]. *He also translated mathematical works of Hero of Alexandria and Archimedes.*

[3] "Sensui quidem; quoniam si accipiantur duodecim pyramides aequilaterae, et applicentur secundum duodecim angulos circa punctum unum, ad sensum apparebit eas non replere locum corporaliter, et hoc ad sensum expertus sum" [2, p. 237].

Sect. 4.3]. In fact, they are not regular; the solid angle at the central vertex is about ten percent larger than that of a regular tetrahedron.

Regiomontanus and Paul of Middelburg

Aristotle's error was detected by the fifteenth century. According to Struik [51], the incorrectness of Averroës's assertion, and of Aristotle's, was likely known to Regiomontanus (Johannes Müller von Königsberg (1436–1476)). The work of Regiomontanus covers symbolic algebra, spherical trigonometry, astronomy, and calendar reform. He apparently obtained a correct measure of solid angles, but the results of his investigations were not published. Only a title is known from a catalogue of his posthumous works: "On the five like-sided bodies, that are usually called regular, and which of them fill their natural place, and which do not, in contradiction to the commentator on Aristotle, Averroës." No manuscript copy is known.

In any event, a definite observation of incorrectness was made by Paul of Middelburg (Paulus van Middelburg (1445–1534)), professor of astrology in Padua circa 1478–1481, in astrological prognostics made for the years 1480 and 1481.[4] He asserts the impossibility of a (local) filling of space using any number of regular tetrahedra, since any such filling would produce a regular polyhedron having the same number of triangular faces, but the only possibilities allowed by Euclid's Book 13, the octahedron and icosahedron, cannot work.

Francesco Maurolico

A modification that corrects Aristotle's assertion by changing the tiling was found by Francesco Maurolico (1494–1575). He was of Greek descent, became a Benedictine monk in 1521 and later abbot in Messina, Sicily, and eventually was in charge of the Messina mint. He was a mathematician and astronomer and wrote many books, including observations of the supernova in 1572. His *Arithmeticorum libri duo* [42], published posthumously, contains an early proof by mathematical induction (see Libri [40, pp. 102–118]). His writings include a manuscript with a title nearly identical to the one of Regiomontanus [41]. This manuscript is now lost, but it was catalogued in Rome in 1883, listing a table of contents and a colophon stating that it was completed on December 9, 1529. According to Libri [40, pp. 242–243], a catalogue of Maurolico's

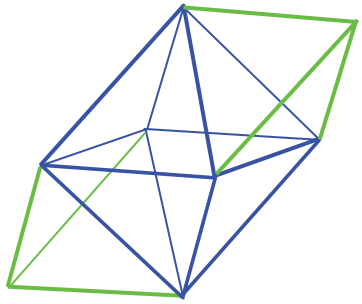


Figure 2. A polyhedral space-filler is obtained from two regular tetrahedra and a regular octahedron.

works lists this one as:[5] "Our booklet on plane and spatial regular figures, which fill their place; although it is certain that Johannes Regiomontanus has written in great detail on this, this work has never been published as far as I know. We show now in this booklet that, of the regular bodies, the cube itself, and pyramids together with octahedra, fill the place whereby it will be clear that Averroës erred in a childish way."

That is, Maurolico knew: *there exists a tiling of space using regular polyhedra other than the cube: this tiling is a periodic face-to-face tiling using a mixture of regular tetrahedra and regular octahedra having the same side length* (cf. [51]).

To describe it, make a polyhedron by gluing two regular tetrahedra to diagonally opposite faces of a regular octahedron; it has six congruent faces, each a 60°–120° rhombus (see Figure 2). This polyhedron then lattice tiles space using the face-centered cubic (fcc) lattice. The tiling has eight tetrahedra and six octahedra meeting at each vertex, and this tiling is vertex-transitive.

Hilbert's 18th Problem

In the extended version of his talk presented at the ICM 1900 in Paris, Hilbert [34] proposed twenty-three unsolved mathematical problems. At the end of his eighteenth problem, he wrote, "I point out the following question, related to the preceding one, and important to number theory and perhaps sometimes useful to physics and chemistry: How can one arrange most densely in space an infinite number of equal solids of given form, e.g., spheres with given radii or regular tetrahedra with given edges (or in prescribed position); that is, how can

[4] *The 1481prognostic reads:*
"Correlarium de errore aristotelis et commentatoris eius averroys patum ex 15 propositione 13 euclidis: quia pyramides ex quibus Icocedron conficit non sunt regularis: ergo pyramides regulares non possunt replere locum nedum si 20 sumant: immo nec in quocunque alio numero facerent corpus regulare quod est impossible" ([51, p. 136]).

[5] "De figuris planis, solidisque regularibus locum implentibus libellus noster; quamquam de hoc negocio Ioannem a Regiomonte accuratissime scripsisse certum sit: verum opus nondum, quod sciam, editum. Demonstramus autem in libello e solidis regularibus cubos per se; pyramides vero cum octahedris compactas duntaxat implere locum, qua in re Averroem pueriliter errasse, manifestum erit."

one so fit them together that the ratio of the filled to the unfilled space may be as great as possible?"

The sphere case has a long and complicated history (see Hales [30], [31] and Lagarias [39]). Kepler's conjecture, made in 1611 [37], asserts that the fcc lattice packing is a densest (general) sphere packing. The fcc packing was determined to be the densest lattice sphere packing by Gauss and Seeber in 1831 by studying the arithmetic of positive definite ternary quadratic forms (see [21], [61, Chap. 2]). Perhaps this was one of the reasons for Hilbert to ask this question.

Let K denote a convex body in the Euclidean space $\mathbb{E}^3$, with boundary $\partial(K)$, nonempty interior $\mathrm{int}(K)$, and volume $\mathrm{vol}(K)$. We define three notions of packing density as follows. Let $W = [-\frac{1}{2}, \frac{1}{2}]^3$ denote a unit cube centered at the origin so that $sW = [-\frac{s}{2}, \frac{s}{2}]^3$. A general packing $\mathcal{P}$ consists of a (possibly infinite) collection of nonoverlapping congruent copies of K, where nonoverlapping means disjoint interiors. For such $\mathcal{P}$ we define an (upper) density

$$\delta(\mathcal{P}, K) := \limsup_{s\to\infty} \frac{\mathrm{vol}(\mathcal{P} \cap sW)}{\mathrm{vol}(sW)}.$$

Then we define the *congruent packing density*, the *translative packing density*, and the *lattice packing density* of K respectively as

$$\delta^c(K) := \sup_{\mathcal{P}}\{\delta(\mathcal{P}, K) : \mathcal{P} \text{ a general packing}\},$$

$$\delta^t(K) := \sup_{\mathcal{P}}\{\delta(\mathcal{P}, K) : \mathcal{P} \text{ uses translates of } K\},$$

and

$$\delta^l(K) := \sup_{\mathcal{P}}\{\delta(\mathcal{P}, K) : \mathcal{P} \text{ is a lattice packing}\}.$$

One can show that each of these suprema is attained: e.g., there exists a general packing $\mathcal{P}$ having

$$\delta(\mathcal{P}, K) = \delta^c(K),$$

and similarly there exist a translative packing and lattice packing attaining their respective suprema. Moreover, such $\mathcal{P}$ can also be chosen to have a limiting density, i.e., having the corresponding lower density equal to their upper density. In fact, for $\delta^c(K)$, $\delta^t(K)$ and $\delta^l(K)$, the unit cube W in the definition of $\delta(\mathcal{P}, K)$ can be replaced by any other fixed convex body. For basic results and problems about these densities we refer to [10], [17], [18], [24], [46], and [61].

It follows from these definitions that

$$\delta^l(K) \le \delta^t(K) \le \delta^c(K) \le 1 \tag{1}$$

hold for every convex body K. Let $\sigma(\mathbf{x})$ denote a nonsingular affine linear transformation from $\mathbb{E}^3$ to $\mathbb{E}^3$. It is known (easy to verify) that both

$$\delta^l(\sigma(K)) = \delta^l(K)$$

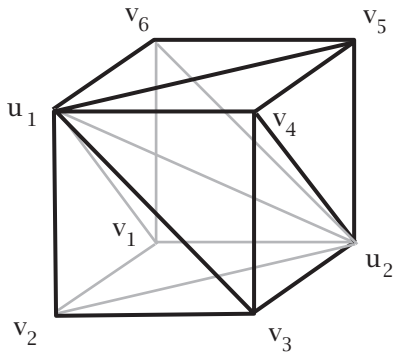


Figure 3. A cube can be divided into six congruent tetrahedra.

and

$$\delta^t(\sigma(K)) = \delta^t(K)$$

hold for all K and σ. However, for some objects K and suitable σ, we may have

$$\delta^c(\sigma(K)) \ne \delta^c(K).$$

For example, let $\mathbf{u}_1$, $\mathbf{u}_2$, $\mathbf{v}_1$, $\mathbf{v}_2$, …, $\mathbf{v}_6$ be the eight vertices of a unit cube, as shown in Figure 3, and let T_i denote the tetrahedron with vertices $\mathbf{u}_1$, $\mathbf{u}_2$, $\mathbf{v}_i$, and $\mathbf{v}_{i+1}$ (we take $\mathbf{v}_7 = \mathbf{v}_1$ in T_6). It is easy to see that the six tetrahedra $T_1, T_2, \ldots, T_6$ are congruent to each other. Thus, since unit cubes tile the space nicely, we have

$$\delta^c(T_1) = 1.$$

In fact, we obtain a periodic tetrahedron tiling of space by copies of T_1 having six tetrahedra in its unit cell. On the other hand, for the regular tetrahedron T we have (see [9], p. 208)

$$\delta^c(T) < 1,$$

and therefore

$$\delta^c(T_1) \ne \delta^c(T),$$

although $T_1 = \sigma(T)$ holds for some suitable affine linear transformation σ. This illustrates the subtle dependence of the maximal density of a (congruent) tetrahedron packing on the shape of the tetrahedron. It remains an open problem to determine those shapes of tetrahedra whose congruent copies tile space; see Senechal [49].

Minkowski's Genius and Mistake

Assume that $\mathbf{a}_1$, $\mathbf{a}_2$, $\mathbf{a}_3$ are three linearly independent vectors in $\mathbb{E}^3$. We call

$$\Lambda = \left\{\sum z_i \mathbf{a}_i : \ z_i \in \mathbb{Z}\right\}$$

a lattice. Lattices are very regular discrete sets in the space, which are additive groups with three generators.

The first work on lattice packing of general convex bodies in E^3 was done by Minkowski [43] in 1904. Let S be a centrally symmetric convex body

centered at the origin **o**. Minkowski proved the following criterion for densest lattice packings:

Theorem 1. *If S has a lattice packing of $S+\Lambda$ of maximal density, then Λ has a basis $\mathbf{a}_1, \mathbf{a}_2$, and $\mathbf{a}_3$ such that either*

$$\{\mathbf{a}_1, \mathbf{a}_2, \mathbf{a}_3, \mathbf{a}_1-\mathbf{a}_2, \mathbf{a}_2-\mathbf{a}_3, \mathbf{a}_3-\mathbf{a}_1\} \subset \partial(2S)$$

or

$$\{\mathbf{a}_1, \mathbf{a}_2, \mathbf{a}_3, \mathbf{a}_1+\mathbf{a}_2, \mathbf{a}_2+\mathbf{a}_3, \mathbf{a}_3+\mathbf{a}_1\} \subset \partial(2S).$$

As an application, he determined the density of the densest lattice packings of an octahedron O. In other words, he proved

$$\delta^l(O) = \frac{18}{19}. \tag{2}$$

Let K be a convex set and define

$$D(K) = \{\mathbf{x}-\mathbf{y} : \mathbf{x}, \mathbf{y} \in K\}.$$

Usually, we call $D(K)$ the difference set of K. Clearly $D(K)$ is a centrally symmetric convex set centered at the origin **o**. It can be shown (see [43]) that

$$(K+\mathbf{x}) \cap (K+\mathbf{y}) \neq \varnothing$$

if and only if

$$\left(\tfrac{1}{2}D(K)+\mathbf{x}\right) \cap \left(\tfrac{1}{2}D(K)+\mathbf{y}\right) \neq \varnothing.$$

Therefore, for a discrete set X in $\mathbb{E}^3$, $K+X$ is a packing if and only if $\frac{1}{2}D(K)+X$ is a packing. Consequently, we get

$$\delta^t(K) = \frac{2^3\mathrm{vol}(K)}{\mathrm{vol}(D(K))} \cdot \delta^t(D(K)) \tag{3}$$

and

$$\delta^l(K) = \frac{2^3\mathrm{vol}(K)}{\mathrm{vol}(D(K))} \cdot \delta^l(D(K)). \tag{4}$$

In [43, p. 312], Minkowski wrote[6] "If K is a tetrahedron, then $\frac{1}{2}D(K)$ is an octahedron with faces parallel to the faces of the tetrahedron." Let O denote the regular octahedron of edge length one. By routine computations, one can get

$$\mathrm{vol}(T) = \sqrt{2}/12$$

and

$$\mathrm{vol}(O) = \sqrt{2}/3.$$

Then, by (2) and (4) Minkowski [43] concluded that

$$\delta^l(T) = \frac{9}{38}. \tag{5}$$

Minkowski's idea was brilliant. Unfortunately, he made a mistake. The difference set of a regular tetrahedron is not an octahedron but a cuboctahedron. As shown in Figure 4, a cuboctahedron is very different from an octahedron.

[6] *"Ist z.B. K ein Tetraeder, so wird $\frac{1}{2}D(K)$ ein Oktaeder mit Flächen parallel den Flächen des Tetraeders."*

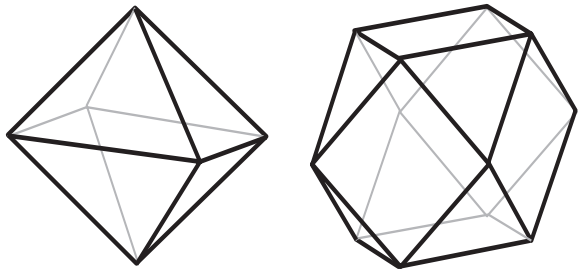


Figure 4. A cuboctahedron is very different from an octahedron.

Groemer's and Hoylman's Work

Minkowski's mistake was discovered by Groemer [23] in 1962.

Let T' denote the tetrahedron with vertices $(-1,1,1)$, $(1,-1,1)$, $(1,1,-1)$ and $(-1,-1,-1)$, and let Λ be the lattice generated by $\mathbf{a}_1 = (2,-\frac{1}{3},-\frac{1}{3})$, $\mathbf{a}_2 = (-\frac{1}{3},2,-\frac{1}{3})$ and $\mathbf{a}_3 = (-\frac{1}{3},-\frac{1}{3},2)$. It can be shown that

$$D(T') = \left\{(x_1,x_2,x_3) : \sum |x_i| \le 4,\ |x_i| \le 2\right\}$$

and

$$\Lambda \cap \mathrm{int}(D(T')) = \mathbf{o}.$$

Therefore both $\frac{1}{2}D(T')+\Lambda$ and $T'+\Lambda$ are lattice packings.[7] By routine computation it follows that the packing density of $\frac{1}{2}D(T')+\Lambda$ and $T'+\Lambda$ are $\frac{45}{49}$ and $\frac{18}{49}$, respectively. Thus, Groemer [23] obtained

$$\delta^l(D(T)) \ge \frac{45}{49} \tag{6}$$

and

$$\delta^l(T) \ge \frac{18}{49}. \tag{7}$$

Clearly Minkowski's conclusion (5) is wrong.

In addition, Groemer also observed that each tetrahedron in $T'+\Lambda$ touches fourteen others. However, he was not able to prove that the equalities in (6) and (7) hold.

In 1970 Hoylman [35] applied Minkowski's criterion to a cuboctahedron C. By considering thirty-eight cases with respect to the possible positions of the three vectors of the bases, he proved

$$\delta^l(C) = \frac{45}{49},$$
$$\delta^l(T) = \frac{18}{49},$$

and the optimal lattice is unique up to certain equivalence. In fact, Groemer's example is the only optimal lattice tetrahedron packing.

[7] *Minkowski's paper also provided a criterion to check whether $K+\Lambda$ is a packing.*

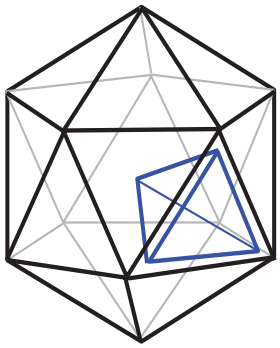


Figure 5. An icosahedron; twenty regular tetrahedra fit in it.

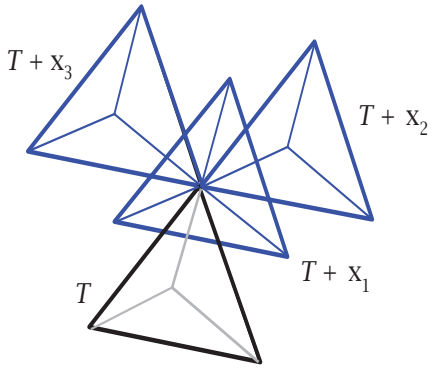


Figure 6. Three tetrahedra meet at a vertex of a fixed tetrahedron.

Based on Minkowski's work, in 2000 Betke and Henk [6] developed an algorithm by which one can determine the density of the densest lattice packing of an arbitrary three-dimensional polytope. As an example of application, Hoylman's result was verified.

Tetrahedra Touching a Point

How many nonoverlapping regular tetrahedra can touch a point?

By considering the solid angle that a regular tetrahedron cuts out, which is

$$3\arccos(1/3) - \pi \approx 0.55129 \quad \text{steradians},$$

and comparing with the full solid angle 4π, it follows that at most twenty-two tetrahedra can occupy the solid angle without overlap.

One finds that twenty regular tetrahedra can touch without overlap. This fact can be deduced from the structure of an icosahedron, as shown in Figure 5, since the distance between its centroid and vertices is shorter than its edge length. One places the twenty tetrahedra so each has one vertex at its centroid of edge length so that their opposite face sits (concentrically) inside a corresponding face of the icosahedron. There are now small gaps between each of the twenty tetrahedra so arranged.

Conjecture 1. *The maximal number of nonoverlapping regular tetrahedra that can meet at a point is twenty.*

This problem has circulated in the mathematical community for some years and has been noted by more than one person. Paul Sally (University of Chicago) [47] said that he encountered the question at Lincoln Laboratories in 1958 and later circulated it.

Conjecture 1 can be reformulated as a two-dimensional packing problem. It is equivalent to the assertion: *The maximum number of equilateral spherical triangles with angle* $\arccos(1/3)$ *that can be placed without overlap on the surface of a sphere is twenty.*

Kissing Numbers of Tetrahedra

The kissing number problem concerns finite packings. It was originally raised as the question: How many spheres, all of the same radius, can touch another sphere of the same radius? In the fourteenth century Thomas Bradwardine observed that twelve such spheres can touch a given sphere [44, Sect. 4.42]. The mathematician David Gregory discussed related problems with Isaac Newton in 1694, and in an unpublished notebook, Gregory recorded the assertion that thirteen spheres can touch one sphere [45, Vol. III, p. 317]. A rigorous mathematical proof that the kissing number of a sphere is twelve was published only in 1953 by Schütte and van der Waerden [48] (see also [9, Chap. 8], [14, Chap. 1], [61, Chap. 1]).

To generalize the thirteen sphere problem of Gregory and Newton, Hadwiger [26] introduced and studied the translative kissing number of a general convex body K. Let $\tau^c(K)$, $\tau^t(K)$ and $\tau^l(K)$ denote the congruent kissing number, the translative kissing number, and the lattice kissing number of K, respectively. For example, $\tau^t(K)$ is the maximal number of nonoverlapping translates of K, all of which touch K at its boundary. Clearly, we have

$$\tau^l(K) \le \tau^t(K) \le \tau^c(K).$$

In addition, both $\tau^l(K)$ and $\tau^t(K)$ are invariant under nonsingular linear transformations. Of course, for $\tau^c(K)$ this is not always true.

In 1961 Grünbaum [25] made the following conjecture: *The translative kissing number of an* n*-dimensional simplex is* $n(n+1)$.

This conjecture lasted only one year, as Groemer's example from the last section disproves it. Groemer's example shows that

$$\tau^c(T) \ge \tau^t(T) \ge \tau^l(T) \ge 14.$$

But what are the values of $\tau^l(T)$, $\tau^t(T)$, and $\tau^c(T)$?

For convenience, we assume that one of the four vertices of T is the origin $\mathbf{o}$ and the other three are $\mathbf{v}_1$, $\mathbf{v}_2$, and $\mathbf{v}_3$.

When Grünbaum made his conjecture, perhaps he thought about the structure that at each vertex of T there are three translates that touch it (as shown in Figure 6), and therefore altogether twelve translates surround T. In fact, this is the local structure of the lattice packing $T + \Lambda_1$, where

$$\Lambda_1 = \left\{ \sum z_i \mathbf{v}_i : \ z_i \in \mathbb{Z} \right\}.$$

In 1996 Zong [59] observed that the holes in $T + \Lambda_1$ are big enough to hold additional translates of T. In fact, we can put a whole copy of $T + \Lambda_1$ into it. We write $\mathbf{a}_1 = \mathbf{v}_1$, $\mathbf{a}_2 = \mathbf{v}_2$, and $\mathbf{a}_3 = \frac{1}{2}(\mathbf{v}_1 + \mathbf{v}_3 + \mathbf{v}_3)$ and define

$$\Lambda_2 = \left\{ \sum z_i \mathbf{a}_i : \ z_i \in \mathbb{Z} \right\}.$$

Then it can be verified that $T + \Lambda_2$ is a lattice packing of density $1/3$ in which each tetrahedron touches eighteen others. Together with Groemer and Hoylman's result, we have (see [60])

Theorem 2. *The density of the densest lattice tetrahedron packings is* $18/49$*, in which each tetrahedron touches fourteen others. There is a lattice tetrahedron packing of density* $1/3$ *in which each tetrahedron touches eighteen others.*

Besides this discovery, Zong [59] proved that

$$\tau^l(T) = 18$$

and

$$18 \le \tau^t(T) \le 19. \tag{8}$$

Three years later, by modifying Zong's method, Talata [53] was able to improve (8) to

$$\tau^t(T) = 18.$$

Congruent Kissing Numbers of Tetrahedra

From the viewpoint of pure mathematics, to determine the value $\tau^c(T)$ for the regular tetrahedron is an interesting and challenging problem.

For a lower bound, one can arrange fifty-six congruent regular tetrahedra touching a fixed one T to form an interesting cluster of fifty-seven regular tetrahedra. We follow a construction[8] given by Chen [12, Chap. 2]. First, put four tetrahedra face-to-face on the original one, forming a cluster $\mathbf{B}_5$ of five tetrahedra. Second, around each of the six edges of T, insert two more tetrahedra, each face-to-face with one of the four tetrahedra added in the first step. The resulting cluster, $\mathbf{B}_{17}$, has five tetrahedra sharing each edge of T, the maximum possible. Third, insert at each vertex new tetrahedra that sit face-to-face with each of the six tetrahedra added at the last step that touch that vertex. This adds twenty-four new nonoverlapping tetrahedra, resulting in a cluster $\mathbf{B}_{41}$. This cluster is invariant under the symmetric group S_4 of twenty-four isometries preserving T. Finally, there is still room at each vertex to insert four more tetrahedra touching it without overlap; these tetrahedra have some room to move and need not sit face-to-face. This adds sixteen more tetrahedra, giving the desired cluster $\mathbf{B}_{57}$. One may check that this cluster has twenty tetrahedra touching each of the vertices of T and furthermore that the final layer of sixteen tetrahedra may be chosen so that $\mathbf{B}_{57}$ has the full S_4-symmetry group of isometries. This construction establishes that

$$\tau^c(T) \ge 56.$$

To obtain an upper bound, let B denote the unit ball centered at the origin. If T^* is congruent to T and $T \cap T^* \neq \emptyset$, then we have

$$T^* \subset T + B.$$

Thus we get

$$(\tau^c(T) + 1) \cdot \mathrm{vol}(T) \le \mathrm{vol}(T + B).$$

By routine computations we get

$$\mathrm{vol}(T) = \frac{\sqrt{2}}{12},$$

$$\mathrm{vol}(T + B) = \frac{\sqrt{2}}{12} + \sqrt{3} + 3\left(\pi - 2\arctan\frac{\sqrt{2}}{2}\right) + \frac{4\pi}{3},$$

and therefore

$$\tau^c(T) \le \left\lfloor \frac{\mathrm{vol}(T + B)}{\mathrm{vol}(T)} \right\rfloor - 1 = 98.$$

In view of the conjecture that at most twenty regular tetrahedra can touch a point, it seems reasonable to guess that the construction above is optimal.

Conjecture 2. *The congruent kissing number of the regular tetrahedron is*

$$\tau^c(T) = 56.$$

The congruent kissing number is not invariant under linear transformations, so it can be considered for tetrahedra of any shape. As the shape of T varies, $\tau^c(T)$ may become arbitrarily large. Consider a tetrahedron T_α having one face an equilateral triangle of side length 1 in the (x, y) plane, with centroid located at the origin, and with a fourth vertex along the positive z-axis at $(0, 0, \alpha)$. As α decreases to 0, the tetrahedron flattens out. Now rotate the tetrahedron T_α so that its equilateral triangular face is parallel to the (y, z) plane. For small α many such rotated tetrahedra can be moved by translations to be stacked in parallel touching the original tetrahedron from below without overlap. Thus the kissing number for T_α grows without bound as α approaches 0.

This leads to the following natural problem.

[8] *Chen gives explicit constructions with coordinates for all the clusters listed, but does not observe the kissing number property of* $\mathbf{B}_{57}$.

Problem 1. Determine the minimal congruent kissing number $\delta^c(T)$ among all possible tetrahedral shapes T.

In particular one may ask: Does the regular tetrahedron have the minimal congruent kissing number among all shapes of tetrahedra?

A Race for Densest Congruent Packing

In 2006 Conway and Torquato [15] made a breakthrough in constructing dense congruent tetrahedron packings. Their idea is simple but very efficient.

1. *Pack twenty regular tetrahedra into an icosahedron* (*see Figure* 5). *The fraction of the icosahedral volume occupied by the tetrahedra can be* $0.8567627\ldots$.

2. *Construct a lattice icosahedra packing with maximum density. According to Betke and Henk* [6] *it is* $0.8363574\ldots$.

Thus we obtain a congruent tetrahedron packing of density approximately

$$0.8363574 \times 0.8567627 \approx 0.716559.$$

In other words, we have

$$\delta^c(T) \geq 0.716559\ldots. \tag{9}$$

They further observed that, by deforming this packing, one can slightly increase the density, and in this way they found a packing with density approximately 0.717455.

It was conjectured by Ulam (see p. 135 of [20]) that the maximal density ($0.74048\ldots$) for packing congruent spheres is smaller than that for any other convex body. Of course, it makes sense to consider a regular tetrahedron as a possible candidate for a counterexample, as Conway and Torquato [15] did.

However, in 2008, by constructing a cluster of eighteen congruent regular tetrahedra and a suitable lattice packing of the cluster, the lower bound (9) of Conway and Torquato was improved by Chen [11] to

$$\delta^c(T) \geq 0.778615\ldots.$$

This shows that the regular tetrahedron does not supply a counterexample to Ulam's conjecture.

Packings of tetrahedra have recently become relevant in materials science, in part because it is now possible to manufacture nanomaterials made of small tetrahedra, and these materials may have interesting physical properties. It has become a very active research topic, with materials scientists, physicists, and mathematicians all studying tetrahedral packings.

As one example, the Glotzer lab in chemical engineering at the University of Michigan studied such packings viewed as a fluid of hard tetrahedra, and Haji-Akbari, Engel, and Glotzer [27], [28] computed by simulation its thermodynamic phase diagram. It was observed that such a fluid appears to have a quasicrystalline solid phase at a wide range of pressures and densities [29], [28]. This is the first example of a quasicrystalline phase associated with identical nonspherical particles. Furthermore, this result appears robust against small changes in the shape of the tetrahedra.

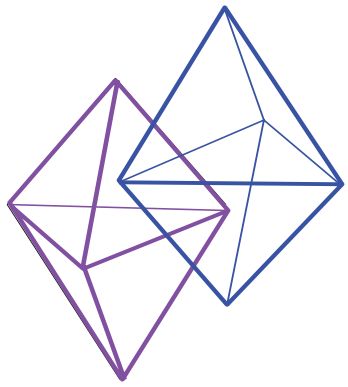


Figure 7. A pair of tetrahedra dimers, each a reflected copy of the other.

Chen's 2008 lower bound was rapidly improved by [55], [56], [29], [36], [57], [13], and [58], some packings being found by computer simulation and others by new constructions.

The current record packing is that of Chen, Engel, and Glotzer [13, Theorem 1]. It is a periodic packing of regular tetrahedra having four tetrahedra in the unit cell, consisting of a dimer of two tetrahedra sharing a face and a reflected copy of this dimer (see Figure 7), and it achieves a packing density $4000/4671 \approx 0.856347$. This packing has a set of isometries that act transitively on the individual dimers. It was found as a deformation of a packing of Kallus et al. [36], which itself used a three-dimensional extension of a double-lattice packing idea of Kuperberg and Kuperberg [38]. The paper [13] presents heuristic evidence based on simulation, suggesting that this packing could be the densest packing of regular tetrahedra. In any case, it establishes

$$\delta^c(T) \geq \frac{4000}{4671} \approx 0.856347\ldots.$$

While the race for better lower bounds may continue, the first nontrivial upper bound for $\delta^c(T)$ was achieved only in 2011. It was proved by Gravel, Elser, and Kallus [22] that

$$\delta^c(T) \leq 1 - 2.6 \times 10^{-25}. \tag{10}$$

Congruent tetrahedron packings are still far from being understood. We end this section with two basic problems.

Problem 2. What is the value of $\delta^c(T)$? Can the optimum be achieved by a periodic packing?

There is a chance that the packing of Chen, Engel, and Glotzer [13] may be extremal. If true, such a result will likely be very hard to prove. It seems harder than the sphere packing problem, because a proof must take into account the orientation of the tetrahedra in a packing.

Problem 3. Let $\mathcal{F}$ denote the family of all tetrahedra shapes. Is it true that among these the regular tetrahedra are the hardest to pack? That is, do we have

$$\min_{K\in\mathcal{F}}\{\delta^c(K)\} = \delta^c(T)?$$

The Translative Packing Density

Perhaps it is easier to determine the value of $\delta^t(T)$ than the value of $\delta^c(T)$. Moreover, since it is invariant under nonsingular affine linear transformations, $\delta^t(T)$ is important.

It was proved by Estermann [16] and Süss [52] in 1928 that

$$\frac{\mathrm{vol}(D(T))}{\mathrm{vol}(T)} = \frac{\mathrm{vol}(C)}{\mathrm{vol}(T)} = 20.$$

Together with (1), (3), and (7), we can deduce

$$\frac{18}{49} \le \delta^t(T) \le \frac{2}{5},$$

where the lower bound is $0.3673469\cdots$. Recently, by introducing a particular local method, Zong [62] has proved

$$\delta^t(C) \le \frac{90\sqrt{10}}{95\sqrt{10}-4} = 0.9601527\cdots$$

and

$$\delta^t(T) \le \frac{36\sqrt{10}}{95\sqrt{10}-4} = 0.384061\cdots.$$

These facts support the following conjecture.

Conjecture 3. *The translative packing density of the regular tetrahedron is*

$$\delta^t(T) = \frac{18}{49}.$$

Acknowledgments

The work of the first author was supported by NSF Grant DMS-1101373. The work of the second author was supported by 973 Program 2013CB834201, the National Natural Science Foundation of China (No. 11071003), and the Chang Jiang Scholars Program of China. The authors thank J. Bell, E. R. Chen, S. J. Miller, and the reviewers for helpful comments. They also thank M. Senechal for providing an English translation of Struik's paper, and B. Lasall for a translation of Peter of Auvergne's commentary.

References

1. Dante Alighieri, *The Inferno*, translated by Robert and Jean Hollander, Introduction and Notes by Robert Hollander, Doubleday, New York, 2000.
2. Thomas Aquinas, Opera Omnia, Volumen Vigesimum-Tertium. In *Aristotelis Stagiritae Libros Nonnullos Commentaria,* vol. 23, Paris, 1875.
3. Aristotle, *On the Heavens,* with an English translation by W. K. C. Guthrie, Loeb Classical Library, No. 338, Harvard Univ. Press, Cambridge, MA, 1939.
4. Averroës, *Averrois Cordubensis commentum magnum super libro De celo et mundo Aristotelis, ex recognitiones Frances James Carmody, in lucem edidit Rüdiger Arnzen,* Tomus II: Libri II–IV, Indices, Peeters, Leuven, Belgium, 2003.
5. R. Bacon, *Fr. Rogeri Bacon Opera Quaedam Hactenus Inedita. Vol I.* Containing Opus tertium, Opus minus, Compendium philosophiae (J. Brewer, ed.), Longman, Green, Longman and Roberts (series: Rerum Britannicarum medii aevi scriptores, No. 15), Her Majesty's Stationery Office, London, 1859.
6. U. Betke and M. Henk, Densest lattice packings of 3-polytopes. *Comput. Geom.* **16** (2000), 157–186.
7. Al-Biṭrûjî, *De Motibus Celorum: Critical Edition of the Latin Translation of Michael Scot*, edited by Francis J. Carmody, Univ. of Calif. Press, Berkeley, CA, 1952.
8. G. Boccaccio, *The Decameron,* translated by Guido Waldman, Introduction and Notes by Jonathan Usher, Oxford Univ. Press, Oxford, 1993.
9. K. Böröczky, *Finite Packing and Covering*, Cambridge Univ. Press, Cambridge, 2004.
10. P. Brass, W. Moser, and J. Pach, *Research Problems in Discrete Geometry,* Springer-Verlag, New York, 2005.
11. E. R. Chen, A dense packing of regular tetrahedra, *Discrete Comput. Geom.* **40** (2008), 214–240.
12. ———, *A picturebook of tetrahedral packings,* Ph.D. Thesis, Univ. of Michigan, 2010.
13. E. R. Chen, M. Engel, and S. C. Glotzer, Dense crystalline dimer packings of regular tetrahedra, *Discrete Comput. Geom.* **44** (2010), 253–280.
14. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 1988; 3rd ed., 1999.
15. J. H. Conway and S. Torquato, Packing, tiling, and covering with tetrahedra, *Proc. Natl. Acad. Sci. USA* **103** (2006), 10612–10617.
16. T. Estermann, Über den Vektorenbereich eines konvexen Körper, *Math. Z.* **28** (1928), 471–475.
17. G. Fejes Tóth and W. Kuperberg, Packing and covering with convex sets, *Handbook of Convex Geometry* (edited by P. M. Gruber and J. M. Wills), North-Holland, Amsterdam, 1993, pp. 799–860.
18. L. Fejes Tóth, *Lagerungen in der Ebene, auf der Kugeln und im Raum*, Springer-Verlag, Berlin, 1953; 2nd ed., 1972.
19. G. Galle, *Peter of Auvergne, Questions on Aristotle's "De Caelo". A Critical Edition with an Interpretative Essay*, Leuven Univ. Press, Leuven, Belgium, 2003.
20. M. Gardner, *The Colossal Book of Mathematics,* Norton, New York, 2001.
21. C. F. Gauss, Untersuchungen über die Eigenschaften der positiven ternären quadratischen Formen von Ludwig August Seeber, *Göttingische gelehrte Anzeigen* (July 9, 1831); *J. Reine Angew. Math.* **20** (1840), 312–320; *Werke, II* (1876), 188–196.

22. S. Gravel, V. Elser, and Y. Kallus, Upper bound on the packing density of regular tetrahedra and octahedra, *Discrete Comput. Geom.* **46** (2011), 799–818.
23. H. Groemer, Über die dichteste gitterförmige Lagerung kongruenter Tetraeder, *Monatsh. Math.* **66** (1962), 12–15.
24. P. M. Gruber, *Convex and Discrete Geometry*, Springer-Verlag, Berlin, 2007.
25. B. Grünbaum, On a conjecture of H. Hadwiger, *Pacific J. Math.* **11** (1961), 215–219.
26. H. Hadwiger, Über Treffanzahlen bei translationsgleichen Eikörpern, *Arch. Math.* **8** (1957), 212–213.
27. A. Haji-Akbari, *Thermodynamics of the hard tetrahedron system,* Ph.D. Thesis, Univ. of Michigan, 2011.
28. A. Haji-Akbari, M. Engel, and S. C. Glotzer, Phase diagram of hard tetrahedra, *J. Chemical Physics* **135** (2011), 194101.
29. A. Haji-Akbari, M. Engel, A. S. Keys, X. Zheng, R. G. Petschek, P. Palffy-Muhoray, and S. C. Glotzer, Disordered, quasicrystalline and crystalline phases of densely packed tetrahedra, *Nature* **462** (2009), 773.
30. T. C. Hales, Cannonballs and honeycombs, *Notices Amer. Math. Soc.* **47** (2000), 440-449.
31. ———, A proof of the Kepler conjecture, *Ann. Math. (2)* **162** (2005), 1065–1185.
32. C. H. Haskins, *Michael Scot and Frederick II*, Isis, vol. 4, 1921/1922, pp. 250–275.
33. I. L. Heiberg, ed., Simplicii in Aristotelis de Caelo Commentaria, in *Commentaria in Aristotelem Graeca,* Band VII, Preussische Akademie der Wissenschaften, 1894.
34. D. Hilbert, Mathematische Probleme, *Arch. Math. Phys.* **3** (1901), 44–63; *Bull. Amer. Math. Soc.* (N.S.) **37** (2000), 407–436.
35. D. J. Hoylman, The densest lattice packing of tetrahedra, *Bull. Amer. Math. Soc.* **76** (1970), 135–137.
36. Y. Kallus, V. Elser, and S. Gravel, Dense periodic packings of tetrahedra with small repeating units, *Discrete Comput. Geom.* **44** (2010), 245–252.
37. J. Kepler, *Strena Seu de Niue Sexangula,* Tampach: Frankfort on Main, 1611. English translation: J. Kepler, *The Six-Cornered Snowflake* (Colin Hardie, Translator), Oxford Univ. Press, Oxford, 1966.
38. G. Kuperberg and W. Kuperberg, Double-lattice packings of convex bodies in the plane, *Discrete Comput. Geom.* **5** (1990), 389–397.
39. J. C. Lagarias, The Kepler conjecture and its proof, Chap. 1 in *The Kepler Conjecture: The Hales-Ferguson Proof*, by Thomas C. Hales, Samuel P. Ferguson (J. C. Lagarias, ed.), Springer-Verlag, New York, 2011.
40. G. Libri, *Histoire des Sciences Mathématiques en Italie, depuis la renaissance des lettres. Tome Troisiéme,* Jules Renouard et Cie, Paris, 1840.
41. F. Maurolico, *De qvinque solidis, qvaue vvlgo regvlaria dicvntvr, qvae videlicet eorvm locvm impleant et qvae non, contra commentatore Aristotelis Averroem*, Manuscript. Catalogued in Bibloth. S. Pataleo, in Bibl. Naz. "Vittorio Emauele II", Rome 14 July 1883, listing table of contents.
42. D. Francisci Mavrolyci, Abbatis Messanensis, *Arithmeticorvm Libri Dvo, nvnc primvm in lvcem editi, cum rerum omnium notabilium. Indice copiosissimo.* Venetijs, apud Franciscum Franciscium Senensem, 1575.
43. H. Minkowski, Dichteste gitterförmige Lagerung kongruenter Körper, *Nachr. K. Ges. Wiss. Göttingen* (1904), 311–355.
44. G. Molland, *Thomas Bradwardine, Geometrica Speculativa*, Latin text and English translation, with an Introduction and a Commentary, Boethius Ser., Band 18, Stuttgart, Steiner Verl., Wiesbaden, 1989.
45. I. Newton, *The Correspondence of Isaac Newton* (9 volumes) (H. W. Turnbull, editor), Cambridge Univ. Press, Cambridge, 1961.
46. C. A. Rogers, *Packing and Covering*, Cambridge Univ. Press, Cambridge, 1964.
47. P. Sally, private communication.
48. K. Schütte and B. L. van der Waerden, Das Problem der dreizehn Kugeln, *Math. Ann.* **125** (1953), 325–334.
49. M. Senechal, Which tetrahedra fill space? *Math. Mag.* **54** (1981), 227–243.
50. L. E. Sigler, *Fibonacci's Liber Abaci. A Translation into Modern English of Leonardo Pisano's Book of Calculation*, Springer-Verlag, New York, 2002.
51. D. J. Struik, Het Probleem 'De impletione loci' (Dutch), Nieuw Archief voor Wiskunde, Series 2, **15** (1925–1928), no. 3, 121–137.
52. W. Süss, Über den Vektorenbereich eines Eikörpers, *Jber. Deutsch. Math. Verein.* **37** (1928), 359–362.
53. I. Talata, The translative kissing number of tetrahedra is 18, *Discrete Comput. Geom.* **22** (1999), 231–248.
54. L. Thorndike, *Michael Scot*, Thomas Nelson and Sons, London, 1965.
55. S. Torquato and Y. Jiao, Dense packings of the Platonic and Archimedean solids, *Nature* **460** (2009), 876.
56. ———, Dense packings of polyhedra: Platonic and Archimedean solids, *Phys. Rev. E* **80** (2009), 041104.
57. ———, Analytical constructions of a family of dense tetrahedron packings and the role of symmetry, `arXiv:0912.4210`.
58. ———, Exact constructions of a family of dense periodic packings of tetrahedra, *Phys. Rev. E (3)* **81** (2010), 041310.
59. C. Zong, The kissing numbers of tetrahedra, *Discrete Comput. Geom.* **15** (1996), 251–264.
60. ———, *Strange Phenomena in Convex and Discrete Geometry*, Springer-Verlag, New York, 1996.
61. ———, *Sphere Packings*, Springer-Verlag, New York, 1999.
62. ———, On the translative packing densities of tetrahedra and cuboctahedra, `arXiv:1208.0420`.

Leibniz's Laws of Continuity and Homogeneity

Mikhail G. Katz and David M. Sherry

From the *Characteristica Universalis* to Ideal Entities

Leibniz envisioned the creation of a universal language, *characteristica universalis*, ambitiously designed to serve as the vehicle for deduction and discovery in all fields of knowledge. Couturat [10] pointed out in 1901 that, in Leibniz's vision, the infinitesimal calculus was but the first salvo, or sample, of his *characteristica universalis*.

Leibniz's vision of the ideal nature of mathematical entities was remarkably modern. His description of infinitesimals as fictional entities shocked his disciples J. Bernoulli, l'Hôpital, and Varignon. And his infinitesimals certainly appeared as "Mysteries" to critics such as Berkeley, whose empiricist philosophy tolerated no conceptual innovations, such as infinitesimals, without an empirical counterpart or referent:

> Yet some there are, who, though they shrink at all other Mysteries, make no difficulty of their own, who strain at a Gnat and swallow a Camel [1, section XXXIV].

While today we are puzzled by Berkeley's rigid rejection of the idea of an infinitely divisible continuum, he also articulated a specifically *logical* criticism of the calculus (see [46]), alleging that the system suffered from logical flaws and even contradictions. Even today, many historians believe Berkeley's criticism to have been on target. Not even Robinson escaped this trend, praising Berkeley's criticism of the foundations of the calculus as "a brilliant exposure of their logical inconsistencies" [45, p. 280].

We argue that, contrary to Berkeley's view, Leibniz's system for the differential calculus was robust and free of contradiction. Leibniz articulated a set of coherent heuristic procedures for his calculus. Thus, Leibniz's system incorporated versatile heuristic principles, such as his law of continuity and laws of homogeneity, which were amenable, in the ripeness of time, to implementation as general principles governing the manipulation of modern infinitesimal and infinitely large quantities, such as the transfer principle and the standard part principle. Kanovei [21] and others performed similar reconstructions of Euler's work.

We will draw on Leibniz's work, more specifically his *Cum Prodiisset*, to argue for the consistency of Leibniz's system for the differential calculus.[1] We will also draw on the work of Leibniz historians Bos, Ferraro, Horváth, Knobloch, and Laugwitz.

Berkeley's attack on infinitesimal calculus focused specifically on the product rule as well as

Mikhail G. Katz is professor of mathematics at Bar Ilan University. His email address is katzmik@macs.biu.ac.il.

David M. Sherry is professor of philosophy at Northern Arizona University. His email address is David.Sherry@nau.edu.

DOI: http://dx.doi.org/10.1090/noti921

[1] *The text* Cum Prodiisset *sheds more light on foundational issues than the terser 1684 text* Nova methodus pro maximis et minimis… [35], *so named because the determination of maxima and minima was one of the central problems of analysis as practiced at the time, with leading scholars having composed works of similar titles (see, e.g.,* [12]*).*

on the derivation of polynomials. Once the logical contradiction, alleged by Berkeley, is resolved in the context of the product rule (see the section "Justification of the Product Rule" below), it can similarly be resolved (namely, by applying the transcendental law of homogeneity) in all other contexts.

In a seminal 1974 study of Leibnizian methodology, Bos described a *pair* of distinct approaches to justifying the calculus:

> Leibniz considered two different approaches to the foundations of the calculus; one connected with the classical methods of proof by "exhaustion", the other in connection with a law of continuity [5, item 4.2, p. 55].

The first approach relies on an Archimedean "exhaustion" methodology. We will therefore refer to it as the A-methodology. The other methodology exploits infinitesimals and the law of continuity. We will refer to it as the B-methodology, in an allusion to Johann Bernoulli, who, having learned an infinitesimal methodology from Leibniz, never wavered from it.

Knobloch explains the role of Leibniz's law of continuity in the following terms:

> In his treatise Leibniz used a dozen rules which constitute his arithmetic of the infinite. He just applied them without demonstrating them, only relying on the *law of continuity*: The rule of the finite remains valid in the domain of the infinite [30, p. 67].

Laugwitz pointed out that Leibniz's law of continuity

> contains an *a priori* assumption: our mathematical universe of discourse contains both finite objects and infinite ones [32, p. 145].

What is the ontological status of such infinitary (infinitesimal or infinite) objects in Leibniz's theory? Leibniz's was a remarkably modern insight that mathematical entities need not have a *referent*, or empirical counterpart. The fictional nature of infinitesimals was stressed by Leibniz in 1706:

> Philosophically speaking, I no more admit magnitudes infinitely small than infinitely great…I take both for mental fictions, as more convenient ways of speaking, and adapted to calculation, just like imaginary roots are in algebra (Leibniz to Des Bosses, 11 March 1706, in [16, II, p. 305]).

Infinitesimals, like imaginaries, were well-founded fictions to Leibniz. The nature of Leibniz's infinitesimals is further clarified by Ferraro, who analyzes a lengthy quotation from Leibniz's famous letter of 1702 [38] to Varignon (which we do not reproduce here to save space) in the following terms:

> According to Leibniz, imaginary numbers, infinite numbers, infinitesimals, the powers whose exponents were not "ordinary" numbers and other mathematical notions are not mere inventions; they are auxiliary and ideal quantities that…serve to shorten the path of thought [13, p. 35].

In Ferraro's view, Leibniz's infinitesimals enjoy an *ideal* ontological status similar to that of the complex numbers, *surd* (irrational) exponents, and other ideal quantities.

In the next section we will examine Leibniz's foundational stance as expressed in his seminal text *Cum Prodiisset*.

Cum Prodiisset

Leibniz's text *Cum Prodiisset* [37] (translated by Child [9]) dates from around 1701 according to modern scholars. The text is of crucial importance in understanding Leibniz's foundational stance. We will analyze it in detail in this section.

Law of Continuity, with Examples

Leibniz formulates his law of continuity in the following terms:

> Proposito quocunque transitu continuo in aliquem terminum desinente, liceat ratiocinationem communem instituere, qua ultimus terminus comprehendatur [37, p. 40].

The passage can be translated as follows:

> In any supposed continuous transition, ending in any terminus, it is permissible to institute a general reasoning, in which the final terminus may also be included.

We have deliberately avoided using the term *limit* in our translation.[2] In fact, translating *terminus* as *limit* would involve a methodological error, because the term *limit* misleadingly suggests its modern technical meaning of a real-valued operation applied to sequences or functions.

In a similar vein, Bos notes that

> the fundamental concepts of the Leibnizian infinitesimal calculus can best be understood as extrapolations to the actually infinite of concepts of the calculus of finite sequences. I use the term "extrapolation"

[2] *This is consonant with Child's translation: "In any supposed transition, ending in any terminus, it is permissible to institute a general reasoning, in which the final terminus may also be included"* [9, p. 147]. *We have reinstated the adjective* continuous *modifying* transition *(deleted by Child possibly in an attempt to downplay a perceived logical circularity of defining a law of continuity in terms of continuity itself).*

here to preclude any idea of taking a limit [5, p. 13].[3]

Leibniz gives several examples of the application of his law of continuity. We will focus on the following three examples.

(1) In the context of a discussion of parallel lines, he writes:

> When the straight line BP ultimately becomes parallel to the straight line VA, even then it converges toward it or makes an angle with it, only that the angle is then infinitely small [9, p. 148].

(2) Invoking the idea that the term *equality* may refer to equality up to an infinitesimal error, Leibniz writes:

> When one straight line[4] is equal to another, it is said to be unequal to it, but that the difference is infinitely small [9, p. 148].[5]

(3) Finally, a conception of a parabola expressed by means of an ellipse with an infinitely removed focal point is evoked in the following terms:

> A parabola is the ultimate form of an ellipse, in which the second focus is at an infinite distance from the given focus nearest to the given vertex [9, p. 148].

Status Transitus

We return to our analysis of the law of continuity as formulated in *Cum Prodiisset*. Leibniz introduces his next observation by the clause "of course it is really true that" and notes that "straight lines which are parallel never meet" [9, p. 148], that "things which are absolutely equal have a difference which is absolutely nothing" [9, p. 148], and that "a parabola is not an ellipse at all" [9, p. 149]. These remarks would seem to rule out the wondrous entities of the previous subsection. How does one, then, account for these examples? Leibniz provides an explanation in terms of a state of transition (*status transitus* in the original Latin [37, p. 42]):

> A state of transition may be imagined, or one of evanescence, in which indeed there has not yet arisen exact equality…or parallelism, but in which it is passing into such a state, that the difference is less than any assignable quantity; also that in this state there will still remain some difference,…some angle, but in each case one that is infinitely small; and the distance of the point of intersection, or the variable focus, from the fixed focus will be infinitely great, and the parabola may be included under the heading of an ellipse [9, p. 149].

A state of transition in which "there has not yet arisen exact equality" refers to example (2) in the previous subsection; "parallelism" refers to example (1); including parabola under the heading of ellipse is example (3).

Thus, the term *terminus* encompasses the *status transitus*, involving a passage into an assignable entity while being as yet inassignable. Translating *terminus* as *limit* amounts to translating it as an assignable entity, the antonym of the meaning intended by Leibniz.

The observation that Leibniz's *status transitus* is an inassignable quantity is confirmed by Leibniz's conceding that its metaphysical status is "open to question":

> Whether such a state of instantaneous transition from inequality to equality,…from convergence [i.e., lines meeting—] to parallelism, or anything of the sort, can be sustained in a rigorous or metaphysical sense, or whether infinite extensions successively greater and greater, or infinitely small ones successively less and less, are legitimate considerations, is a matter that I own to be possibly open to question [9, p. 149].

Yet Leibniz asserts that infinitesimals may be utilized independently of metaphysical controversies:

> But for him who would discuss these matters, it is not necessary to fall back upon metaphysical controversies, such as the composition of the continuum, or to make geometrical matters depend thereon [9, pp. 149–150].

To summarize, Leibniz holds that the inassignable status of *status transitus* is no obstacle to its effective use in geometry. The point is reiterated in the next paragraph:

> If any one wishes to understand these [i.e., the infinitely great or the infinitely small—] as the ultimate things, or as truly infinite, it can be done, and that too without falling back upon a controversy about the reality of extensions, or of infinite continuums in general, or of the infinitely small, ay, even though he think that such things

[3] *Bos goes on specifically to criticize the Bourbaki's* limite *wording "(Leibniz) se tient très près du calcul des différences, dont son calcul différentiel se déduit par un passage à la limite"* [6, p. 208].

[4] *Here Leibniz is using the term* line *in its generic meaning of a* segment.

[5] *Equality up to an infinitesimal is a state of transition from inequality to equality (this anticipates the transcendental law of homogeneity, dealt with in the section "Assignable and Inassignable Quantities" below).*

> are utterly impossible; it will be sufficient simply to make use of them as a tool that has advantages for the purpose of the calculation, just as the algebraists retain imaginary roots with great profit [9, p. 150].

Leibniz has just asserted the possibility of the *mathematical* infinite: "it can be done", without *philosophical* commitments as to its ontological reality.

Mathematical Implementation of *Status Transitus*

We will illustrate Leibniz's concept of *status transitus* by implementing it mathematically in the three examples mentioned by Leibniz.

In the subsection "*Status Transitus*", we mentioned that Leibniz viewed infinitesimals as fictions, and so his methods avoided any metaphysical commitments. Ishiguro [20] and others viewed a Leibnizian infinitesimal as a *logical* fiction, involving a syncategorematic paraphrase with a hidden quantifier applied to ordinary real values. We have argued against the syncategorematic interpretation in [28]. Rather, Leibnizian infinitesimals are *pure* fictions akin to imaginaries. Thus, Leibniz exploited infinitely large and infinitely small quantities in the same sense in which Albert Girard (1595–1632) and others exploited imaginary roots in order to simplify algebra. In neither case is there a commitment to corresponding mathematical entities. Thus, Leibniz anticipates modern formalist positions such as Hilbert's and Robinson's.

Of course, the structural properties of Leibniz's infinite and infinitely small quantities are different from those of modern day infinitesimals. Nonetheless, modern theories of infinitesimals *are* a way of implementing Leibniz's heuristic procedures. Thus, example (2) can be illustrated as follows. Leibniz denotes a finite positive quantity by

$$(d)x$$

(Bos [5, p. 57] replaced this by $\underline{d}x$). The assignable quantity $(d)x$ passes via infinitesimal dx on its way to absolute 0. Then the infinitesimal dx is the *status transitus*. Zero is merely the assignable *shadow*[6] of the infinitesimal. Then a *line* (i.e., segment) of length $2x + dx$ will be equal to one of length $2x$, up to an infinitesimal. This particular *status transitus* is the foundation of the Leibnizian definition of the differential quotient.

Example (1) of parallel lines can be elaborated as follows. Let us follow Leibniz in building the line through $(0, 1)$ parallel to the x-axis in the plane. Line L_H with y-intercept 1 and x-intercept H is given by $y = 1 - \frac{x}{H}$. For infinite H, the line L_H has negative infinitesimal slope, meets the x-axis at an infinite point, and forms an infinitesimal angle with the x-axis at the point where they meet. We will denote by $\mathrm{st}(x)$ the assignable (i.e., real) shadow[7] of a finite x. Then every finite point $(x, y) \in L_H$ satisfies

$$\begin{aligned}\mathrm{st}(x, y) &= (\mathrm{st}(x), \mathrm{st}(y)) \\ &= \left(\mathrm{st}(x), \mathrm{st}\left(1 - \tfrac{x}{H}\right)\right) \\ &= (\mathrm{st}(x), 1).\end{aligned}$$

Hence the finite portion of L_H is infinitely close to the line $y = 1$ parallel to the x-axis, which is its *shadow*. Thus, the parallel line is constructed by varying the oblique line depending on a parameter. Such variation passes via the *status transitus* defined by an infinite value of H.

To implement example (3), let's follow Leibniz in deforming an ellipse, via a *status transitus*, into a parabola. The ellipse with vertex (apex) at $(0, -1)$ and with foci at the origin and at $(0; H)$ is given by

$$(1) \qquad \sqrt{x^2 + y^2} + \sqrt{x^2 + (y - H)^2} = H + 2.$$

We square (1) to obtain

$$\begin{aligned}(2) \qquad & x^2 + y^2 + x^2 + (H - y)^2 \\ & \quad + 2\sqrt{(x^2 + y^2)(x^2 + (H - y)^2)} \\ & = H^2 + 4H + 4.\end{aligned}$$

We move the radical to one side:

$$\begin{aligned}(3) \qquad & 2\sqrt{(x^2 + y^2)(x^2 + (H - y)^2)} \\ & = H^2 + 4H + 4 - \left(x^2 + y^2 + x^2 + (H - y)^2\right)\end{aligned}$$

and square again. After cancellation we see that (1) is equivalent to

$$(4) \qquad \left(y + 2 + \tfrac{2}{H}\right)^2 - (x^2 + y^2)\left(1 + \tfrac{4}{H} + \tfrac{4}{H^2}\right) = 0.$$

The calculation (1) through (4) depends on habits of *general reasoning*, such as:

- squaring undoes a radical,
- the binomial formula,
- terms in an equation can be transferred to the other side, etc.

General reasoning of this type is familiar in the realm of ordinary assignable (finite) numbers, but why does it remain valid when applied to the fictional "realm" of inassignable (infinite or infinitesimal) numbers? The validity of transferring such general reasoning, originally instituted in

[6] *See footnote 7.*

[7] *Here "st" stands for the standard part function in the context of the hyperreals. Of course, Leibniz used neither the term "shadow" nor the "st" notation. Rather, these notations from modern infinitesimal analysis implement mathematically a heuristic principle of Leibniz's called the transcendental law of homogeneity, discussed in the section "Assignable and Inassignable Quantities" below.*

the finite realm, to the "realm" of the infinite is precisely the content of Leibniz's law of continuity.[8]

We therefore apply Leibniz's law of continuity to equation (4) for an infinite H. The resulting entity is still an ellipse of sorts, to the extent that it satisfies all of the equations (1) through (4). However, this entity is no longer finite. It represents a Leibnizian *status transitus* between ellipse and parabola. This *status transitus* has foci at the origin and at an infinitely distant point $(0, H)$. Assuming x and y are finite, we set $x_0 = \mathrm{st}(x)$ and $y_0 = \mathrm{st}(y)$ to obtain an equation for a real shadow of this entity:

$$\begin{aligned}
&\mathrm{st}\left(\left(y + 2 + \tfrac{2}{H}\right)^2 - (x^2 + y^2)\left(1 + \tfrac{4}{H} + \tfrac{4}{H^2}\right)\right)\\
&\quad = \left(y_0 + 2 + \mathrm{st}\left(\tfrac{2}{H}\right)\right)^2\\
&\qquad - \left(x_0^2 + y_0^2\right)\left(1 + \mathrm{st}\left(\tfrac{4}{H} + \tfrac{4}{H^2}\right)\right)\\
&\quad = (y_0 + 2)^2 - \left(x_0^2 + y_0^2\right)\\
&\quad = 0.
\end{aligned}$$

Simplifying, we obtain

$$y_0 = \frac{x_0^2}{4} - 1. \tag{5}$$

Thus, the finite portion of the *status transitus* (4) is infinitely close to its *shadow* (5), namely, the real parabola $y = \frac{x^2}{4} - 1$. This is the kind of payoff Leibniz is seeking with his law of continuity.

Some historians have been reluctant to interpret Leibniz's mathematics in terms of modern mathematical theories. Thus, Dauben presents a list of authors, including Detlef Laugwitz, who "have used nonstandard analysis to rehabilitate or 'vindicate' earlier infinitesimalists," and concludes:

> Leibniz, Euler, and Cauchy…had, in the views of some commentators, "Robinsonian" nonstandard infinitesimals in mind from the beginning. The most detailed and methodically [*sic*] sophisticated of such treatments to date is that provided by Imre Lakatos; in what follows, it is his analysis of Cauchy that is emphasized [11, p. 179].

However, Lakatos's treatment was certainly not "the most detailed and methodically sophisticated" one by the time Dauben's text appeared in 1988. Thus, in 1987, Laugwitz had published a detailed scholarly study of Cauchy in *Historia Mathematica* [31]. Laugwitz's text in *Historia Mathematica* seems to be the published version of his 1985 preprint "Cauchy and infinitesimals". Laugwitz's 1985 preprint does appear in Dauben's bibliography [11, p. 199], indicating that Dauben was familiar with it. It is odd to suggest, as Dauben seems to, that a scholarly study published in *Historia Mathematica* would countenance a view that Leibniz and Cauchy could have had "'Robinsonian' nonstandard infinitesimals in mind from the beginning." Surely Dauben has committed a strawman fallacy here.

To a historian, the claim that Leibniz's differential calculus was free of logical fallacies may seem analogous to claiming that the circle can be squared,[9] but only if the historian embraces the triumviratist story of analysis as an ineluctable march from incoherent infinitesimalism toward the yawning heights of Weierstrassian epsilontics.

Rather, Lakatos, Laugwitz, Bråting [8], and others have argued that infinitesimals as employed by Leibniz, Euler, and Cauchy have found a set-theoretic implementation in the framework of modern theories of infinitesimals. The existence of such implementations indicates that the historical infinitesimals were less prone to contradiction than has been routinely maintained by triumvirate historians.[10] The issue is dealt with in more detail by Katz and Katz [22], [23], [24], [25]; Błaszczyk et al. [2]; Borovik et al. [3]; Katz and Leichtnam [26]; Katz, Schaps, and Shnider [27].

Assignable versus Unassignable

In this section we will retain the term "unassignable" from Child's translation [9] (*inassignabiles* in the original Latin; see [37, p. 46]). After introducing finite quantities $(d)x, (d)y, (d)z$, Leibniz notes that

> the unassignables dx and dy may be substituted for them by a method of supposition even in the case when they are evanescent [9, p. 153].

Leibniz proceeds to derive his multiplicative law in the case $ay = xv$. Simplifying the differential quotient, Leibniz obtains

$$\frac{ady}{dx} = \frac{xdv}{dx} + v + dv. \tag{6}$$

At this point Leibniz proposes to transfer "the matter, as we may, to straight lines that never become evanescent," obtaining[11]

$$\frac{a\,(d)y}{(d)x} = \frac{x\,(d)v}{(d)x} + v + dv. \tag{7}$$

The advantage of (7) over (6) is that the expressions $\frac{(d)y}{(d)x}$ and $\frac{(d)v}{(d)x}$ are assignable (real). At this stage, Leibniz points out that "dv is superfluous." The reason given is that "it alone can become evanescent."

[8] *When the* general reasoning *being transferred to the infinite "realm" is generalized to encompass arbitrary elementary properties (i.e., first-order properties), one obtains the Łoś-Robinson transfer principle.*

[9] *Such was indeed the tenor of a recent referee report; see* http://u.cs.biu.ac.il/~katzmik/straw2.html

[10] *C. Boyer refers to Cantor, Dedekind, and Weierstrass as "the great triumvirate;" see (*[7, p. 298]*).*

[11] *Child incorrectly transcribes formula* (7) *from Gerhardt, replacing the equality sign in Gerhardt by a plus sign. Note that Leibniz himself used the sign* ⌐ *(see* [42, p. 371]*).*

The transcendental law of homogeneity (see the section "Assignable and Inassignable Quantities") is not mentioned explicitly in *Cum Prodiisset*; therefore the discussion of this step necessarily remains a bit vague. Discarding the dv term, one obtains the expected product formula $\frac{a\,(d)y}{(d)x} = \frac{x\,(d)v}{(d)x} + v$ in this case. Note that thinking of the left-hand side of (7) as the assignable *shadow* of the right-hand side is consistent with Leibniz's example (2) (see the subsection "Law of Continuity, with Examples").

Souverain Principe

In a February 2, 1702, letter to Varignon, Leibniz formulated the law of continuity as follows:

> …et il se trouve que les règles du fini réussissent dans l'infini comme s'il y avait des atomes (c'est à dire des éléments assignables de la nature) quoiqu'il n'y en ait point la matière étant actuellement sousdivisée sans fin; et que vice versa les règles de l'infini réussissent dans le fini, comme s'il y'avait des infiniment petits métaphysiques, quoiqu'on n'en n'ait point besoin; et que la division de la matière ne parvienne jamais à des parcelles infiniment petites: c'est parce que tout se gouverne par raison, et qu'autrement il n'aurait point de science ni règle, ce qui ne serait point conforme avec la nature du souverain principe [38, p. 350].

This formulation was cited by Robinson in 1966, [45, p. 262]. To summarize: *the rules of the finite succeed in the infinite, and conversely.*

Assignable and Inassignable Quantities

How did Leibniz view the relation of assignable and inassignable quantities?

Relation of Being Infinitely Close

The rule governing infinitesimal calculation that Knobloch represents as Leibniz's rule 2.2 states:

> 2.2. x, y finite, $x = (y+$ infinitely small$) \iff x - y \approx 0$ (not assignable difference) [30, p. 67].

Here the pair of parallel wavy lines represents the relation of being infinitely close. Leibnizian assignable quantities mark locations in what would be called today an Archimedean continuum, or A-continuum for short. Such a continuum stems from the sixteenth-century work of Simon Stevin (1548–1620) [47], [48]. Stevin initiated a systematic approach to decimal representation of measuring numbers, marking a transition from a discrete arithmetic as practiced by the Greeks, to the arithmetic of the continuum taken for granted today (see [41], [44], and [2]).

Closely related to the distinction between the A- and B-methodologies is a distinction between two types of continua, which could be called an A-continuum and a B-continuum. The latter encompasses inassignable entities such as infinitesimals (in addition to assignable ones) and can be described as a "thick" continuum.[12] On occasion, Leibniz describes such entities as "incomparable quantities" and defines them in terms of the violation of what today is called the Archimedean property. Thus, Leibniz writes in a letter to l'Hôpital:

> I call incomparable quantities of which the one can not become larger than the other if multiplied by any finite number. This conception is in accordance with the fifth definition of the fifth book of Euclid ([36, p. 288], cited in [19, p. 63]).[13]

Transcendental Law of Homogeneity

To mediate between assignable and inassignable quantities, Leibniz developed an additional principle called the *transcendental law of homogeneity*. Leibniz's transcendental law of homogeneity governs equations involving differentials. Bos interprets it as follows:

> A quantity which is infinitely small with respect to another quantity can be neglected if compared with that quantity. Thus all terms in an equation except those of the highest order of infinity, or the lowest order of infinite smallness, can be discarded. For instance,
>
> (8) $$a + dx = a,$$
> $$dx + ddy = dx,$$
>
> etc. The resulting equations satisfy this…requirement of homogeneity [5, p. 33], paraphrasing [39, pp. 381–382].

The title of Leibniz's 1710 text is *Symbolismus memorabilis calculi algebraici et infinitesimalis in comparatione potentiarum et differentiarum, et de lege homogeneorum transcendentali.* The inclusion of the transcendental law of homogeneity (*lex homogeneorum transcendentalis*) in the title of the text attests to the importance Leibniz attached to this law.

How did Leibniz use the transcendental law of homogeneity in developing the calculus? In the next section we will illustrate an application of the transcendental law of homogeneity to the particular example of the derivation of the product rule.

---

[12] *The B-continuum can be thought of as "thicker" than the A-continuum, because the B-continuum is, as it were, packed chock-full of numbers, including infinitesimals.*

[13] *Horváth notes that Leibniz is actually referring to the* fourth *definition of the fifth book.*

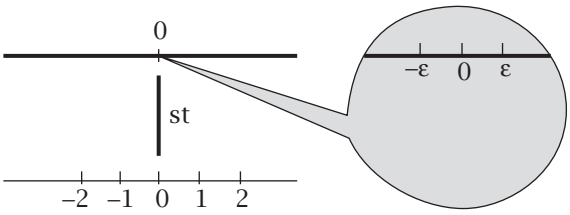


Figure 1. Zooming in on infinitesimal ϵ (here $\mathrm{st}(\pm\epsilon) = 0$).

Justification of the Product Rule

The issue is the justification of the last step in the following calculation:

$$\begin{aligned} d(uv) &= (u+du)(v+dv) - uv \\ &= udv + vdu + du\,dv \\ &= udv + vdu. \end{aligned} \tag{9}$$

The last step in the calculation (9), namely,

$$udv + vdu + du\,dv = udv + vdu,$$

is an application of Leibniz's law of homogeneity.[14]

In his 1701 text *Cum Prodiisset* [37, pp. 46–47], Leibniz presents an alternative justification of the product rule (see [5, p. 58]). Here he divides by dx and argues with differential quotients rather than differentials. We analyzed Leibniz's calculation in the subsection "Assignable versus Unassignable". Adjusting Leibniz's notation to fit with (9), we obtain an equivalent calculation:[15]

$$\begin{aligned} \frac{d(uv)}{dx} &= \frac{(u+du)(v+dv) - uv}{dx} \\ &= \frac{udv + vdu + du\,dv}{dx} \\ &= \frac{udv + vdu}{dx} + \frac{du\,dv}{dx} \\ &= \frac{udv + vdu}{dx}. \end{aligned}$$

Under suitable conditions the term $\frac{du\,dv}{dx}$ is infinitesimal, and therefore the last step

$$\frac{udv + vdu}{dx} + \frac{du\,dv}{dx} = u\frac{dv}{dx} + v\frac{du}{dx}$$

is legitimized as a special case of the transcendental law of homogeneity, which interprets the equality sign in (8) as the relation of being infinitely close, i.e., an equality up to infinitesimal error. Note that the use of the equality sign "=" to denote a nonsymmetric relation of discarding the "inhomogeneous" terms as in (8) and (9) should hardly shock the modern reader accustomed to the "big O" notation: we write $\sin x = O(1)$, but we would certainly not write $O(1) = \sin x$. Leibniz's transcendental law of homogeneity involved such an "asymmetric" relation, since it replaced an inassignable quantity such as $2x + dx$ by the assignable quantity $2x$.

[14] *Leibniz had two laws of homogeneity, one for dimension and the other for the order of infinitesimalness. Bos notes that they "disappeared from later developments"* [5, p. 35], *referring to Euler and Lagrange.*

[15] *The special case treated by Leibniz is $u(x) = x$. This limitation does not affect the conceptual structure of the argument.*

Was Leibniz's System for Differential Calculus Consistent?

Berkeley's *logical criticism* of the calculus is that the evanescent increment is first assumed to be nonzero to set up an algebraic expression and then *treated as zero* in *discarding* the terms that contained that increment when the increment is said to vanish. The criticism, however, involves a misunderstanding of Leibniz's method. The rebuttal of Berkeley's criticism is that the evanescent increment need *not* be "treated as zero" but, rather, merely *discarded* through an application of the transcendental law of homogeneity by Leibniz, as illustrated in the previous section in the case of the product rule.

While consistent, Leibniz's system unquestionably relied on heuristic principles, such as the laws of continuity and homogeneity, and would thus fall short of a standard of rigor if measured by today's criteria. On the other hand, the consistency and resilience of Leibniz's system is confirmed through the development of modern implementations of Leibniz's heuristic principles. Thus, in the 1940s, Hewitt [18] developed a modern implementation of a hyperreal B-continuum extending $\mathbb{R}$ by means of a technique referred to today as the ultrapower construction. We will denote such a B-continuum by the new symbol $\mathbb{R}$. Denoting by $\mathbb{R}_\infty$ the subset of $\mathbb{R}$ consisting of inverses of nonzero infinitesimals, we obtain a partition $\mathbb{R} = \mathbb{R}_{<\infty} \cup \mathbb{R}_\infty$, where $\mathbb{R}_{<\infty}$ is the complement of $\mathbb{R}_\infty$. We then have the standard part function

$$\mathrm{st} : \mathbb{R}_{<\infty} \to \mathbb{R}, \tag{10}$$

illustrated in Figure 1. Note that the hyperreals can be constructed out of integers (see [4]). The traditional quotient construction using Cauchy sequences, usually attributed to Cantor (and actually due to Méray [43], who published three years earlier than E. Heine), can be factored through the hyperreals (see [17]). In 1955, Łoś [40] proved his celebrated theorem on ultraproducts, implying in particular that elementary (more generally, first-order) statements over $\mathbb{R}$ are true if and only if they are true over $\mathbb{R}$, yielding a modern implementation of the Leibnizian law of *continuity*. Such a result is equivalent to what is known in the literature as the *transfer principle* (see [29]). The map that associates to every finite element of $\mathbb{R}$ the real number infinitely close to it is known in the literature as

the *standard part function* (10) (alternatively, the *shadow*). Such a map is a mathematical implementation of the Leibnizian transcendental law of *homogeneity*.

Acknowledgments

The authors are grateful to S. Wenmackers for helpful comments. The influence of Hilton Kramer (1928–2012) is obvious.

References

[1] G. Berkeley, *The Analyst, a Discourse Addressed to an Infidel Mathematician*, 1734.

[2] P. Błaszczyk, M. Katz, and D. Sherry, Ten misconceptions from the history of analysis and their debunking, *Foundations of Science*, 2012. See http://dx.doi.org/10.1007/s10699-012-9285-8 and http://arxiv.org/abs/1202.4153.

[3] A. Borovik and M. Katz, Who gave you the Cauchy–Weierstrass tale? The dual history of rigorous calculus, *Foundations of Science* **17** (2012), no. 3, 245–276. See http://dx.doi.org/10.1007/s10699-011-9235-x and http://arxiv.org/abs/1108.2885.

[4] A. Borovik, R. Jin, and M. Katz, An integer construction of infinitesimals: Toward a theory of Eudoxus hyperreals, *Notre Dame Journal of Formal Logic* **53** (2012), no. 4 557–570.

[5] H. J. M. Bos, Differentials, higher-order differentials and the derivative in the Leibnizian calculus, *Arch. History Exact Sci.* **14** (1974), 1–90.

[6] N. Bourbaki, Eléments d'histoire des mathématiques, *Histoire de la Pensée*. IV, Hermann, Paris, 1960.

[7] C. Boyer, *The Concepts of the Calculus*, Hafner Publishing Company, 1949.

[8] K. Bråting, A new look at E. G. Björling and the Cauchy sum theorem, *Arch. Hist. Exact Sci.* **61** (2007), no. 5, 519–535.

[9] Child, J. M. (ed.), *The Early Mathematical Manuscripts of Leibniz*, translated from the Latin texts published by Carl Immanuel Gerhardt, with critical and historical notes by J. M. Child, The Open Court Publishing Co., Chicago and London, 1920.

[10] L. Couturat, *La logique de Leibniz*, F. Alcan, Paris, 1901; reprinted, Olms, Hildesheim, 1961.

[11] J. Dauben, Abraham Robinson and nonstandard analysis: History, philosophy, and foundations of mathematics. In William Aspray and Philip Kitcher, eds., *History and Philosophy of Modern Mathematics* (Minneapolis, MN, 1985), pp. 177–200, Minnesota Stud. Philos. Sci., XI, Univ. of Minnesota Press, Minneapolis, MN, 1988. Available online at http://www.mcps.umn.edu/philosophy/11_7Dauben.pdf.

[12] P. Fermat, Méthode pour la recherche du maximum et du minimum, pp. 121–156 in Tannery's edition [48].

[13] G. Ferraro, Geometrical quantities and series in Leibniz. In *The Rise and Development of the Theory of Series Up to the Early* 1820s. *Sources and Studies in the History of Mathematics and Physical Sciences*, 2008, Part I, pp. 25–44. See http://dx.doi.org/10.1007/978-0-387-73468-2_2.

[14] C. I. Gerhardt (ed.), *Historia et Origo Calculi Differentialis a G. G. Leibnitio Conscripta*, Hannover, 1846.

[15] C. I. Gerhardt (ed.), *Leibnizens Mathematische Schriften*, Eidmann, Berlin and Halle, 1850–1863.

[16] C. I. Gerhardt (ed.), *G. W. Leibniz: Philosophische Schriften*, 7 vols. (1875–1890). Reprint, Georg Olms Verlag, Hildesheim, 1962.

[17] P. Giordano and M. Katz, Two ways of obtaining infinitesimals by refining Cantor's completion of the reals, preprint, 2011; see http://arxiv.org/abs/1109.3553.

[18] E. Hewitt, Rings of real-valued continuous functions. I, *Trans. Amer. Math. Soc.* **64** (1948), 45–99.

[19] M. Horváth, On the attempts made by Leibniz to justify his calculus, *Studia Leibnitiana* **18** (1986), no. 1, 60–71.

[20] H. Ishiguro, *Leibniz's Philosophy of Logic and Language*, second edition, Cambridge University Press, Cambridge, 1990.

[21] V. Kanovei, Correctness of the Euler method of decomposing the sine function into an infinite product (Russian), *Uspekhi Mat. Nauk* **43** (1988), no. 4 (262), 57–81, 255; translation in *Russian Math. Surveys* **43** (1988), no. 4, 65–94.

[22] K. Katz and M. Katz, A Burgessian critique of nominalistic tendencies in contemporary mathematics and its historiography, *Foundations of Science* **17** (2012), no. 1, 51–89. See http://dx.doi.org/10.1007/s10699-011-9223-1 and http://arxiv.org/abs/1104.0375.

[23] ———, Cauchy's continuum, *Perspectives on Science* **19** (2011), no. 4, 426–452. See http://arxiv.org/abs/1108.4201 and http://www.mitpressjournals.org/doi/abs/10.1162/POSC_a_00047.

[24] ———, Stevin numbers and reality, *Foundations of Science*, 17 (2012), no. 2, 109–123. See http://arxiv.org/abs/1107.3688 and http://dx.doi.org/10.1007/s10699-011-9228-9.

[25] ———, Meaning in classical mathematics: Is it at odds with intuitionism? *Intellectica* **56** (2011), no. 2, 223–302. See http://arxiv.org/abs/1110.5456.

[26] M. Katz and E. Leichtnam, Commuting and noncommuting infinitesimals, *American Mathematical Monthly* (to appear).

[27] M. Katz, D. Schaps, and S. Shnider, Almost equal: The method of adequality from Diophantus to Fermat and beyond, *Perspectives on Science* **20** (2012), no. 4, to appear.

[28] M. Katz and D. Sherry, Leibniz's infinitesimals: Their fictionality, their modern implementations, and their foes from Berkeley to Russell and beyond, *Erkenntnis*, 2012 (online first). See http://dx.doi.org/10.1007/s10670-012-9370-y and http://arxiv.org/abs/1205.0174.

[29] H. J. Keisler, The ultraproduct construction, *Proceedings of the Ultramath Conference*, Pisa, Italy, 2008, Contemp. Math., 530, Amer. Math. Soc., Providence, RI, 2010.

[30] E. Knobloch, Leibniz's rigorous foundation of infinitesimal geometry by means of Riemannian sums. Foundations of the formal sciences I (Berlin, 1999), *Synthese* **133** (2002), no. 1-2, 59–73.

[31] D. Laugwitz, Infinitely small quantities in Cauchy's textbooks, *Historia Math.* **14** (1987), no. 3, 258–274.

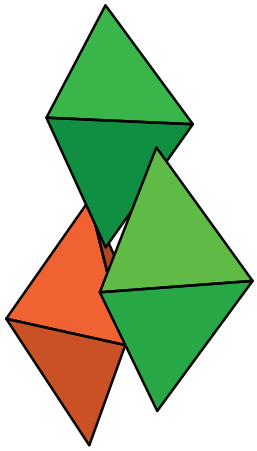
[32] ———, *Leibniz' principle and omega calculus*, Le labyrinthe du continu (Colloq., Cerisy-la-Salle, France, 1990), Springer, Paris, 1992, pp. 144–154.

About the Cover

Does it get any better?

The theme of this month's cover is taken from the article by Jeff Lagarias and Chuanming Zong in this issue. As they mention, the highest known packing density of regular tetrahedra is 4000/4671 (about 0.856347…). The packing is reported in "Dense crystalline dimer packings of regular tetrahedra", an article in *Discrete and Computational Geometry* by Elizabeth Chen, Michael Engel, and Sharon Glotzer. It is a lattice made up of a basic assembly of 4 regular tetrahedra, grouped in pairs. Each pair, called a dimer, is a pair of tetrahedra joining face-to-face. One of these dimers is the inversion of the other, so that the two dimers are complementary, and are tightly bound to each other, with faces intersecting as in the figure at left on the cover.

In the packing, a layer of dimers is laid out in a slightly rising plane. A layer of inverted dimers is then inserted tightly onto that one, and then more alternating layers are added. Some idea of how the layers fit can be seen in the top view on the cover, and in the figure below.



One thing notable about the packing is how similar it appears to the well-known packing of spheres proved not so long ago by Tom Hales to be optimal.

The packing was constructed so as to be optimal among lattice packings with faces intersecting tightly. Chen et al. include in their article some heuristic reasoning that they might in fact have discovered the densest possible packing of regular tetrahedra, although it is hard to imagine that this can ever be proved. The article includes in an appendix a remarkable set of pictures illustrating the construction, drawn by Chen.

—Bill Casselman
Graphics Editor
(notices-covers@ams.org)

[33] G. W. Leibniz, De quadratura arithmetica circuli ellipseos et hyperbolae cujus corollarium est trigonometria sine tabulis, Kritisch herausgegeben und kommentiert von Eberhard Knobloch, Vandenboeck & Ruprecht, Göttingen, 1993 [*Abhandlungen der Akademie der Wissenschaften in Göttingen, Mathematisch-physikalische Klasse* **3**, 43].

[34] _____, *Quadrature Arithmétique du Cercle, de L'ellipse et de L'hyperbole*, Marc Parmentier (trans. and ed.)/Latin text, Eberhard Knobloch (ed.), J. Vrin, Paris, 2004.

[35] _____, Nova methodus pro maximis et minimis…, in *Acta Erud.*, Oct. 1684. See [15], V, pp. 220–226.

[36] Leibniz to l'Hospital, 21 June 1695, in [15], II, pp. 287–289.

[37] G. W. Leibniz (1701) *Cum Prodiisset*…, "Cum prodiisset atque increbuisset Analysis mea infinitesimalis…", in [14], pp. 39–50.

[38] Leibniz to Varignon, 2 February, 1702, in [15], IV, pp. 91–95.

[39] G. W. Leibniz, (1710) Symbolismus memorabilis calculi algebraici et infinitesimalis in comparatione potentiarum et differentiarum, et de lege homogeneorum transcendentali. In [15], V, pp. 377–382].

[40] J. Łoś, Quelques remarques, théorèmes et problèmes sur les classes définissables d'algèbres. In *Mathematical Interpretation of Formal Systems*, North-Holland Publishing Co., Amsterdam, 1955, pp. 98–113.

[41] A. Malet, Renaissance notions of number and magnitude, *Historia Mathematica* **33** (2006), no. 1, 63–81.

[42] R. B. McClenon, A contribution of Leibniz to the history of complex numbers. *American Mathematical Monthly* **30** (1923), no. 7, 369–374.

[43] H. C. R. Méray, Remarques sur la nature des quantités définies par la condition de servir de limites à des variables données, *Revue des sociétiés savantes des départments, Section sciences mathématiques, physiques et naturelles, 4th ser.* **10** (1869), 280–289.

[44] J. Naets, How to define a number? A general epistemological account of Simon Stevin's art of defining, *Topoi* **29** (2010), no. 1, 77–86.

[45] A. Robinson, *Non-standard Analysis*, North-Holland Publishing Co., Amsterdam, 1966.

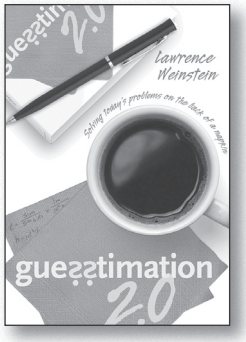
[46] D. Sherry, The wake of Berkeley's *Analyst*: rigor mathematicae? *Stud. Hist. Philos. Sci.* **18** (1987), no. 4, 455–480.

[47] S. Stevin (1585), L'Arithmetique. In A. Girard (ed.), *Les Oeuvres Mathematiques de Simon Stevin*, Leyde, 1634, part I, pp. 1–101.

[48] _____, *The Principal Works of Simon Stevin. Vols. IIA, IIB: Mathematics*, edited by D. J. Struik, C. V. Swets & Zeitlinger, Amsterdam, 1958. Vol. IIA: v+pp. 1–455 (1 plate); Vol. IIB: iv+pp. 459–976.

[49] P. Tannery and C. Henry, *Oeuvres de Fermat, Vol. 3*, Gauthier-Villars, 1891.

Do the Math



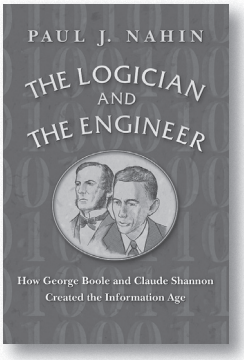
Guesstimation 2.0

Solving Today's Problems on the Back of a Napkin

Lawrence Weinstein

"*Guesstimation 2.0* is an entertaining read, with the added attraction that it can be consumed in small portions by opening it on almost any page. I can easily see having this book close by and returning to it again and again."
—Mark Levi, author of *Why Cats Land on Their Feet*

Paper with French folds $19.95 978-0-691-15080-2



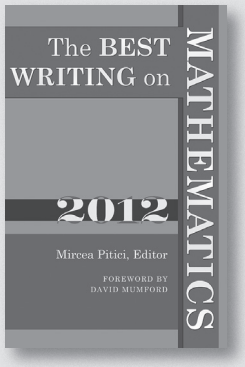
The Logician and the Engineer

How George Boole and Claude Shannon Created the Information Age

Paul J. Nahin

"Written with the skill and ability that we have come to expect from Paul Nahin, *The Logician and the Engineer* is an interesting and informative account of the history of formal logic, the lives of its two great investigators, and the applications of Boolean algebra in electronic computation."
—Chuck Adler, St. Mary's College

Cloth $24.95 978-0-691-15100-7

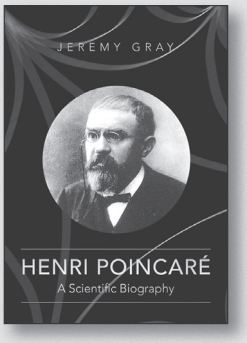


The Best Writing on Mathematics 2012

Edited by Mircea Pitici
Foreword by David Mumford

This annual anthology brings together the year's finest mathematics writing from around the world. Featuring promising new voices alongside some of the foremost names in the field, *The Best Writing on Mathematics 2012* makes available to a wide audience many articles not easily found anywhere else.

Paper $19.95 978-0-691-15655-2



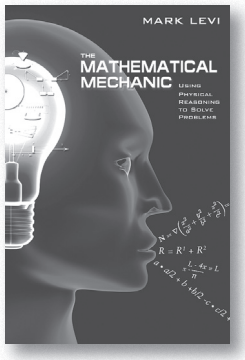
Henri Poincaré

A Scientific Biography

Jeremy Gray

"Poincaré was much more than a mathematician: he was a public intellectual, and a rare scientist who enthusiastically rose to the challenge of explaining and interpreting science for the public. With amazingly lucid explanations of Poincaré's ideas, this book is one that any reader who wants to understand the context and content of Poincaré's work will want to have on hand."
—Dana Mackenzie, author of *The Universe in Zero Words*

Cloth $35.00 978-0-691-15271-4



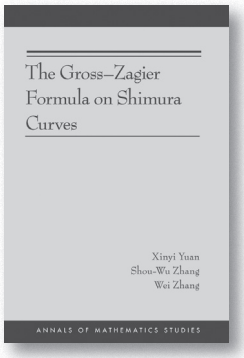
The Mathematical Mechanic

Using Physical Reasoning to Solve Problems

Mark Levi

"This book is a fresh, insightful, and highly original presentation of mathematical physics that will appeal to a broad spectrum of readers. I have not seen anything like it before. It is a book that a physicist or engineer would be proud to have written, and the fact that it has been written by a mathematician only adds to the book's authority. A definite winner."
—Paul J. Nahin, author of *Digital Dice*

Paper $14.95 978-0-691-15456-5



The Gross-Zagier Formula on Shimura Curves

Xinyi Yuan, Shou-wu Zhang & Wei Zhang

This comprehensive account of the Gross-Zagier formula on Shimura curves over totally real fields relates the heights of Heegner points on abelian varieties to the derivatives of L-series. The formula will have new applications for the Birch and Swinnerton-Dyer conjecture and Diophantine equations.

Annals of Mathematics Studies, 184
Phillip A. Griffiths, John N. Mather, and Elias M. Stein, Series Editors
Paper $75.00 978-0-691-15592-0
Cloth $150.00 978-0-691-15591-3

PRINCETON UNIVERSITY PRESS

See our E-Books at press.princeton.edu

WHAT IS . . .

a Shimura Variety?

James S. Milne

Most mathematicians have encountered modular functions. For example, when the group theorists discovered the monster group, they were surprised to find that the degrees of its irreducible representations were already encoded in the q-coefficients of the j-function. The theory of Shimura varieties grew out of the applications of modular functions and modular forms to number theory. Roughly speaking, Shimura varieties are the varieties on which modular functions live.

Shimura Curves

According to the uniformization theorem, every simply connected Riemann surface is isomorphic to the Riemann sphere, the complex plane, or the open unit disk (equivalently the complex upper half plane D_1). The Shimura curves are the quotients of D_1 by the actions of certain discrete groups, which I now describe.

The action $\left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right) z = \frac{az+b}{cz+d}$ of $\mathrm{SL}_2(\mathbb{R})$ on D_1 realizes $\mathrm{SL}_2(\mathbb{R})/\{\pm I\}$ as the group of holomorphic automorphisms $\mathrm{Hol}(D_1)$ of D_1. Let B be a quaternion algebra over a totally real number field F such that $\mathbb{R} \otimes_F B$ is isomorphic to $M_2(\mathbb{R})$ for exactly one embedding of F into $\mathbb{R}$, and let G be the algebraic group over $\mathbb{Q}$ whose R-points for any $\mathbb{Q}$-algebra R are the elements of $B \otimes_{\mathbb{Q}} R$ of norm 1. Then $G(\mathbb{R})$ is a product of $\mathrm{SL}_2(\mathbb{R})$ with a compact group, and so there is a surjective homomorphism $\varphi\colon G(\mathbb{R}) \to \mathrm{Hol}(D_1)$ with compact kernel. A Shimura curve is the quotient of D_1 by the image in $\mathrm{Hol}(D_1)$ of a congruence subgroup of $G(\mathbb{Q})$.

For example, when $B = M_2(\mathbb{Q})$, the group G is SL_2, and we get the familiar elliptic modular curves, namely, the quotients of D_1 by a discrete subgroup Γ of $\mathrm{Hol}(D_1)$ containing the image of a principal congruence subgroup

$$\Gamma(N) \stackrel{\text{def}}{=} \{A \in \mathrm{SL}_2(\mathbb{Z}) \mid A \equiv I \bmod N\}.$$

In this case, the Riemann surface $\Gamma\backslash D_1$ can be compactified in a natural way by adding a finite number of points (called the cusps), and so $\Gamma\backslash D_1$ has a unique structure of an algebraic curve compatible with its analytic structure. In all other cases, $\Gamma\backslash D_1$ is compact and so is automatically an algebraic curve.

Each Shimura curve has a natural embedding in projective space. Consider, for example, the elliptic modular curve $Y(N) \stackrel{\text{def}}{=} \Gamma(N)\backslash D_1$. A cusp form of weight $2k$ for $\Gamma(N)$ is a holomorphic function f on D_1 vanishing at the cusps and such that

(1) $$f(Az) = (cz+d)^{2k} \cdot f(z) \text{ for all } A = \left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right) \in \Gamma(N).$$

For some fixed k, a basis $f_0, \dots, f_n$ for the cusp forms of weight $2k$ defines an embedding

$$P \mapsto (f_0(P)\colon \dots \colon f_n(P))\colon Y(N) \to \mathbb{P}^n(\mathbb{C})$$

of $Y(N)$ as an algebraic subvariety of $\mathbb{P}^n(\mathbb{C})$. In fact, we can do better. Each of the cusps is fixed by a unipotent matrix $\left(\begin{smallmatrix} 1 & h \\ 0 & 1 \end{smallmatrix}\right)$ with h a positive integer. For such a matrix, (1) becomes $f(z) = f(z+h)$, and so a cusp form f has an expansion

(2) $$f(z) = a_1 q + a_2 q^2 + a_3 q^3 + \cdots, \quad q = e^{2\pi i/h}.$$

Let $\mathbb{Q}[\zeta_N]$ be the field generated over $\mathbb{Q}$ by a primitive Nth root of 1. It is possible to choose the basis $f_0, \dots, f_n$ so that the coefficients in (2) lie in the field $\mathbb{Q}[\zeta_N]$ and, when this is done, the homogeneous polynomials defining $Y(N)$ have coefficients in $\mathbb{Q}[\zeta_N]$. Thus $Y(N)$ has a canonical model over $\mathbb{Q}[\zeta_N]$. This property of $Y(N)$ is very unusual. Typically, an algebraic variety over $\mathbb{C}$ will not have a model over an algebraic number field, and when it does, it will have many distinct models, none of which is to be preferred.

The above explanation for why $Y(N)$ has a canonical model over $\mathbb{Q}[\zeta_N]$ is that of the analysts.

James S. Milne is emeritus professor of mathematics at the University of Michigan. His email address is jmilne@umich.edu.

DOI: http://dx.doi.org/10.1090/noti923

The geometers have an entirely different explanation. For an elliptic curve E over $\mathbb{C}$, the group $E(\mathbb{C})_N$ of elements of order N is a free $\mathbb{Z}/N\mathbb{Z}$-module of rank 2 equipped with a skew-symmetric pairing e_N taking values in the group of Nth roots of 1 in $\mathbb{C}$. A level-N structure on E is a basis (t_1, t_2) for $E(\mathbb{C})_N$ such that $e_N(t_1, t_2) = \zeta_N$. For $N \geq 3$, the canonical model of $Y(N)$ represents the functor sending a $\mathbb{Q}[\zeta_N]$-algebra R to the set of isomorphism classes of elliptic curves over R equipped with a level-N structure.

Both explanations fail when $B \neq M_2(\mathbb{Q})$: then the curves are compact, so there are no cusps and no q-expansions, and they are not moduli varieties in any natural way. Thus both the analysts and the geometers were surprised when Shimura (in 1967) proved that *all* these curves do have canonical models over specific number fields. The theory of Shimura varieties, as distinct from the theory of moduli varieties, can be said to have been born with Shimura's paper. Ihara (in 1968) attached Shimura's name to these curves.

Shimura Varieties, according to Shimura

A complex manifold is symmetric if each point is an isolated fixed point of an involution. For example, D_1 is symmetric because it is homogeneous and i is an isolated fixed point of the involution $z \mapsto \left(\begin{smallmatrix} 0 & -1 \\ 1 & 0 \end{smallmatrix}\right) z = -1/z$. A connected symmetric complex manifold is called a hermitian symmetric domain if it is isomorphic to a bounded open subset of $\mathbb{C}^n$ for some n. Every hermitian symmetric domain is simply connected, and so the Riemann mapping theorem shows that D_1 is the only hermitian symmetric domain of dimension one. The connected Shimura varieties are the quotients of hermitian symmetric domains by the actions of certain discrete groups, which I now describe.

The group of holomorphic automorphisms of a hermitian symmetric domain D is a semisimple Lie group whose identity component we denote by $\mathrm{Hol}(D)^+$. To define a family of connected Shimura varieties covered by D, we need a semisimple algebraic group G over $\mathbb{Q}$ and a surjective homomorphism $G(\mathbb{R}) \to \mathrm{Hol}(D)^+$ with compact kernel. The connected Shimura varieties are then the quotients $\Gamma\backslash D$ of D by a torsion-free subgroup Γ of $\mathrm{Hol}(D)^+$ containing the image of a congruence subgroup of $G(\mathbb{Q})$ as a subgroup of finite index.

Baily and Borel proved that, as in the curve case, the modular forms on D relative to Γ embed $\Gamma\backslash D$ as an algebraic subvariety of some projective space. Thus, each manifold $\Gamma\backslash D$ has a canonical structure as an algebraic variety over $\mathbb{C}$, and a later theorem of Borel shows that the algebraic structure is in fact unique.

Shimura introduced the notion of a canonical model for these algebraic varieties. This is a model of the variety over a specific number field that is uniquely determined by specifying the fields generated by the coordinates of certain special points. Shimura and his students Miyake and Shih proved the existence of canonical models for several fundamental families of connected Shimura varieties.

Shimura Varieties, according to Deligne

When Deligne was asked to report on Shimura's work in a 1971 Bourbaki seminar, he rewrote the foundations. For Deligne, a Shimura variety is defined by a reductive group G over $\mathbb{Q}$ and a $G(\mathbb{R})$-conjugacy class of homomorphisms $h\colon \mathbb{C}^\times \to G(\mathbb{R})$ satisfying certain axioms. The Shimura variety itself is a certain double coset space. The axioms ensure that, on the one hand, this double coset space is a finite disjoint union of the varieties considered in the preceding section and on the other hand, that it is the base space for a variation of Hodge structures. Sometimes the variation of Hodge structures arises from a family of abelian varieties, in which case the existence of a canonical model follows from the theory of moduli varieties. In other cases, Deligne was able to prove the existence of a canonical model by relating the Shimura variety to one that is a moduli variety. In the remaining cases, the existence of a canonical model was proved by the author and Borovoi (somewhat independently).

Shimura varieties interested Langlands as a source of Galois representations and as a test for his idea that all zeta functions are automorphic. In a 1974 lecture he introduced the term "Shimura variety" for the varieties defined by Deligne. Once the existence (and uniqueness) of their canonical models had been demonstrated, it became customary to refer to the canonical model as the Shimura variety (rather than the variety over $\mathbb{C}$). The connected components of these varieties are the canonical models of the preceding section.

Further Reading

For Shimura's approach, I suggest looking first at his notes *Automorphic Functions and Number Theory*[1] and his ICM talks. For Deligne's approach there are the difficult original articles of Deligne[2] and the author's *Introduction to Shimura Varieties*.[3]

[1] *Lecture Notes in Mathematics, No. 54, Springer, 1968.*

[2] *Travaux de Shimura. Séminaire Bourbaki (1970/71), Exp. No. 389; Variétés de Shimura, Proc. Sympos. Pure Math., 33, AMS, 1979, pp. 247–289.*

[3] *Clay Math. Proc., 4, AMS, 2005, pp. 265–378.*

Book Review

The Universe in Zero Words and In Pursuit of the Unknown

Reviewed by Gerald B. Folland

The Universe in Zero Words: The Story of Mathematics as Told through Equations
Dana Mackenzie
Princeton University Press, April 2012
224 pages, US$27.95
ISBN-13: 978-0691152829

In Pursuit of the Unknown: 17 Equations That Changed the World
Ian Stewart
Basic Books, March 2012
352 pages, US$26.99
ISBN-13:978-0465029730

A decade ago, Graham Farmelo got a dozen scientists and science writers to contribute essays on the "great equations of modern science" and compiled them into an interesting and informative book titled *It Must Be Beautiful* [2]. That book has now, it seems, engendered twin children. This year, two well-known expositors of mathematics, Dana Mackenzie and Ian Stewart, have simultaneously and independently produced books that employ a list of "great equations" (24 of them for Mackenzie, 17 for Stewart) as a framing device for discussing mathematics and its impact on civilization. Do we have a case of overkill here? Perhaps. But let me address that question after examining the evidence.

Gerald B. Folland is emeritus professor of mathematics at the University of Washington. His email address is folland@math.washington.edu.

DOI: http://dx.doi.org/10.1090/noti924

The first point to be made is that, in spite of their common theme, the books are quite dissimilar. Farmelo's book has already been reviewed in the *Notices* by Bill Faris [1], so I will say little about it here except to note a few points of comparison. Most importantly, the fact that it is the work of multiple authors, only one of whom is a mathematician, gives it a decidedly different flavor from the books of Mackenzie and Stewart under review, and its restriction to twentieth-century science gives it a narrower scope. Stewart does not assume much mathematical background on the part of his readers, and he tries to be very careful about explaining the meaning of the ingredients in his equations. In one of the early chapters he explains the concept of derivative, and thereafter he is willing to use it frequently so that some differential equations can be put on his list, but that is about as high as the mathematics goes. (Even integrals are described only briefly and used in only one chapter.) Mackenzie operates at a somewhat higher level of mathematical sophistication. He starts out simply enough—his first equation is "1 + 1 = 2", which leads into a discussion of the development of arithmetic in ancient times—but in the later chapters he is not afraid to include some equations whose precise meaning will be over the heads of many of his readers, as long as he can say something interesting about their general significance on a nontechnical level.

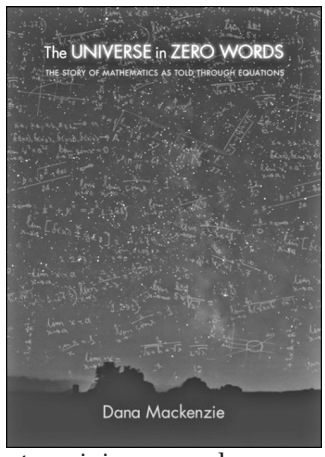
Now, what sorts of equations have the authors found worthy of inclusion in these "Top n" lists?

To begin with, the winner of the popularity contest—the one equation that is featured in all three books—is of little intrinsic interest in mathematics and only a small part of a bigger picture in physics, but it is so famous that it could not be omitted. Can you guess what it is? I'll give you a hint: one would be wrong, but not far wrong, to guess that the E on its left-hand side is in honor of Einstein.

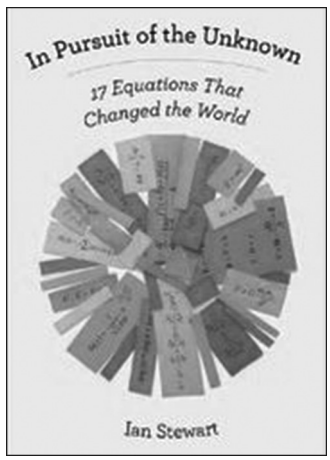
The other equations common to both Stewart and Mackenzie have a lot more mathematical meat attached to them: the Pythagorean theorem, Newton's law of gravity, Maxwell's equations, and the Black-Scholes equation. (The last of these, as the concluding topic of both books and one of the technical ideas that contributed to the recent global economic crisis, functions as a *memento mori*: an admonition that the graces of mathematics can turn into disgraces as well.) There are also other chapters with a parallel purpose in the two books, although the featured equations are different. For example, both books have a chapter on chaotic dynamics, but Stewart introduces it with the discrete logistic equation $x_{n+1} = kx_n(1 - x_n)$, whereas Mackenzie uses the Lorenz differential equations with their "strange attractor" solutions. And they each have a chapter on quantum mechanics: Stewart chooses Schrödinger's equation to frame it; Mackenzie chooses Dirac's. (Farmelo has both.)

As for the rest, one will find most of the usual suspects either in the chapter headings or elsewhere in the texts, but the authors have had to stretch things a bit to fulfill their purposes. Five of Stewart's seventeen "equations" are not actually equations, at least if an equation is an assertion that two apparently distinct things are equal. Three of them are just the definitions of the derivative, the normal distribution, and the Fourier transform, and one is just the defining relation $i^2 = -1$; the other ringer is an inequality, $dS \geq 0$. (S stands for entropy, in case you were wondering.) Similarly, one of Mackenzie's equations is $\pi = 3.1415926535\ldots$, and while π is a worthy topic of discussion, its decimal expansion is hardly its most interesting feature. In all these cases as well as others it quickly becomes clear that the equation that heads a chapter is merely what Alfred Hitchcock called "the McGuffin": the device that sets the plot in motion.

And most of those plots are quite engaging. For example, Stewart's chapter on the Pythagorean theorem begins with some remarks on its emergence in the geometry of ancient Greece and elsewhere, then leads the reader through a bit of trigonometry to Cartesian geometry, nonEuclidean geometry, and finally the apotheosis of the Pythagorean theorem in its infinitesimal form as the cornerstone of Riemannian geometry. Mackenzie's most arcane offering is the Chern-Weil-Allendoerfer-Gauss-Bonnet formula, which leads into an account of the eventful life of S. S. Chern and his role in the development of modern differential geometry and its connections to quantum physics.



Stewart is writing for the general literate reader. He tries hard to keep the technicalities at a minimum, and he spends a lot of time discussing historical developments and the phenomena of the "real world", whose study involves the mathematics in his equations. As a mathematician I sometimes wished that he would get to the point more quickly, but his discursive style is probably quite agreeable to his intended audience. As one would expect from such an experienced writer, he is generally successful in getting the essential points across in a nontechnical way without too much distortion. A few sentences here and there are obscure, and one equation (the Einstein gravitational equation including the cosmological constant, on page 236) is seriously garbled. The one chapter that I think quite unsatisfactory is the one on the second law of thermodynamics; I found Stewart's description of the relation between heat and temperature puzzling and off-kilter, and his explanation of situations where the second law apparently fails is inadequate.



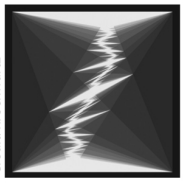
Stewart's chapter on logarithms (equation: $\log xy = \log x + \log y$) focuses on their original employment as a (powerful!) labor-saving device for numerical calculations. But computers have now rendered that use obsolete, and Stewart is at a bit of a loss to come up with modern applications. The chapter ends rather lamely by pointing out that the decibel scale of sonic intensity is a logarithmic one and that to find the half-life of an isotope from its decay law $N = N_0e^{-kt}$, one needs to know what $\log 2$ is. I think Stewart has missed a trick by not picking up on the great structural feature of his logarithmic equation: it is, to use a professional term that he would probably not want to employ,

ICERM

Institute for Computational and Experimental Research in Mathematics

Low-dimensional Topology, Geometry, and Dynamics

September 9 – December 6, 2013



Credit: R. Schwartz

Program Description: This semester-long program focuses on the recent impact of computation and experiment on the study of the pure mathematics sides of topology, geometry, and dynamics. Specific areas include 3-dimensional topology, the study of locally symmetric spaces, low-dimensional dynamics, and geometric group theory. Included are areas where computation has not yet had an impact, but might do so in the near future.

Workshop 1: Exotic Geometric Structures
September 15–20, 2013

Workshop 2: Topology, Geometry and Group Theory, Informed by Experiment
October 21–25, 2013

Workshop 3: Geometric Structures in Low-Dimensional Dynamics
November 18–22, 2013

Organizing Committee:
Marc Culler, University of Illinois, Chicago
Nathan Dunfield, University of Illinois, Urbana-Champaign
Walter Neumann, Barnard College, Columbia University
Richard Schwartz, Brown University
Caroline Series, University of Warwick
Dylan Thurston, Barnard College, Columbia University
Genevieve Walsh, Tufts University
Anton Zorich, IMJ, University Paris-7

To learn more about ICERM's programs, organizers, confirmed program participants, and to submit an application, please visit our website:

http://icerm.brown.edu

Participation: ICERM welcomes applications for long- and short-term visitors. Support for local expenses may be provided. Full consideration will be given to applications received by March 15, 2013. Decisions about online applications are typically made 1–3 months before the program, as space and funding permit. ICERM encourages women and members of underrepresented minorities to apply.

About ICERM: The Institute for Computational and Experimental Research in Mathematics is a National Science Foundation Mathematics Institute at Brown University in Providence, Rhode Island. Its mission is to broaden the relationship between mathematics and computation.

NSF BROWN

one of the earliest examples of a group homomorphism. With a little work, he could have used it to introduce one of the great themes of modern mathematics—the exploitation of correspondences between apparently different structures and some of its many recent applications.

Mackenzie's ideal readers have a little more mathematical background than Stewart's; I envision them as bright undergraduates or high school seniors who are oriented toward mathematics and science or people to whom this description would have applied in the not-too-distant past. They should probably know some calculus, and they should be comfortable enough with symbolic expressions to be able to look at an unfamiliar one with more curiosity than distaste. Mackenzie's chapters are pithier and generally more mathematically adventurous than Stewart's (and therefore, for my taste, more fun to read). For the ideal reader just described, they should serve as inviting doorways into many intriguing areas of mathematics. Like Stewart, Mackenzie is skillful at sketching things with clarity and simplicity. His weak spot is the chapter on the Dirac equation, which contains several confusions and misstatements.

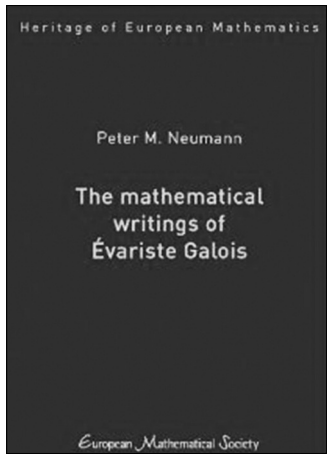
In summary, the books of Mackenzie and Stewart, as well as Farmelo, are all worthy additions to the popular scientific literature, and they are of sufficiently diverse character that their considerable overlap is not mere duplication. However, individually and collectively, they do demonstrate that the "great equations" conceit is not particularly natural or productive and that the attempt to shoehorn a wide range of mathematics into this format is a procrustean one. I don't think we now have a surfeit of "great equations" books, but we do have a sufficiency.

References

[1] W. G. Faris, Review of *It Must Be Beautiful: Great Equations of Modern Science*, by G. Farmelo, *Notices Amer. Math. Soc.* **50** (2003), 361–367.

[2] G. Farmelo (ed.), *It Must Be Beautiful: Great Equations of Modern Science*, Granta Books, London and New York, 2002.

The Mathematical Writings of Évariste Galois



Reviewed by Charles W. Curtis

The Mathematical Writings of Évariste Galois
Peter M. Neumann
European Mathematical Society, October 2011
Hardcover, 421 pages, 78.00 euros
ISBN-13:978-3-03719-104-0

The name Évariste Galois and the subject known today as Galois theory are familiar to anyone who has studied modern algebra. In his short life of twenty years, ended following a duel in May 1832, Galois created the foundations of a large part of algebra as it is studied today, together with individual results that have never lost their sparkle.

There were several French editions of his published work and other writings. These include the testamentary letter to his friend Auguste Chevalier, written on the eve of the fatal duel and published as Galois had requested in the *Revue Encyclopédique* in September 1832. Chevalier served as Galois's literary executor, made copies of two of the most important unpublished works of Galois, and gave them to Joseph Liouville in 1843. Liouville published the *Oeuvres Mathématiques d'Évariste Galois* [10] in his *Journal de Mathématiques pures et appliquées* in 1846. Other editors of the Galois manuscripts were Jules Tannery, who published *Manuscrits et Papiers inédits de Évariste Galois* in 1906, and Robert Bourgne and Jean-Pierre Azra, whose critical edition *Écrits et Mémoires Mathématiques d'Évariste Galois* appeared in 1962.

Translations of the manuscripts into German and Italian have appeared, along with English translations of some of them. The book that is the subject of this review, by Peter M. Neumann, contains an English translation of all of Galois's writings published by Liouville and Tannery and more, with the original on the facing page for purposes of comparison. The author has done a painstaking analysis of the manuscripts, so that the French edition is not simply a reissue of older ones, and has included images of some of the Galois manuscripts from the archives de l'Institut de France. The reproductions provide a fascinating counterpoint to the texts and the translations. The author has also included extensive commentary "focussed on the symbols on the page, on the syntax, on establishing an accurate text." He acknowledges that commentaries "on the semantics, the meaning of what Galois wrote, would be a quite different exercise" and "must be the subject of further studies." Hints of what further mathematical studies might be are included at several places in the notes on individual items. Comments on some of the existing English translations appear, with comparison with the author's version.

The translations begin with the five mathematical articles published in Galois's lifetime, beginning with an article on continued fractions published when he was seventeen in *Annales de Mathématiques pures et appliquées*, edited and published by J. D. Gergonne. In an introductory note, the author states that the article received a friendly review and was cited as recently as 1962 by Davenport, who commented, however, that the material was implicit in earlier work of Lagrange. The fourth, "Sur la théorie des nombres", published when Galois was eighteen, was of great interest and importance, as it contained the original version of a substantial part of the theory of finite fields.

A translation of the testamentary letter of 29 May 1832 addressed to Chevalier appears next. The letter contains a survey of Galois's ideas on the subject of what is now called Galois theory, along with a remarkable new result (with a proof) concerning the simple groups $PSL(2,p)$ and some material on

Charles W. Curtis is emeritus professor of mathematics at the University of Oregon. His email address is cwc@uoregon.edu.

DOI: http://dx.doi.org/10.1090/noti925

integrals of algebraic functions and the theory of elliptic functions.

Several of Galois's works besides the Galois theory of equations led to new developments. A striking example is the result on the simple groups $PSL(2,p)$ contained in the letter to Chevalier. Half a century later Gierster [8] gave a determination of the subgroups of $PSL(2,p)$. This included a new proof of Galois's result. It was taken up again in the last half of the twentieth century by J. H. Conway [4] in connection with exceptional properties of the known simple groups and the discovery of new nonabelian finite simple groups—the sporadic simple groups. Galois's foray into group theory in the letter to Chevalier began with a summary of some properties of the group of linear fractional transformations

$$x \to \frac{ax+b}{cx+d}$$

with x in the finite field F of p elements, for an odd prime p and $ad-bc \neq 0$, which can be identified with the quotient $PSL(2,p)$ of the finite group $SL(2,p)$ of 2×2 matrices of determinant one by its center, of order 2. Galois stated (Neumann's translation), "Thus simplified, the group has

$$\frac{(p+1))p(p-1)}{2},$$

permutations. But it is easy to see that it is not further decomposable properly unless $p=2$ or $p=3$." In modern terminology, Galois stated that $PSL(2,p)$ is a simple group if $p \neq 2,3$. As the group $PSL(2,p)$ has a subgroup of index $p+1$, it has a transitive permutation representation on $p+1$ elements. Galois raised the question as to whether $PSL(2,p)$ has a transitive permutation representation on a set of fewer than $p+1$ elements, first pointing out that this is not possible for a set of fewer than p elements. He then stated and gave an outline of a proof of the theorem that the group $PSL(2,p)$ has a transitive permutation representation on a set of p elements when $p = 5,7,11$ and does not have a nontrivial permutation representation on a set of fewer than $p+1$ elements if $p > 11$. The theorem applies to the simple groups $PSL(2,p)$ for $p \geq 5$. It can also be mentioned that the group $PSL(2,3)$ of order 12 has a transitive permutation representation on a set of 3 elements. Conway examined more closely the cases $p = 3,5,7,11$ in Galois's theorem, leading to exceptional properties of the groups $PSL(2,p)$ in these cases. For example, these include isomorphisms $PSL(2,3) \cong A_4, PSL(2,5) \cong A_5$, and a presentation of the sporadic Mathieu simple group M_{12} of order $12 \cdot 11 \cdot 10 \cdot 9 \cdot 8$ related to a presentation of the simple group $PSL(2,11)$. Conway continued with an illustration of the way the exceptional permutation representations of the small simple groups $PSL(2,p)$ can arise in other situations by considering the permutation representation of Janko's sporadic simple group J of order 175560 on 266 letters, involving the simple group $PSL(2,11)$.

In a note preceding the translation of the article "Mémoire sur les conditions de résolubilitié des équations par radicaux", usually referred to as the First Memoir (Premier Memoir), Neumann states, "The memoir on the conditions for solubility of equations by radicals is undoubtedly Galois's most important work. It is here that he presented his original approach to the theory of equations which has now become known as Galois Theory." Galois had submitted it to the Académie des Sciences on 17 January 1831, only to have it rejected and returned to him on the basis of a referees' report by Lacroix and Poisson. In the notes on the first memoir, Neumann provides a translation of the referees' report on it, with comments on the report by J. Tits and the author and some history of further attempts by Galois to interest the Académie des Sciences in his work. In the testamentary letter, Galois gave his view on the situation: "Le premier est écrit, et malgré ce qu'en a dit Poisson, je le maintiens avec les corrections que j'y ai faites." (Neumann's translation: "The first [memoir] is written, and in spite of what Poisson has said about it, I stand by it with the corrections that I have made on it.")

The purpose of the first memoir was to define a finite group, today called the *Galois group*, associated with a polynomial equation $f(x) = 0$ and to derive the necessary and sufficient conditions the group must satisfy in order for the equation to be solvable by radicals. The basic ideas about finite groups needed to carry this out were developed in the memoir for the first time and are part of the early history of finite group theory.

In his book *Galois Theory* [6], Harold Edwards gave an account of the subject "in a way that would not only explain it, but explain it in terms close enough to Galois's own to make his memoir accessible to the reader." With Neumann's translation and commentary on the first memoir now available, Edwards has given a step-by-step presentation, addressed to "modern readers", of the main results in the first memoir [7].

A modern approach to Galois theory (see for example [1]) is based on a study of the splitting field of a separable polynomial with coefficients in a base field. The Galois group of the field extension is the set of automorphisms of the splitting field that leave elements of the base field fixed. The main theorem of Galois theory is the statement that there is a one-to-one correspondence between subgroups of the Galois group and intermediate fields, which are subfields of the splitting field containing the base field. An intermediate field is a normal extension of the base field if and only if the corresponding subgroup of the Galois group is a normal subgroup.

The ideas involved in Galois's description of the subfields of the splitting field of a polynomial in terms of the subgroups of the Galois group have appeared later in other parts of mathematics. For example, they were acknowledged in Chevalley's ap-

proach to the notion of a covering space of a topological space and the Poincaré group (or fundamental group) associated with the simply connected covering space. Chevalley stated in his book *Theory of Lie Groups* [2, p. 27]: "The Poincaré group is the group of automorphisms of the simply connected covering space, playing therefore a role similar to that played by the Galois group of an algebraic extension."

The comments I make in this review about Galois's result in group theory in the testamentary letter and the reference to Chevalley's comment about Galois in his *Theory of Lie Groups* represent my own expanded appreciation of Galois beyond the Galois theory of equations. This began when I heard Conway's lecture on exceptional groups at Oxford (where I had been lecturing about Chevalley groups and thinking about simple groups) and realized that, at least for me, Galois's result put his overall contribution in a new light. The reference to Chevalley's book comes from a course on Lie groups which I gave at Wisconsin in the 1950s to an audience including students of R. H. Bing who all knew more topology than I did and were rather dismissive of Chevalley's treatment of covering spaces. I developed the parallel with Galois theory in more detail than Chevalley and found it quite satisfying, even though the topologically inclined students were probably not impressed.

The second memoir, "Des équations primitives qui sont solubles par radicaux", contains further development of the theory of permutation groups in connection with the problem stated in the title. As Neumann says, "That this is an old unfinished piece of work that Galois had intended to amplify, polish and publish seems clear." With reference to the second memoir, the author says in an epilogue "Myths and Mysteries" (p. 386): "The *Lettre testamentaire* bears witness to the fertility of his mind and very strongly suggests that he had created much mathematics that goes a long way beyond what he had published and what he had drafted in the *Premier Mémoire*. One can—and many writers do—build an edifice of conjecture on the brief sketch he gave there. Much, though not all, of what he wrote about primitive soluble equations (or groups) and about the groups now known as $PSL(2,p)$ is supported in part in the *Second Mémoire*."

The remaining translations, in a chapter entitled "The Minor Mathematical Manuscripts", include what are often fragments relating to the first and second memoirs and other topics, such as Galois's explanation of how his work was independent of Abel's work on the general equation of the fifth degree. On this point Galois stated (in Neumann's translation), "but he has left nothing on the general discussion of the problem which has occupied us. Once and for all, what is remarkable in our theory is to be able to answer yes or no in all cases" (with the last few words crossed out and replaced by the single word "répondre"). This is surely an indication of Galois's anticipation of the modern approach to parts of the mathematics of today, characterized by the search for general solutions to problems.

The items in the chapter are organized into dossiers from a volume of manuscripts in the library of the Institut de France. Neumann has "sought to reproduce [each] manuscript as accurately as possible in print, with all its crossings-out, emendations, additions, and quirks of writing." Notes are included before and after each item, with detailed comparisons to corresponding parts of the material in the editions of Tannery and of Bourgne and Azra, and occasionally mathematical topics the author plans to explore. This part of the book with the texts and the accompanying notes fills in the sketchy picture we have of Galois's mathematical persona in a particularly satisfying way and will be an important reference for further studies of Galois's mathematics.

The collected works show that Galois's thinking was not restricted to his group-theoretic approach to the theory of equations, complete and satisfying as it was. His results on exceptional permutation representations of the simple groups $PSL(2,p)$ put him in the company of twentieth-century group theorists in their search for new nonabelian finite simple groups. Another topic that started with Galois and which would require a long and multifaceted article in order to describe its place in today's mathematics is the theory of finite fields. I shall mention here only a few things about finite fields and linear groups. The starting point is the great book of C. Jordan [9], *Traité des substitutions et des équations algébriques*, published in 1870, on linear groups over the finite field of p elements for a prime p, with applications to Galois theory. In the preface the author mentions works he consulted, beginning with the works of Galois, on which, he states, his book (of over 600 pages) is a commentary! He credits Galois for calling attention to the distinction of whether a group is simple or not. He defines what are now called the classical groups—the general linear group, the orthogonal group and the symplectic group—on a finite dimensional vector space over the finite field of p elements. For each type of group, he calculates the order and the composition factors. In 1900 L. E. Dickson published *Linear Groups, with an Exposition of the Galois Field Theory* [5]. The first part of the book contains a thorough presentation of Galois's theory of finite fields. The main point of the book is to carry over Jordan's work on the classical groups over the field of p elements to the corresponding theory for classical groups over a general finite field. The nonabelian finite simple groups obtained as composition factors of the classical groups, along with twisted versions of them and the alternating groups, were the only known infinite families of nonabelian simple groups until Chevalley's paper "Sur certains groupes simples" [3] gave new infinite families of nonabelian

finite simple groups associated with the exceptional simple Lie algebras.

The book, in the author's words, "is conceived as a contribution to the history of mathematics." It also gives a mathematically knowledgeable reader a chance to follow a series of groundbreaking mathematical events, from Galois's invention of what he needed from group theory in order to solve the problem stated in the title of the first memoir to his first steps towards establishing group theory as an independent subject, beginning with the second memoir and continuing with his determination, in the letter to Chevalier, of the exceptional permutation representations of the linear fractional groups. It's quite a story.

References

[1] E. Artin, *Galois Theory*, Notre Dame Mathematical Lectures, Number 2, University of Notre Dame, 1946.

[2] C. Chevalley, *Theory of Lie Groups*, Princeton University Press, 1946.

[3] C. Chevalley, Sur certains groupes simples, *Tôhoku Math. J.* (2) **7** (1955), 14–66.

[4] J. H. Conway, Three lectures on exceptional groups, Chapter VII in *Finite Simple Groups*, M. B. Powell and G. Higman, eds., Academic Press, London, 1971.

[5] L. E. Dickson, *Linear Groups, with an Exposition of the Galois Field Theory*, Dover Publications, New York, 1958.

[6] H. M. Edwards, *Galois Theory*, Springer-Verlag, New York, 1984.

[7] H. M. Edwards, Galois for 21st century readers, *Notices Amer. Math. Soc.* **59**, no. 7 (2012), 912–923.

[8] J. Gierster, Die Untergruppen der Galois'schen Gruppe der Modulargleichungen für den Fall eines primzahligen Transformationsgrades, *Math. Annalen* **18** (1881), 319–365.

[9] C. Jordan, *Traité des substitutions et des équations algébriques*, Gauthier-Villars, Paris, 1870.

[10] J. Liouville (ed.), Oeuvres Mathématiques d'Évariste Galois, *Journal de Mathématiques pures et appliquées* **XI** (1846), 381–444.

Mathematical Sciences Center
Tsinghua University, Beijing, China

Positions:

Distinguished Professorship; Professorship;

Associate Professorship; Assistant Professorship

The MSC invites applications for the above positions in the full spectrum of mathematical sciences: ranging from pure mathematics, applied PDE, computational mathematics to statistics. The currentannual salary range is between 0.15-1.0 million RMB.Salary will be determined by applicants' qualification.Strong promise/track record in research and teaching are required. Completed applications must be electronically submitted, and must contain curriculum vitae, research statement, teaching statement, selected reprints and /or preprints, three reference letters on academic research And one reference letter on teaching, sent electronically to msc-recruitment@math.tsinghua.edu.cn

The review process starts in December 2012, and closes by April 30, 2013. Applicants are encouraged to submit their applications before December 15，2012.

****

Positions: post-doctorate fellowship

Mathematical Sciences Center (MSC) will hire a substantial number of post-doctorate fellows in the full spectrum of mathematical sciences. New and recent PhDs are encouraged for this position.

A typical appointment for post-doctorate fellowship of MSC is for three-years. Salary and compensation package are determined by qualification, accomplishment, and experience. MSC offers very competitive packages.

Completed applications must contain curriculum vitae, research statement, teaching statement, selected reprints and /or preprints, three reference letters, sent electronically to msc-recruitment@math.tsinghua.edu.cn

The review process starts in December 2012, and closes by April 30, 2013. Applicants are encouraged to submit their applications before December 15, 2012.

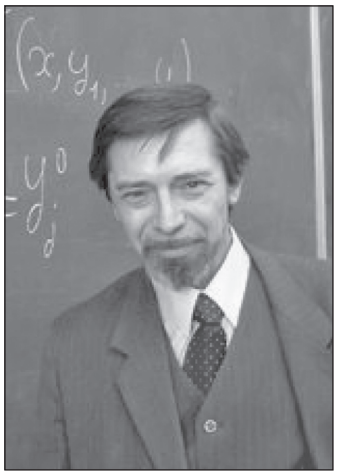
Alexander Abrosimov

Valery Beloshapka, Aleksey Kalinin, Michael Kuznetsov, Kirill Mayorov, Grigory Polotovskiy, Ivan Remizov, Yakov Sennikovskiy, George Shabat, Mikhail Tokman, Alexander Tumanov, Grigoriy Zhislin

On June 20, 2011, the outstanding mathematician and teacherAlexander V. Abrosimov passed away in the city of Nizhny Novgorod in Russia, due to a serious illness.

Alexander Abrosimov was born on November 16, 1948, in the city of Kuibyshev (now Samara). In 1971 he graduated from the Department of Mechanics and Mathematics of the State University of Gorky (now Lobachevsky State University of Nizhny Novgorod).

Dr. Abrosimov undertook graduate studies in the Department of Mechanics and Mathematics of Lomonosov Moscow State University under the supervision of Professor Boris Shabat. In 1984 he defended his Ph.D. dissertation "Complex differential systems and the tangential Cauchy-Riemann equations". Dr. Abrosimov was associate professor in the theory of functions subdepartment in the Department of Mechanics and Mathematics and Invited Lecturer in the Advanced School of General and Applied Physics (the base department of the Institute of Applied Physics and the Institute for Physics of Microstructures of the Russian Academy of Sciences).



Photograph by Ivan Remizov.

Alexander V. Abrosimov

Beginning with his first works in 1971–73, Abrosimov studied overdetermined systems of partial differential equations, where he successfully applied an original approach which he developed.

A bright mathematical work, "On locally biholomorphic equivalence of smooth hypersurfaces in C^2", was devoted to an explicit procedure enabling one to decide whether two given smooth real hypersurfaces are locally *CR*-diffeomorphic.

Subsequently, Abrosimov applied his original technique to describe *CR*-automorphisms of real quadrics of higher codimension. In this direction, he obtained

Valery Beloshapka is professor of mathematics at Lomonosov Moscow State University. His email address is vkb@strogino.ru.

Aleksey Kalinin is professor of mathematics at Nizhny Novgorod State University. His email address is avk@mm.unn.ru.

Michael Kuznetsov is professor of mathematics at Nizhny Novgorod State University. His email address is kuznets-1349@yandex.ru.

Kirill Mayorov is model risk specialist at BMO Financial Group. His email address is mayorok@gmail.com.

Grigory Polotovskiy is professor of mathematics at Lobachevsky State University of Nizhni Novgorod. His email address is polotovsky@gmail.com.

DOI: http://dx.doi.org/10.1090/noti915

Ivan Remizov is Research Assistant at Lomonosov Moscow State University. His email address is ivan.remizov@gmail.com.

Yakov Sennikovskiy is professor of mathematics at Volga State Academy of Water Transportation. His email address is yansenn@mail.ru.

George Shabat is professor of mathematics at Russian State University for the Humanities (Moscow). His email address is george.shabat@gmail.com.

Mikhail Tokman is Leading Researcher at the Institute of Applied Physics of the Russian Academy of Sciences. His email address is tokman@appl.sci-nnov.ru.

Alexander Tumanov is professor of mathematics at the University of Illinois. His email address is tumanov@illinois.edu.

Grigoriy Zhislin is the main scientist at the Federal State Radiophysical Research Institute and professor of mathematics at the Higher School of General and Applied Physics of the Nizhny Novgorod State University. His email address is gzhislin@yandex.ru.

Please make sure that the AMS *Notices* and *Bulletin* find their new home.

- Email your new address to us: amsmem@ams.org
- or make the change yourself online at: www.ams.org/cml-update
- or send the information to:

Member and Customer Services
American Mathematical Society
201 Charles Street
Providence, RI 02904-2294 USA
Phone: (800) 321-4267 (US & Canada)
(401) 455-4000 (Worldwide)

AMS
American Mathematical Society
www.ams.org

important results and elaborated methods nowadays well known to *CR*-geometry specialists.

Firstly, Abrosimov proved that holomorphic automorphisms of a quadric of codimension two are furnished by birational transformations of degree two.

Secondly, he convincingly demonstrated the power of the machinery of differential algebra in *CR*-geometry. In particular, he proved that, under mild conditions, the stabilizer of a point in the group of automorphisms of a quadric in C^n is a linear group.

Thirdly, he was among the first researchers to look into a class of *CR*-manifolds of codimension one. To date, the class has remained a focus of active attention.

Overall, Alexander Abrosimov published more than twenty-five scientific works on complex analysis, including the fundamental paper "A description of locally biholomorphic automorphisms of standard quadrics of codimension two". Some of the works of Abrosimov in *CR*-geometry and adjacent fields in complex analysis are deemed pioneering.

Abrosimov was a brilliant teacher and lecturer; he enjoyed igniting the fire in students and inspiring them to learn and develop mathematics. He passed away, but his spirit of optimism and belief in cognizance of the world are alive in his disciples and will live on for years to come.

You are welcome to visit the Wiki page about A. V. Abrosimov: `http://en.wikipedia.org/wiki/Alexander_Abrosimov`.

Selected papers of Dr. A. V. Abrosimov

1. A. V. Abrosimov and L. G. Mikhailov, On some overdetermined systems in partial derivatives, *Proceedings of the Academy of Sciences of the Tadjik SSR,* vol. 14, No. 6 (1971), 9–13.
2. _____, A generalized Cauchy-Riemann system in several independent variables, *Proceedings of the USSR Academy of Sciences*, Vol. 210, No. 1 (1973), 26–29.
3. A. V. Abrosimov, The Beltrami system in several independent complex variables, *Proceedings of the USSR Academy of Sciences*, Vol. 236, No. 6 (1977), 1289–1292.
4. _____, Complex differential systems and tangential Cauchy-Riemann equations, *Mat. Sb. (N.S.)* Vol. 122, No. 4 (1983), 419–434.
5. _____, On locally biholomorphic equivalence of smooth hypersurfaces in C^2, *Proceedings of the USSR Academy of Sciences*, Vol. 299 (1988), No. 4, 777–781.
6. _____, A description of locally biholomorphic automorphisms of standard quadrics of codimension two, *American Mathematical Society*, 1064–5616/95, 1995 (42 pages).
7. _____, On the linearity of automorphisms standard quadrics of codimension m in C^{m+n}, *Math. Notes* **73** (2003), no. 1–2, 3–7.

The University of California Cal Teach Program: Recruiting Highly Qualified Future Teachers of Mathematics and Science

Edward Landesman and Gretchen Andreasen

Every Tuesday and Friday morning, Ms. Lindsey Wilson's eighth grade Algebra 1A students at Mission Hill Middle School in Santa Cruz, California, had some extra excitement when University of California, Santa Cruz (UCSC) senior mathematics major Crystal Calderón ('12) came to class. Crystal led warm-up activities, helped students solve algebra problems, and created answer keys, all in an effort to prepare herself for a career as a mathematics teacher. Crystal's confidence in achieving her goal was bolstered by knowing that her host teacher, Ms. Wilson, was in Crystal's position a few short years ago—an undergraduate mathematics major and an intern in the University of California Cal Teach program. As a result of her participation in Cal Teach, Ms. Wilson won a scholarship to enroll in UCSC's one-year MA/teaching credential program, and she is now in her third year of a successful teaching career.

Crystal and Lindsey each have been the beneficiaries of an agreement made in 2005 between the University of California and the governor of California to increase efforts to recruit and prepare greater numbers of mathematics, science, and engineering majors for K–12 mathematics and science teaching careers. The agreement, the Science Mathematics Initiative, was a response to the decades-long shortage of well-prepared K–12 mathematics and science teachers, particularly in schools serving low-income students. The Initiative recognized the fact that nearly half of mathematics, science, and engineering baccalaureate degrees awarded in California are awarded by the University of California (UC) system.* In response to the Initiative, the recruitment of greater numbers of highly qualified mathematics and science teachers took on increased significance at UC, and each UC campus initiated a "Cal Teach" program.

Cal Teach at UC Santa Cruz

The UCSC Cal Teach program is typical of Cal Teach programs implemented since 2005 across the UC system. Cal Teach is designed not only to recruit more highly qualified future teachers but also to prepare those teachers to remain in teaching for the long term. At UCSC the program includes a sequence of three new seminar-type courses designed for prospective K–12 mathematics or science teachers, each course featuring a K–12 classroom internship. The coursework and internships have been incorporated into new undergraduate majors, including a physics

Edward Landesman is professor emeritus of mathematics at the University of California, Santa Cruz. His email address is elandesm@comcast.net.

Gretchen Andreasen is Cal Teach director at the University of California, Santa Cruz. Her email address is gha@ucsc.edu.

This article was written during the 2011–12 academic year; program data and personal experiences cited reflect this timing.

Members of the Editorial Board for Doceamus *are: David Bressoud, Roger Howe, Karen King, William McCallum, and Mark Saul.*

DOI: http://dx.doi.org/10.1090/noti908

**Source of data is the California Postsecondary Education Commission website,* http://www.cpec.ca.gov/OnLineData/OnLineData.asp, *data for 2009.*

education major that integrates a mathematics emphasis and a new science, technology, engineering, and mathematics (STEM) education minor. Mathematics majors participate in high numbers. Over one-third of participants in UCSC's program have been mathematics majors, and over one-half of the internships have been in mathematics classrooms. Through the new sequence of courses and classroom field work, undergraduates are introduced to students at various grade levels within middle schools and high schools and at multiple levels of performance, ranging from honors to remedial. The students also encounter host teachers and schools in communities of varying socioeconomic status and cultural diversity.

At UCSC, as on other UC campuses, a Cal Teach Resource Center was established and serves as the campus's central point for information about mathematics and science teaching careers and also coordinates the internship and academic programs. The center provides information to any interested undergraduate with appropriate mathematics or science preparation, to faculty and staff who may advise students, to prospective transfer students, and to professional scientists and engineers who may be considering career changes.

Statewide Efforts and California Community College Partnerships

Early in the formation of Cal Teach, the first author led a UC/California Community College (CCC) partnership to identify, support, and recruit community college students to teach mathematics and science. As a result, as many as twenty-five community colleges around the state developed internship programs similar to Cal Teach and formed relationships with their local UC campuses to ease the transfer of mathematics and science majors to the university. This year, for the first time, a UCSC Cal Teach mathematics major is working as a math tutor at UCSC's nearest community college partner (Cabrillo College), with a goal of expanding the recruitment of future mathematics and science teachers to UC.

Frances Venegas, now a successful fourth-year science teacher at Harden Middle School in Salinas, California, transferred to UCSC from her local community college. Frances credits Cal Teach with introducing her to teaching and with altering her career path. Frances started college in 2003 after twenty-two years in the restaurant business, planning to become a marine biologist. After an academic quarter of field work in French Polynesia, she returned to campus, where she enrolled in a Cal Teach internship. This catalyzed her decision to teach. Frances's experience reflects the importance of reaching out to community college transfer students in the Cal Teach recruitment process. The two-year California community colleges are the entry point to UC for many lower-income students from diverse backgrounds who are underrepresented as mathematics and science teachers. These transfer students often express an interest in teaching careers and in returning to their communities to assist future generations of students. For example, Frances is now teaching in the same low-income community where she has lived for many years.

Impact

Since UC began its Science and Mathematics Initiative in 2005, over five thousand undergraduates system-wide have completed a K–12 classroom internship. Currently, Cal Teach programs across the UC system coordinate about two thousand classroom placements each year. As Cal Teach undergraduates across the state have gained crucial experience for their own professional development, they have also enriched the classroom experience of hundreds of thousands of K–12 students across California.

The teachers who serve as classroom mentors welcome the energetic and inspired college students as an additional resource in their classrooms and value the exposure of their students to these successful role models. At UCSC alone, over fifty teachers will host interns in at least ten regional schools this year. Most of these mentor teachers continue to volunteer year after year. One skilled and generous host teacher of over twenty-five UCSC undergraduates says he is waiting for the right Cal Teach graduate to come along to fill his job so he can retire! He may soon get his wish. Approximately two hundred forty UCSC Cal Teach students have graduated, and seventy-five (nearly one-third of those graduates) have entered a teaching credential program. Over twenty-five of these graduates have begun teaching in Santa Cruz or a nearby county. Of course, it is too early to have data on the relative effectiveness or retention of these recent Cal Teach graduates, but anecdotal evidence from school district collaborators suggests that the new teachers are thriving. One partner district is happily recruiting new teachers from the Cal Teach graduates, while another partner district was grateful to fill a midyear opening with a Cal Teach graduate. A third district reports that its new teachers with Cal Teach experience are "hitting the ground running."

Sustaining and Extending the Model

To continue to thrive, the UC Cal Teach program will require the ongoing support of university faculty in the mathematics, science, engineering, and education departments, as well as partnerships with community colleges and K–12 schools. The good will developed among the many partners and the successes of these first years, along with help from alumni and private donors who understand the importance of producing future highly qualified

mathematics and science teachers, should help sustain the program.

The Cal Teach model can be replicated. The single most important requirement for building such a program is the designation of a staff or faculty member whose time is committed to developing and sustaining the program. This effort includes the coordination of partnerships among the many university, community college, and K–12 stakeholders, as well as concentrated interaction with the students who participate. Most, but not all, UC Cal Teach programs are housed in a division of mathematics, science, or engineering with partners in the school or department of education. This partnership and organizational structure help to ensure that academic planning and student support are tailored to meet the needs of future math and science teachers.

A successful program of internships along with academic seminars also requires financial support to ensure small class sizes and to cover the costs of placing students in K–12 classrooms. On most UC campuses, stipends are provided to K–12 teachers who host the interns and to the interns themselves. Most host teachers would participate without an honorarium, although the honoraria do help build a sense of professional responsibility and commitment to the Cal Teach students. Similarly, many students would participate without internship "stipends", but the stipends help recruit a greater number of students and reinforce the value of their career choice. Details of the Cal Teach programs vary from campus to campus, depending upon local campus traditions and strengths. However, the basic model—engaging greater numbers of STEM majors to explore and prepare for future careers in K–12 teaching—has been implemented successfully on UC campuses throughout the state. The Cal Teach model can be replicated throughout the country. For further information about the program, the second author can be contacted at calteach@ucsc.edu.

Acknowledgment

Professor Landesman retired from the University of California in February 2011, but he continues to support future teachers through fundraising for UCSC's Cal Teach program. Dr. Andreasen serves as the director of the UC Santa Cruz Cal Teach program, collaborating with UC and CCC colleagues around the state.

THE CHINESE UNIVERSITY OF HONG KONG

Applications are invited for:-

Department of Mathematics

Assistant Professor

(Ref. 1213/003(576)/2) (Closing date: March 15, 2013)

The Department invites applications for an Assistant Professorship in all areas of mathematics. Applicants should have a relevant PhD degree and an outstanding profile in research and teaching. Appointment will normally be made on contract basis for up to three years initially commencing August 2013, which, subject to mutual agreement, may lead to longer-term appointment or substantiation later.

Salary and Fringe Benefits

Salary will be highly competitive, commensurate with qualifications and experience. The University offers a comprehensive fringe benefit package, including medical care, a contract-end gratuity for an appointment of two years or longer, and housing benefits for eligible appointee. Further information about the University and the general terms of service for appointments is available at *http://www.per.cuhk.edu.hk*. The terms mentioned herein are for reference only and are subject to revision by the University.

Application Procedure

Please send full resume, copies of academic credentials, a publication list and/or abstracts of selected published papers, together with names, addresses and fax numbers/e-mail addresses of three referees to whom the applicants' consent has been given for their providing references (unless otherwise specified), to the Personnel Office, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong (Fax: (852) 3943 1462) by the closing date. The Personal Information Collection Statement will be provided upon request. Please quote the reference number and mark 'Application - Confidential' on cover.

CENTRE INTERFACULTAIRE BERNOULLI

CIB

CALL FOR PROPOSALS

The Bernoulli Center (CIB), funded jointly by the Swiss National Science Foundation and the Swiss Federal Institute of Technology in Lausanne, has started its activity in March 2002.

Its mission is to support research in mathematics and its applications, to organize and host thematic programs, to provide a supportive and stimulating environment for researchers, and to launch and foster collaborations between mathematicians working in different areas as well as mathematicians and other scientists.

The CIB launches a call for proposals of four one-semester programs during the **period July 1, 2014 - June 30, 2016**. A thematic program consists of a six months period (January 1 - June 30 or July 1 - December 31) of concentrated activity in a specific area of current research interest in the mathematical sciences. In exceptional cases, one year and three month programs will also be considered.

Those who are interested in organizing a program at the CIB should submit a **two page letter of intent by April 1st, 2013**. This letter should give the names of the organizers, of the potential visitors, and outline the program.

For more details see http://cib.epfl.ch/

École Polytechnique Fédérale de Lausanne
Centre Interfacultaire Bernoulli (CIB)
SB CIB-GE
AAC034 (Bâtiment AAC)
Station 15
CH-1015 Lausanne

Geometry & Topology: A Community-Based Publishing Initiative

Colin Rourke

Morton's Fork was named after Cardinal Morton who was Lord Chancellor of England in the reign of King Henry VII. By visiting noblemen of the time, he would judge their tax for the coming year. If the hospitality he was given was economical, it was reasoned that his host was saving money and could afford a large gift to the King. If, on the contrary, the hospitality was sumptuous, he was evidently wealthy and could afford a large gift to the King. These arguments were the two prongs of the Fork.

Commercial publishers have gripped research mathematicians in a similar fork. On the one hand, whilst carrying out our research, we need—indeed demand—total access to the literature. If we want to consult a paper, we will do whatever we need to do to find it…in the old days, we would look in our filing cabinets, then colleagues' cabinets, then search libraries or telephone more distant colleagues. These days we are more likely to start at the arXiv or Google before resorting to hard-copy search. The methods may have altered, but the purpose has not. We need to check or use previous work and nothing will stop us until we find it in some form or other. This is the first prong of the fork. The other is that, once we have produced a piece of new research, we want everyone to see it. We don't hide it under a bushel; we want to give it away for all to see. We eagerly talk about it to colleagues and students, freely give lectures on it (in all gory detail if asked). We do the same for everyone else's research, including anonymous refereeing, editorial advising, and so on. This is the second prong of the fork.

These two prongs, (a) that we demand access to all other research and (b) that we offer our research and research-related services for free, have given our publishers a huge lever over us. We create a product (published research), give it away free, and then buy it back with a totally inelastic demand. Given the current financial ethos under which companies exist only to make money, incidentally providing a service, it is not at all surprising that we are now paying exorbitant fees for access to our research. The usual countervailing mechanism in capitalism—competition—is totally absent in this market because there is *no* competition between journals. Each publishes a different set of papers. *The Annals* (a well-run, academically-owned, moderately-priced journal) is not in competition with *Inventiones* (an exorbitantly overpriced Springer journal), although they are of similar standard in a similar subject, because they each carry a different set of papers which we all need to read. We need permanent access to *both* of them. The only journals to which we don't need access are the (very few) journals which publish only low-level papers.

This situation came home to me with full force about seventeen years ago when I was chair of the University of Warwick Mathematics Department. My research partner Brian Sanderson was Library Representative, and we faced the annual journal cutting exercise. We reasoned: Journals are produced by the community, largely using free labor; mathematicians even do their own

Colin Rourke is emeritus professor at the University of Warwick. His email address is cpr@msp.warwick.ac.uk.

Members of the Editorial Board for Scripta Manent *are: Jon Borwein, Thierry Bouche, John Ewing, Andrew Odlyzko, Ann Okerson.*

DOI: http://dx.doi.org/10.1090/noti920

typesetting using TEX; the cost of printing in small runs is dropping (it has now dropped to the same as large runs)—journals ought to be getting cheaper. Instead, they are rising in price far faster than inflation and causing a crisis leading to irreversible damage to libraries. It is interesting to note that a pledge to keep price inflation below 10 percent per annum was regarded as reasonable by the UK Competition Commission when considering the merger of Reed Elsevier and Harcourt in 2001.

Ulf Rehmann maintains a webpage listing relative prices for mathematics journals, http://www.mathematik.uni-bielefeld.de/~rehmann/BIB/AMS/Price_per_Page.html. Comparing like with like, the price ratio is about fifty to one between the lowest priced journals at approximately 15¢ per page and the highest at about $7.50 per page.

Brian and I decided to demonstrate that a high quality journal could be run well and be essentially free and this is why we started *Geometry & Topology*.

Initially the journal was conceived as an electronic journal. At the time electronic publishing was outside the mainstream and had a somewhat tacky image. So our first concern was to ensure real quality. We did this by recruiting as high a quality academic editorial board as we could. We were ably assisted in this by John Jones and Rob Kirby. Our editorial board can be seen on our site http://msp.warwick.ac.uk/gt/about/journal/editorial.html. It includes three Fields medallists and is one of the highest standard boards in pure mathematics. This was the first step.

The second step was to involve this board positively in all the decision making. We set up a strong, published procedure skewed towards rejection. While one editor can reject a paper, it takes three (a proposer and two seconders) to accept one; each of these has her/his name published on the title page of the paper, which militates against casual propositions/secondings.

The third step was to fix and publish a handling and refereeing procedure so that everything was clear and above board. All three steps made it very difficult for a weak paper to slip though the net.

The drive to quality paid off handsomely and *Geometry & Topology* is now one of the world's foremost specialist journals, publishing around 3,000 pages annually.

Initially the journal was produced entirely at Warwick. Brian and I programmed the procedure using perl scripts and we used the university print shop for hard copy. We started as a fully open-access journal and we covered incidental expenses by selling hard copy at a modest profit. We built on the success of *Geometry & Topology* to start a monograph series and a sister journal *Algebraic & Geometric Topology*. The obvious weakness of the arrangement was that it relied to a large extent on our own unpaid labor. Rob Kirby, recognizing that this model was unsustainable in the long run, started a nonprofit publishing company, Mathematical Sciences Publishers, based at Berkeley, to take over production. The story of MSP needs a separate article to do it justice. Here it is enough to say that MSP has properly paid staff and has given *Geometry & Topology* and our other ventures a permanent stable home. We are no longer fully open access because the economic climate has made this impossible but we are still extremely low-priced and intend to remain so.

In its own terms, *Geometry & Topology* has been an unparalleled success. The electronic versus nonelectronic dichotomy has vanished since we started and all journals are now produced as we have always done, with a primary electronic version published before the print version. However, in terms of changing the ethos of academic publication and reducing overall prices, it has been a dismal failure. There has been no change in the gloomy vice-like grip in which commercial publishers hold our libraries. The current move towards "open access" publishing has no value whatsoever unless the ownership of journals is changed at the same time. By shifting an exorbitant publication cost from library to author, nothing is changed. What is needed is concerted government action to buy back the rights to our, predominantly publicly funded, research from the commercial journals and pass ownership of the journals over to the academic community to run as we run *Geometry & Topology*. In this way the publication cost, however financed, will be reduced to a fair sustainable level. It will be expensive in the short term, but it will lead to a situation where we can all once again afford to consult our own research.

Mathematics People

Viehmann Awarded von Kaven Prize

EVA VIEHMANN of the Technical University of Munich has been awarded the 2012 von Kaven Award in mathematics "in recognition of her outstanding research in the field of arithmetic algebraic geometry." The prize, which is administered by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), carries a cash award of 10,000 euros (approximately US$13,000).

Viehmann was honored for her work on the Langlands program, which consists of a wide-ranging series of conjectures that relate algebraic number theory to representation theory of algebraic groups. The program, according to the prize citation, "has developed into an important and highly relevant field of mathematical research." Viehmann, "through her investigations into the global structure of moduli spaces of p-divisible groups and into the definition of local G-shtukas, has contributed new and original findings in this specialized area."

The von Kaven prize is funded from the proceeds of the von Kaven Foundation, which was established in 2004 by mathematician Herbert von Kaven, who died in 2009 at the age of 101.

—From a DFG announcement

Prizes of the Canadian Mathematical Society

MATTHEW KENNEDY of Carleton University has been awarded the 2012 Doctoral Prize of the Canadian Mathematical Society (CMS). In his Ph.D. thesis at the University of Waterloo he provided "a detailed structure theorem for an important class of linear operators, namely row isometries, which can be used to generate families of wavelets used for data compression. The structure theorem sheds new light on this area of application."

The prize citation states, "The research Kennedy completed in his doctoral studies is related to an important class of algebras and operators. In his thesis entitled 'Free semigroup algebras and the structure of an isometric tuple' he made great strides towards completing the structure theory of free semigroup algebras, in particular fully resolving three questions that have been recognized to be of central importance to this project for at least a decade. Furthermore, he generalized the classical Lebesgue-von Neumann-Wold decomposition of Hilbert space isometries to the situation of isometric n-tuples."

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

MELANIA ALVAREZ of the University of British Columbia and the Pacific Institute for the Mathematical Sciences (PIMS) has been awarded the 2012 Adrien Pouliot Award of the Canadian Mathematical Society in recognition of her contributions to mathematics education in Canada. She has focused largely on working with First Nations students to improve their mathematical education and reduce their dropout rates. She also helps organize the Elementary Mathematics Contest (ELMACON), problem-solving workshops for students at elementary and secondary schools, and math workshops for elementary and secondary school teachers, and engages in active fundraising to support a wide range of education activities.

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.

—From CMS announcements

Shiller Awarded 2012 CME/ MSRI Prize

ROBERT SHILLER of Yale University has been awarded the 2012 CME Group-MSRI Prize in Innovative Quantitative Applications. Shiller is cocreator of the Case-Shiller Index of U.S. house prices and author of the book *Irrational Exuberance*, which warned about the possible bursting of speculative bubbles. 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.

—Elaine Kehoe

NDSEG Fellowships Awarded

Fourteen young mathematicians have been awarded National Defense Science and Engineering Graduate (NDSEG) Fellowships by the Department of Defense (DoD) for 2012. 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: DANIEL BEYLKIN, Yale University, Air Force Office of Scientific Research (AFOSR); ISSAC BUENROSTRO, Stanford University, AFOSR; MY HUYNH, Stanford University, AFOSR; MARKUS KLIEGL, Princeton University, AFOSR; ANDREW LI, Massachusetts Institute of Technology, Office of Naval Research (ONR); ALEXANDER LUEDTKE, Harvard University, ONR; HANNAH MANUEL, Princeton University, ONR; EMILY MEISSEN, University of Arizona, AFOSR; DEREK OLSON, University of Minnesota, Twin Cities, ONR; ZOHAR STRINKA, University of Michigan, Ann Arbor, Army Research Office (ARO); ILA VARMA, Princeton University, AFOSR; CHELSEA WEAVER, University of California Davis, ONR, ANDREW WILSON, University of California San Diego, AFOSR; and JASON XU, University of Washington, ARO.

—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. JANINE MCINTOSH of the Australian Mathematical Sciences Institute has been a primary school teacher and a member of the Mathematics Challenge for Young Australians Problems Committee, is an author of a series of textbooks, and provides professional development for teachers. GRAHAM K. MEIKLEJOHN, state director for Queensland Australian Mathematics Competition (AMC), is a coauthor of several resource books for mathematics teachers. WEN-HSIEN SUN is a mathematics book publisher and mathematics bookstore owner in Beijing and Taipei; he hosted the International Mathematics Competition in Taipei in 2012 and is the Taiwan national director for the AMC.

—From an Australian Mathematics Trust announcement

香港城市大學
City University of Hong Kong

Worldwide Search for Talent

City University of Hong Kong is a dynamic, fast-growing university that is pursuing excellence in research and professional education. As a publicly-funded institution, the University is committed to nurturing and developing students' talent and creating applicable knowledge to support social and economic advancement. Currently, the University has six Colleges/Schools. Within the next two years, the University aims to recruit **100 more scholars** from all over the world in various disciplines, including **science**, **engineering**, **business**, **social sciences**, **humanities**, **law**, **creative media**, **energy**, **environment**, and other strategic growth areas.

Applications and nominations are invited for:

Chair Professor/Professor
Associate Professor/Assistant Professor
Department of Mathematics *[Ref. A/094/49]*

Duties : Conduct research in areas of Applied Mathematics including Analysis and Applications, Mathematical Modelling (including biological/physical/financial problems), Scientific Computation and Numerical Analysis, and Probability and Statistics; teach undergraduate and postgraduate courses; supervise research students; and perform any other duties as assigned.

Requirements : A PhD in Mathematics/Applied Mathematics/Statistics with an excellent research record.

Salary and Conditions of Service
Remuneration package will be driven by market competitiveness and individual performance. Excellent fringe benefits include gratuity, leave, medical and dental schemes, and relocation assistance (where applicable). Initial appointment will be made on a fixed-term contract.

Information and Application
Further information on the posts and the University is available at http://www.cityu.edu.hk, or from the Human Resources Office, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong [Fax : (852) 2788 1154 or (852) 3442 0311/email : hrojob@cityu.edu.hk].

Please send the nomination or application with a current curriculum vitae to Human Resources Office. **Applications and nominations will receive full consideration until the positions are filled.** Please quote the reference of the post in the application and on the envelope. Shortlisted candidates for the post of Assistant Professor will be requested to arrange for at least 3 reference reports sent directly by their referees to the Department, specifying the position applied for. The University reserves the right not to fill the positions. Personal data provided by applicants will be used strictly in accordance with the University's personal data policy, a copy of which will be provided upon request.

The University also offers a number of visiting positions through its "CityU International Transition Team" for current graduate students and for early-stage and established scholars, as described at http://www.cityu.edu.hk/provost/cityu_international_transition.htm.

City University of Hong Kong is an equal opportunity employer and we are committed to the principle of diversity. We encourage applications from all qualified candidates, especially those who will enhance the diversity of our staff.

Mathematics Opportunities

AWM Announces Two New Research Prizes

The Executive Committee of the Association for Women in Mathematics (AWM) has established two new research prizes.

The AWM-Microsoft Research Prize in Algebra and Number Theory will highlight exceptional research in some area of algebra by a woman early in her career. The prize is made possible by a generous contribution from Microsoft Research. When reviewing nominations for this award, the field will be broadly interpreted to include number theory, cryptography, combinatorics, and other applications, as well as more traditional areas of algebra.

The AWM-Sadosky Research Prize in Analysis will highlight exceptional research in analysis by a woman early in her career. The prize is funded by generous contributions from family and friends of former AWM president Cora Sadosky (1940–2010). When reviewing nominations for this award, the field will be broadly interpreted to include all areas of analysis.

Both prizes will be awarded every other year, with the first prizes presented at the AWM Reception at the Joint Mathematics Meetings in Baltimore, Maryland, in January 2014. The recipients will receive a cash prize and an honorary plaque and will be featured in an article in the AWM newsletter. Candidates should be women within ten years of receiving the Ph.D. or who have not yet received tenure. For full consideration, nominations should be submitted by **February 15, 2013**.

For further information on both prizes and nomination materials, see the website `http://www.awm-math.org`.

—From an AWM announcement

STaR Program for Early Career Mathematics Educators

The National Science Foundation (NSF) funds the STaR (Service, Teaching and Research) program, consisting of a summer institute, an 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 fourth cohort of STaR Fellows will meet for a Summer Institute in Park City, Utah, the week of July 14–19, 2013, in conjunction with the Park City Mathematics Institute (PCMI). Eligibility is limited to new faculty members 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 in a school, college, or department of education.

For more information about the STaR program, see the website `http://matheddb.missouri.edu/star/` or contact Robert Reys, Curators' Professor of Mathematics Education, University of Missouri, at `reysr@missouri.edu`. The deadline for applications is **December 15, 2012.** Applications are available at `matheddb.missouri.edu/star/application.php`.

—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, D.C., 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 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 is **February 5, 2013**. For priority consideration for the Los Angeles, New York City, Utah, and Washington, D.C., fellowships, the deadline is **January 2, 2013**. 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 10, 2012**. 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 degree by fall of 2013. Fellows selected in spring 2013 must begin their fellowship tenure in fall 2013. 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 14, 2012**. 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 the Bernoulli Center

Call for Proposals. The Bernoulli Center (CIB), funded jointly by the Swiss National Science Foundation and the Swiss Federal Institute of Technology in Lausanne, began its activity in March 2002. Its mission is to support research in mathematics and its applications, to organize and host thematic programs, to provide a supportive and stimulating environment for researchers, and to launch and foster collaborations between mathematicians working in different areas as well as mathematicians and other scientists.

The CIB is launching a call for proposals of four one-semester programs to be held during the period July 1, 2014–June 30, 2016. A thematic program consists of a six-month period (January 1–June 30 or July 1–December 31) of concentrated activity in a specific area of current research interest in the mathematical sciences. In exceptional cases, one-year and three-month programs will also be considered.

Those who are interested in organizing a program at the CIB should submit a two-page letter of intent by **April 1, 2013**. This letter should give the names of organizers and potential visitors, and outline the program. For more details, see http://cib.epfl.ch/.

—From a CIB announcement

For Your Information

Departments Coordinate Job Offer Deadlines

For the past thirteen 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 fifty-six 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 4, 2013. The NSF has already agreed that it will complete its review of applications by January 25, 2013, at the latest and that all applicants will be notified electronically at that time.

The American Mathematical Society facilitated 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, 2012, 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 your consideration of the proposal.

—Donald McClure, AMS Executive Director
Ellen Maycock, AMS Associate Executive Director

New PIMS Headquarters

The University of British Columbia (UBC) headquarters for the Pacific Institute for the Mathematical Sciences (PIMS) has moved to a new state-of-the-art, centrally located facility on the fourth floor of the brand new Earth Sciences Building (ESB) at UBC.

This impressive building is centrally located at UBC's Point Grey Campus, and PIMS's new space includes a reception area, offices for administration, offices for up to twenty-four visitors and postdoctoral fellows, and lab workspace for ten graduate students. It also boasts a dedicated video-conferencing room and a spacious lounge. In addition, an array of classrooms throughout the building is available for PIMS seminars and workshops.

The $75 million ESB is home to Earth, Ocean, and Atmospheric Sciences, Statistics, PIMS, and the dean's office of the Faculty of Science. It is the largest panelized wood building and the largest application of cross-laminated timber in North America. The building uses over 1,300 tons of British Columbia-sourced and engineered cross-laminated timber.

The ESB was made possible by generous investments from the British Columbia government, partners in the minerals industry, UBC Science alumnus Ross Beaty, and the Canada Wood Council.

PIMS looks forward to welcoming all members of the mathematical sciences community to our new site!

—PIMS announcement

Inside the AMS

2012 Trjitzinsky Memorial Awards Presented

The AMS has made awards to seven 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 memory of her husband to assist needy students in mathematics.

For the 2012 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 2012, the names of the students receiving Trjitzinsky awards, and brief biographical sketches of the students.

University of California, Berkeley: ANAKAREN SANTANA. Santana was born and raised in Monterrey, Mexico, and graduated from high school with high honors. At Berkeley she is studying for a double major in mathematics and art practice. She works as a physics tutor.

University of Denver: EMILY MAVADDAT. Mavaddat was inspired to pursue a mathematics major by her AP calculus teacher at Ridgefield High School in Connecticut. As a member of the National Honor Society, she was a peer tutor; she also volunteered with the National Charity League, helping at community events such as Special Olympics. She is a giant slalom racer and loves skiing great mountains.

Hendrix College: MATTHEW P. LARSON. Larson is a double major in mathematics and philosophy at Hendrix College. His goal is to attend graduate school to continue study in mathematics.

Lebanon Valley College: ABIGAIL M. SKELTON. Skelton is a third-year student majoring in mathematics and German. She has participated in summer research in quantum information science with the Mathematical Physics Research Group at Lebanon Valley College and presented results at the undergraduate poster session at the 2012 Joint Mathematics Meeting. She is a peer tutor and participates in the Putnam Exam Team. She wants to continue to study mathematics in graduate school.

University of Missouri, St. Louis: RYAN UDING. Uding participated in mathematics competitions from grade school through high school. He has been working full time in a variety of industrial occupations to support himself and the costs of his education. He plans to graduate in May 2013 with a B.S. in mathematics and hopes to pursue a graduate degree in analytic number theory or analysis.

Pennsylvania State University: BENJAMIN HEEBNER. Heebner is a third-year student majoring in actuarial mathematics and minoring in economics and statistics. In each of the past four years he has volunteered for a week at an overnight camp for children who have experienced abuse, neglect, or abandonment. He enjoys playing and watching all sports and spending time with family and friends.

Purdue University Calumet: TYLER R. BILLINGSLEY. Billingsley is doing research involving polynomial factoring in computer algebra systems and plans to attend graduate school to study pure math.

—Elaine Kehoe

Project NExT Fellows Chosen

Six mathematicians have been selected as AMS Project NExT fellows for the 2012–2013 academic year. Their names, affiliations, and areas of research are: EMILY BRALEY, Duke University, algebraic geometry and combinatorics; STEVE BUTLER, Iowa State University, spectral graph theory; NEIL EPSTEIN, George Mason University, commutative algebra; JOEL LOUWSMA, University of Oklahoma, geometric group theory; KATHERINE MORRISON, University of Northern Colorado, algebraic coding theory; BLERTA SHTYLLA, Mount Holyoke College, applied mathematics.

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.

—Aparna Higgins, Director, Project NExT

MSC/SKOS—The New Implementation of the MSC as a Linked Open Dataset

Mathematical Reviews and Zentralblatt MATH collaborate in developing and maintaining the Mathematics Subject Classification (MSC). The MSC is used by their services, and generally in the mathematics profession and related fields, to organize the mathematics literature. The current version, MSC2010, is the result of a careful public revision process, culminating in its public release in January 2010. Now we are pleased to announce MSC2010 availability as a Linked Open Dataset, a modernized form following the standard called SKOS (Simple Knowledge Organization System) of the World Wide Web Consortium (W3C). SKOS is one of the newer standards set out for the developing Semantic Web and is based on RDF (Resource Description Framework). The new MSC/SKOS version results from the effort to make the MSC more available to the Semantic Web movement and on the Internet. It will be maintained as the authoritative source of the MSC, from which other forms may be derived, and will be available as linked data at `http://msc2010.org/resources/MSC/2010/MSC2010`. This is a large authority file in XML form. For other forms of the data perhaps more suitable for special applications, see `http://msc2010.org/resources/MSC/2010/info/`.

The MSC/SKOS preserves the contents of MSC2010. It offers a new format better suited to the Semantic Web and adds authoritative translations into Chinese, Russian, and Italian. In addition, there are cross-references to earlier MSC versions and to some other mathematics classification systems, such as the Dewey system. It is expected that similar information will be added, in ways made possible by the new format, as a result of ongoing efforts to improve the MSC.

Comments about the MSC in general can be submitted through a Web form at `http://msc2010.org/feedback` or by email to `feedback@msc2010.org`. All information concerning MSC is shared fully by Mathematical Reviews and Zentralblatt MATH.

—Graeme Fairweather, Executive Editor, Mathematical Reviews
Gert-Martin Greuel, Editor-in-Chief, Zentralblatt MATH

Free Grant Writing Workshop Offered

The American Mathematical Society, in conjunction with the National Science Foundation Directorate for Education & Human Resources (NSF-EHR), is pleased to offer a FREE workshop entitled "Writing a Competitive Grant Proposal to NSF-EHR". This grant writing workshop will be held prior to the start of the Joint Mathematics Meetings on Monday, January 7, 2013, from 3:00 p.m. to 6:00 p.m. at the San Diego Marriott Marquis & Marina Hotel.

Workshop Goals:

· Familiarize participants with current direction/priorities in EHR

· Familiarize participants with key EHR education research and development programs

· Consider common issues of competitive proposals

· Prepare participants to write a competitive proposal

Topics covered will include: discussion of key programs in EHR; the merit review process and merit review criteria; discussion of scenarios—short passages drawn from proposals in the EHR portfolio designed to stimulate discussion about strengths and weaknesses of a proposal; and the opportunity to discuss possible proposal ideas with program officers.

This free workshop is open to all interested participants who have registered by December 14th at `http://www.ams.org/profession/RSVPForm.NSF-EHRGrantWritingWorkshop2013.pdf`

—from the AMS Washington Office

Deaths of AMS Members

Steve A. Corning, of Lombard, Illinois, died on June 4, 2012. Born on May 16, 1956, he was a member of the Society for 6 years.

James A. Jenkins, of St. Louis, Missouri, died on September 16, 2012. Born on September 23, 1923, he was a member of the Society for 67 years.

Banwarilal Sharma, professor, University of Allahabad, India, died on September 26, 2012. Born on May 20, 1935, he was a member of the Society for 40 years.

Cleon R. Yohe, professor, Washington University, died on June 26, 2012. Born on July 8, 1941, he was a member of the Society for 47 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.

Information for *Notices* Authors

The *Notices* welcomes unsolicited articles for consideration for publication, as well as proposals for such articles. The following provides general guidelines for writing *Notices* articles and preparing them for submission. Contact information for *Notices* editors and staff may be found on the *Notices* website, http://www.ams.org/notices.

Upcoming Deadlines

November 15, 2012: Nominations for 2013 Vasil A. Popov Prize. See http://imi.cas.sc.edu/popov-prize-call-nominations/.

November 19, 2012: Applications for NRC-Ford Foundation Dissertation and Postdoctoral 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 10, 2012: Proposals for NSF Program in Computational and Data-Enabled Science and Engineering in Mathematical and Statistical Sciences. See "Mathematics Opportunities" in this issue.

December 1, 2012: Applications for PIMS Postdoctoral Fellowships. See 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*.

AMS Bylaws—*January 2012, p. 73*

AMS Email Addresses—*February 2012, p. 328*

AMS Ethical Guidelines—*June/July 2006, p. 701*

AMS Officers 2010 and 2011 Updates—*May 2012, p. 708*

AMS Officers and Committee Members—*October 2012, p. 1290*

Conference Board of the Mathematical Sciences—*September 2012, p. 1128*

IMU Executive Committee—*December 2011, p. 1606*

Information for *Notices* Authors—*June/July 2012, p. 851*

Mathematics Research Institutes Contact Information—*August 2012, p. 979*

National Science Board—*January 2012, p. 68*

NRC Board on Mathematical Sciences and Their Applications—*March 2012, p. 444*

NRC Mathematical Sciences Education Board—*April 2011, p. 619*

NSF Mathematical and Physical Sciences Advisory Committee—*May 2012, p. 697*

Program Officers for Federal Funding Agencies—*October 2012, p. 1284 (DoD, DoE); December 2012, p. 1585 (NSF Mathematics Education)*

Program Officers for NSF Division of Mathematical Sciences—*November 2012, p. 1469*

December 1, 2012: Applications for AMS Centennial Fellowships. 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 3, 2012: Entries for Ferran Sunyer i Balaguer Prize. See http://ffsb.iec.cat.

December 14, 2012: Applications for NDSEG Fellowship Program. See "Mathematics Opportunities" in this issue.

December 15, 2012: Applications for National Science Foundation STaR (Service, Teaching and Research) program. See "Mathematics Opportunities" in this issue.

December 15, 2012: Applications for AMS Epsilon Fund grants. See http://www.ams.org/programs/edu-support/epsilon/emp-epsilon or contact the AMS Membership and Programs Department, email: prof-serv@ams.org; telephone: 800-321-4267, ext. 4170.

December 15, 2012: Applications for Fields Institute postdoctoral fellowships for the Thematic Program on Calabi-Yau Varieties: Arithmetic, Geometry, and Physics. See http://www.fields.utoronto.ca/honours/postdoc.html.

December 31, 2012: Nominations for IMU Prizes: Leelavati Prize, Fields Medals, Nevanlinna Prize, Gauss Prize, Chern Medal, and Noether Lectureship. See http://www.mathunion.org/general/prizes/leelavati/details/ for the Leelavati Prize; http://www.mathunion.org/general/prizes/nomination-guidelines/ for other prizes; and http://www.mathunion.org/general/prizes/prize-committee-chairs/2014/ for committee chairs.

December 31, 2012: Nominations for Otto Neugebauer Prize of the EMS. See the website http://www.euro-math-soc.eu/otto_neugebauer_prize.html.

January 2, 2013: Applications for priority consideration for Los Angeles, New York City, Utah, and Washington, D.C., fellowships of Math for America. See "Mathematics Opportunities" in this issue.

January 7, 2013: Applications for Institut Mittag-Leffler postdoctoral fellowship grants for 2013–2014. See "Mathematics Opportunities" in this issue.

January 13, 2013: Applications for Jefferson Science Fellows Program. See email jsf@nas.edu, telephone 202-334-2643, or see the website http://sites.nationalacademies.org/PGA/Jefferson/PGA_046612.

January 31, 2013: Entries for AWM Essay Contest. Contact the contest organizer, Heather Lewis, at hlewis5@naz.edu.

February 1, 2013: 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; or telephone: 703-934-0163; e-mail: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

February 4, 2013: Proposals for programs in mathematical sciences for Institut Mittag-Leffler for academic year 2015–2016. See http://www.mittag-leffler.se.

February 5, 2013: Applications for Boston, Los Angeles, New York City, Utah, and Washington, D.C., fellowships of Math for America. See "Mathematics Opportunities" in this issue.

February 12, 2013: Applications for IPAM undergraduate program Research in Industrial Projects for Students (RIPS). See www.ipam.ucla.edu.

February 15, 2013: Nominations for AWM-Microsoft Research Prize in Algebra and Number Theory and AWM-Sadosky Research Prize in Analysis. See "Mathematics Opportunities" in this issue.

February 15, 2013: 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 25, 2013: Applications for EDGE Summer Program. See http://www.edgeforwomen.org/.

March 31, 2013: Applications for IPAM graduate summer school on computer vision. See www.ipam.ucla.edu.

April 1, 2013: Proposals for thematic programs for 2014–2016 at the Bernoulli Center (CIB), Lausanne, Switzerland. See "Mathematics Opportunities" in this issue.

April 15, 2013: Applications for fall 2013 semester of Math in Moscow. See http://www.mccme.ru/mathinmoscow, or write to: Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax: +7095-291-65-01; e-mail: 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 by writing to: 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, 2013: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; or telephone: 703-934-0163; e-mail: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 1, 2013: Applications for AWM Travel Grants and Mathematics Education Research Travel Grants. See https://sites.google.com/site/awmmath/programs/travel-grants; or telephone: 703-934-0163; e-mail: awm@awm-math.org; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 4, 2013: Letters of intent for NSF Program ADVANCE Institutional Transformation and Institutional Transformation Catalyst awards. See http://www.nsf.gov/pubs/2012/nsf12584/nsf12584.htm?WT.mc_id=USNSF_36&WT.mc_ev=click.

November 12, 2013: Full proposals for NSF Program ADVANCE Institutional Transformation and Institutional Transformation Catalyst awards. See http://www.nsf.gov/pubs/2012/nsf12584/nsf12584.htm?WT.mc_id=USNSF_36&WT.mc_ev=click.

NSF Mathematics Education Staff

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

Office of the Assistant Director

Joan Ferrini-Mundy
Assistant Director
703-292-4682
jferrini@nsf.gov

Division of Research on Learning in Formal and Informal Settings

John Cherniavsky
Acting Division Director
703-292-5136
jchernia@nsf.gov

Karen King
703-292-8620
kking@nsf.gov

Barry Sloane
703-292-8465
fsloane@nsf.gov

Division of Graduate Education

James Lightbourne
Division Director
703-292-4628
jhlightb@nsf.gov

Division of Undergraduate Education

Ron Buckmire
703-292-5323
rbuckmir@nsf.gov

Mike Jacobson
703-292-4641
mjacobso@nsf.gov

Lee Zia
703-292-5140
lzia@nsf.gov

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.

Adventures in Group Theory: Rubik's Cube, Merlin's Machine, and Other Mathematical Toys, by David Joyner. Johns Hopkins University Press (second edition), December 2008. ISBN-13: 978-08018-9013-0.

**Algorithmic Puzzles,* by Anany Levitin and Maria Levitin. Oxford University Press, October 2011. ISBN-13: 978-01997-404-44.

American Mathematicians as Educators, 1893–1923: Historical Roots of the "Math Wars" by David Lindsay Roberts. Docent Press, July 2012, ISBN-13: 978-09837-004-49.

The Annotated Turing: A Guided Tour Through Alan Turing's Historic Paper on Computability and the Turing Machine, by Charles Petzold. Wiley, June 2008. ISBN-13: 978-04702-290-57. (Reviewed September 2011.)

The Beginning of Infinity: Explanations That Transform the World, by David Deutsch. Viking Adult, July 2011. ISBN-13: 978-06700-227-55. (Reviewed April 2012.)

**The Best Writing on Mathematics 2012,* edited by Mircea Pitici. Princeton University Press, November 2012. ISBN-13: 978-06911-565-52.

Bibliography of Raymond Clare Archibald by Scott Guthery. Docent Press, April 2012. ISBN-13: 978-0983700425.

The Big Questions: Mathematics, by Tony Crilly. Quercus, April 2011. ISBN: 978-18491-624-01.(Reviewed October 2012.)

Calculating Curves: The Mathematics, History, and Aesthetic Appeal of T. H. Gronwall's Nomographic Work, by Thomas Hakon Gronwall, with contributions by Ron Doerfler and Alan Gluchoff, translation by Paul Hamburg, and bibliography by Scott Guthery. Docent Press, April 2012. ISBN-13: 978-09837-004-32.

The Calculus of Selfishness, by Karl Sigmund. Princeton University Press, January 2010. ISBN-13: 978-06911-427-53. (Reviewed January 2012.)

Chasing Shadows: Mathematics, Astronomy, and the Early History of Eclipse Reckoning, by Clemency Montelle. Johns Hopkins University Press, April 2011. ISBN-13: 978-08018-969-10. (Reviewed March 2012.)

Classic Problems of Probability, by Prakash Gorroochurn. Wiley, May 2012. ISBN: 978-1-1180-6325-5.

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.

The Crossing of Heaven: Memoirs of a Mathematician, by Karl Gustafson. Springer, January 2012. ISBN-13: 978-36422-255-74.

Elegance with Substance, by Thomas Colignatus. Dutch University Press, 2009. ISBN-13: 978-90361-013-87.

Elliptic Tales: Curves, Counting, and Number Theory, by Avner Ash and Robert Gross. Princeton University Press, March 2012. ISBN-13: 978-06911-511-99.

Emmy Noether's Wonderful Theorem, by Dwight E. Neuenschwander. Johns Hopkins University Press, November 2010. ISBN-13: 978-08018-969-41.

Excursions in the History of Mathematics, by Israel Kleiner. Birkhäuser, 2012. ISBN-13: 978-08176-826-75.

Experimental and Computational Mathematics: Selected Writings, by Jonathan Borwein and Peter Borwein. PSIpress, 2011. ISBN-13: 978-19356-380-56.

Flatland, by Edwin A. Abbott, with notes and commentary by William F. Lindgren and Thomas F. Banchoff.

Cambridge University Press, November 2009. ISBN-13: 978-05217-599-46

The Foundations of Geometry And Religion From An Abstract Standpoint, by Salilesh Mukhopadhyay. Outskirts Press, July 2012. ISBN: 978-1-4327-9424-8.

Galileo's Muse: Renaissance Mathematics and the Arts, by Mark Austin-Peterson. Harvard University Press, October 2011. ISBN-13: 978-06740-597-26. (Reviewed November 2012.)

**Game Theory and the Humanities: Bridging Two Worlds,* by Steven J. Brams. MIT Press, September 2012. ISBN-13: 978-02625-182-53.

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

Guesstimation 2.0: Solving Today's Problems on the Back of a Napkin, by Lawrence Weinstein. Princeton University Press, September 2012. ISBN: 978-06911-508-02.

In Pursuit of the Traveling Salesman: Mathematics at the Limits of Computation, by William J. Cook. Princeton University Press, December 2011. ISBN-13: 978-06911-527-07.

In Pursuit of the Unknown: 17 Equations That Changed the World, by Ian Stewart. Basic Books, March 2012. ISBN-13: 978-04650-297-30. (Reviewed in this issue.)

In Service to Mathematics: The Life and Work of Mina Rees, by Amy Shell-Gellasch. Docent Press, December 2010. ISBN-13: 978-0-9837004-1-8.

**Infinity: New Research Frontiers,* edited by Michael Heller and W. Hugh Woodin. Cambridge University Press, February 2011. ISBN-13: 978-11070-038-73.

The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe, by Frank Close. Basic Books, November 2011. ISBN-13: 978-04650-214-44. (Reviewed September 2012.)

The Information: A History, a Theory, a Flood, by James Gleick. Pantheon, March 2011. ISBN-13: 978-03754-237-27.

**Introduction to Mathematical Thinking,* by Keith Devlin. Keith Devlin, July 2012. ISBN-13: 978-06156-536-31.

The Irrationals: A Story of the Numbers You Can't Count On, by Julian Havil. Princeton University Press, June 2012. ISBN-13: 978-0691143422.

Knots Unravelled: From String to Mathematics, by Meike Akveld and Andrew Jobbings. Arbelos, October 2011. ISBN-13: 978-09555-477-20.

**The Joy of x: A Guided Tour of Math, from One to Infinity,* by Steven Strogatz. Eamon Dolan/Houghton Mifflin Harcourt, October 2012. ISBN-13: 978-05475-176-50.

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.

Lemmata: A Short Mathematical Thriller, by Sam Peng. CreateSpace, December 2011. ISBN-13: 978-14681-442-39.

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: 978-06911-510-07.

Lost in a Cave: Applying Graph Theory to Cave Exploration, by Richard L. Breisch. National Speleological Society, January 2012. ISBN-13: 978-1-879961-43-2.

The Lost Millennium: History's Timetables Under Siege, by Florin Diacu. Johns Hopkins University Press (second edition), November 2011. ISBN-13: 978-14214-028-88.

Magical Mathematics: The Mathematical Ideas That Animate Great Magic Tricks, by Persi Diaconis and Ron Graham. Princeton University Press, November 2011. ISBN-13: 978-06911-516-49. (Reviewed August 2012.)

The Man of Numbers: Fibonacci's Arithmetic Revolution, by Keith Devlin. Walker and Company, July 2011. ISBN-13: 978-08027-781-23. (Reviewed May 2012.)

Math Girls, by Hiroshi Yuki (translated from the Japanese by Tony Gonzalez). Bento Books, November 2011. ISBN-13: 978-09839-513-15. (Reviewed August 2012.)

**Math Goes to the Movies,* by Burkard Polster and Marty Ross. Johns Hopkins University Press, July 2012. ISBN-13: 978-14214-048-44.

Math is Murder, by Robert C. Brigham and James B. Reed. Universe, March 2012. ISBN-13: 978-14697-972-81.

The Mathematical Writings of Évariste Galois, edited by Peter M. Neumann. European Mathematical Society, October 2011. ISBN-13: 978-3-03719-104-0. (Reviewed in this issue.)

Mathematical Excursions to the World's Great Buildings, by Alexander J. Hahn. Princeton University Press, July 2012. ISBN-13: 978-06911-452-04

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

Mathematics in Popular Culture: Essays on Appearances in Film, Fiction, Games, Television and Other Media, edited by Jessica K. Sklar and Elizabeth S. Sklar. McFarland, February 2012. ISBN-13: 978-07864-497-81.

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

**Meaning in Mathematics*, edited by John Polkinghorne. Oxford University Press, July 2011. ISBN-13: 978-01996-050-57.

**Measurement,* by Paul Lockhart. Belknap Press of Harvard University Press, September 2012. ISBN-13: 978-06740-575-55.

Newton and the Counterfeiter: The Unknown Detective Career of the World's Greatest Scientist, by Thomas Levenson. Houghton Mifflin Harcourt, June 2009. ISBN-13: 978-01510-127-87.

The Noether Theorems: Invariance and Conservation Laws in the Twentieth Century, by Yvette Kosmann-Schwarzbach. Springer, December 2010. ISBN-13: 978-03878-786-76.

Nine Algorithms That Changed the Future: The Ingenious Ideas That Drive Today's Computers, by John MacCormick. Princeton University Press, December 2011. ISBN-13: 978-06911-471-47.

Number-Crunching: Taming Unruly Computational Problems from Mathematical Physics to Science Fiction, by Paul J. Nahin. Princeton University Press, August 2011. ISBN: 978-06911-442-52.

Numbers: A Very Short Introduction, by Peter M. Higgins. Oxford University Press, February 2011. ISBN-13: 978-0-19-958405-5. (Reviewed January 2012.)

On the Formal Elements of the Absolute Algebra, by Ernst Schröder (translated and with additional material by Davide Bondoni; with German parallel text). LED Edizioni Universitarie, 2012. ISBN: 978-88-7916-516-7.

Our Days are Numbered: How Mathematics Orders Our Lives, by Jason Brown. Emblem Editions, April 2010. ISBN-13: 978-07710-169-74. (Reviewed October 2012.)

The Philosophy of Mathematical Practice, Paolo Mancosu, editor. Oxford University Press, December 2011. ISBN-13: 978-01996-401-02. (Reviewed March 2012.)

Pricing the Future: Finance, Physics, and the 300-Year Journey to the Black-Scholes Equation, by George G. Szpiro. Basic Books, November 2011. ISBN-13: 978-04650-224-89.

Proof and Other Dilemmas: Mathematics and Philosophy, edited by Bonnie Gold and Roger A. Simons. Mathematical Association of America, July 2008. ISBN-13: 978-08838-556-76. (Reviewed December 2011.)

Proving Darwin: Making Biology Mathematical, by Gregory Chaitin. Pantheon, May 2012. ISBN: 978-03754-231-47.

Scientific Reflections: Selected Multidisciplinary Works, by Richard Crandall. PSIpress, 2011. ISBN-13: 978-19356-380-87.

**Secrets of Triangles: A Mathematical Journey*, by Alfred S. Posamentier and Ingmar Lehman. Prometheus Books, August 2012. ISBN-13: 978-16161-458-73.

**Seduced by Logic: Emilie Du Châelet, Mary Somerville and the Newtonian Revolution*, by Robyn Arianrhod. Oxford University Press, September 2012. ISBN: 978-01999-316-13.

**Simon: The Genius in My Basement,* by Alexander Masters. Delacorte Press, February 2012. ISBN-13: 978-03853-410-80.

Six Gems of Geometry, by Thomas Reale. PSIpress, 2010. ISBN-13: 978-19356-380-25.

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.

A Strange Wilderness: The Lives of the Great Mathematicians, by Amir D. Aczel. Sterling, October 2011.ISBN-13: 978-14027-858-49.

Taking Sudoku Seriously: The Math behind the World's Most Popular Pencil Puzzle, by Jason Rosenhouse and Laura Taalman. Oxford University Press, January 2012. ISBN-13: 978-01997-565-68.

The Theory That Would Not Die: How Bayes' Rule Cracked the Enigma Code, Hunted Down Russian Submarines, and Emerged Triumphant from Two Centuries of Controversy, by Sharon Bertsch McGrayne. Yale University Press, April 2011. ISBN-13: 978-03001-696-90. (Reviewed May 2012.)

Top Secret Rosies: The Female Computers of World War II. Video documentary, produced and directed by LeAnn Erickson. September 2010. Website: `http://www.topsecretrosies.com`. (Reviewed February 2012.)

Transcending Tradition: Jewish Mathematicians in German Speaking Academic Culture, edited by Birgit Bergmann, Moritz Epple, and Ruti Ungar. Springer, January 2012. ISBN: 978-3642224638.

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: 978-08218-691-47.

Uneducated Guesses: Using Evidence to Uncover Misguided Education Policies, by Howard Wainer. Princeton University Press, August 2011. ISBN-13: 978-06911-492-88. (Reviewed June/July 2012.)

The Universe in Zero Words: The Story of Mathematics as Told through Equations, by Dana Mackenzie. Princeton University Press, April 2012. ISBN-13: 978-06911-528-20. (Reviewed in this issue.)

Vilim Feller, istaknuti hrvatsko-americki matematicar/William Feller, Distinguished Croatian-American Mathematician, by Darko Zubrinic. Bilingual Croatian-English edition, Graphis, 2011. ISBN-13: 978-953-279-016-0.

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.

What's Luck Got to Do with It? The History, Mathematics and Psychology of the Gambler's Illusion, by Joseph Mazur. Princeton University Press, July 2010. ISBN-13: 978-0-691-13890-9. (Reviewed February 2012.)

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.

Why Beliefs Matter: Reflections on the Nature of Science, by E. Brian Davies. Oxford University Press, June 2010. ISBN-13: 978-01995-862-02. (Reviewed April 2012.)

Why Cats Land on Their Feet (and 76 Other Physical Paradoxes and Puzzles), by Mark Levi. Princeton University Press, May 2012. ISBN-13: 978-0691148540.

Mathematics Calendar

December 2012

* 1–August 31, 2013 **Activities Academic Year 2012-2013**, Centre de Recerca Matemmàtica, Bellaterra, Barcelona.
Information: http://www.crm.cat/en/Activities/Pages/Activities_2012_2013.aspx.

2–5 **Inaugural meeting of the Australian and New Zealand Association of Mathematical Physics (ANZAMP)**, Cumberland resort, Lorne, Victoria, Australia. (Sept. 2012, p. 1165)

* 3 **SmartGridSec12 – First Open EIT ICT Labs Workshop on Smart Grid Security**, The Berlin Co-location Centre, Berlin, Germany.
Description: There is a clear need in Europe to integrate the fragmented research and development efforts in securing the Smart Grid. This workshop will be a venue to share and consolidate results, plan joint work, and create networks to accomplish these ambitioned goals. Follow the instructions at the submission web page: https://www.easychair.org/conferences/?conf=smartgridsec12.
Submission deadline: Of full paper (5-10 pages), extended abstract (2-5 pages) or short paper (2-5 pages): October 31, 2012.
Information: http://www.easychair.org/conferences/?conf=smartgridsec12.

3–7 **Combinatorial Commutative Algebra and Applications**, Mathematical Sciences Research Institute, Berkeley, California. (May 2012, p. 718)

3–16 **ICTS Program: Groups, Geometry and Dynamics**, CEMS, Kumaun University, Almora, Uttarakhand, India. (Sept. 2012, p. 1165)

3–20 **ICTS Program: Winter School on Stochastic Analysis and Control of Fluid Flow**, School of Mathematics, Indian Institute of Science Education and Research, Thiruvananthapuram, Kerala, India. (Sept. 2012, p. 1165)

4–6 **New Zealand Mathematical Society Colloquium**, Massey University, Palmerston North, New Zealand. (Sept. 2012, p. 1166)

6–8 **Thailand-Japan Joint Conference on Computational Geometry and Graphs TJJCCGG2012**, Department of Mathematics, Srinakharinwirot University, Bangkok, Thailand. (Oct. 2012, p. 1302)

7–9 **International Conference on Frontiers of Mathematical Sciences with Applications (ICFMSA-2012)**, Calcutta Mathematical Society, Kolkata, India. (Sept. 2012, p. 1166)

7–9 **17th Annual Conference of Gwalior Academy of Mathematical Sciences and National Symposium on Computational Mathematics and Information Technology**, Department of Mathematics, Department of CSE, Jaypee University of Engineering & Technology, A. B. Road, Raghogarh Distt. Guna-M.P, India-473226. (Nov. 2012, p. 1479)

9–13 **15th International Conference of International Academy of Physical Sciences (CONIAPS XV)**, Rajamangala University of Technology Thanyaburi, Pathumthani, Thailand. (Nov. 2012, p. 1480)

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/.

10–14 **AIM Workshop: Log minimal model program for moduli spaces**, American Institute of Mathematics, Palo Alto, California. (May 2012, p. 718)

10–14 **36ACCMCC—The 36th Australasian Conference on Combinatorial Mathematics and Combinatorial Computing**, University of New South Wales, Sydney, Australia. (Feb. 2012, p. 340)

10–14 **Reproducibility in Computational and Experimental Mathematics**, Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, Rhode Island. (Sept. 2012, p. 1166)

10–21 **VI-MSS Event: Winter School and Conference on Computational Aspects of Neural Engineering**, Bangalore, India. (Sept. 2012, p. 1166)

* 11–13 **5th Minimeeting on Differential Geometry**, Centre for Research in Mathematics (CIMAT), Guanajuato, Mexico.
Description: This is the fifth of a series of annual events (school/workshop) held in CIMAT.
Aim: The aim of the 5th Minimeeting on Differential Geometry is to bring distinguished U.S. based mathematicians to CIMAT to deliver a series of lectures for researchers and postgraduate students working in the area of Differential Geometry, in order to enrich and stimulate the research environment in Mexico and and provide a space for academic interactions.
Guest Speakers: Howard Jacobowitz (Rutgers University), Distinguished Professor Guest of the Mexican Academy of Sciences (AMC) and the United States-Mexico Foundation for Science (FUMEC); John Ratcliffe (Vanderbilt University).
Registration/Support: There is no registration fee. There will be some financial support for local expenses for participants, mainly graduate students who wish to attend the conference.
Information: `https://sites.google.com/site/5meetingdg/`.

15–16 **2nd International Conference on Mathematical Sciences and Applications**, India International Centre, 40, Max Mueller Marg, Lodhi Estate, New Delhi-110 003, India. (Sept. 2012, p. 1166)

16–18 **Southeastern Lie Theory Workshop: Vertex Algebras, Conformal Field Theory, and Integrable Systems**, College of Charleston, Charleston, South Carolina. (Nov. 2012, p. 1480)

16–22 **Commutative Rings, Integer-Valued Polynomials and Polynomial Functions**, Graz University of Technology, Graz, Austria. (Nov. 2011, p. 1495)

* 17–19 **Aspects of Topology in Geometry and Physics**, Mathematical Institute, University of Oxford, Oxford, United Kingdom.
Description: The conference aims to gather leading researchers to showcase topological ideas in a variety of current research developments. It marks and honours the 70th birthday of Graeme Segal.
Speakers: Michael Atiyah, David Ben-Zvi, Kevin Costello, Simon Donaldson, Nigel Hitchin, Michael Hopkins (Astor Lecturer), Soren Galatius, Maxim Kontsevich, Gregory Moore, Constantin Teleman.
Information: `https://people.maths.ox.ac.uk/tillmann/ASPECTS.html`.

* 17–19 **7th International Young Researchers Workshop on Geometry, Mechanics and Control**, Institute for the Mathematical Sciences (ICMAT (CSIC-UAM-UC3M-UCM)), Madrid, Spain.
Description: The conference will be the seventh in a series of workshops that have previously taken place in Madrid (2006, 2007), Barcelona (2008), Ghent (2009), La Laguna (2010), and Coimbra (2012). Its goal is to bring together young researchers working in geometric mechanics and control theory and to offer a platform to present the results of their research to an international audience. The main idea of this conference is to offer 3 courses of 4 hours which serve as an introduction to different topics related to geometric structures in mechanics and control theory. The courses will be at a Ph.D. level, so the young researchers would, at the end of the workshop, access to the recent literature on the corresponding topics. Along with the courses, there will be short talks (30 minutes) by the participants willing to present their results. Moreover, there will be a poster session.
Information: `http://gmcnetwork.org/?q=activity-detail1/666`.

17–20 **9th IMA International Conference on Mathematics in Signal Processing**, Austin Court, Birmingham, United Kingdom. (Nov. 2011, p. 1495)

17–21 **AIM Workshop: Rational Catalan Combinatorics**, American Institute of Mathematics, Palo Alto, California. (May 2012, p. 718)

17–21 **International Conference on the Theory, Methods and Applications of Nonlinear Equations**, Department of Mathematics, Texas A&M University-Kingsville, Kingsville, Texas. (Feb. 2012, p. 340)

17–22 **The Legacy of Srinivasa Ramanujan–An International Conference**, University of Delhi, Delhi, India. (Oct. 2012, p. 1302)

18–21 **5th HiPC Student Research Symposium (SRS) *** Held in conjunction with the 19th International Conference on High Performance Computing (HIPC 2012)**, Pune, India. (Nov. 2012, p. 1480)

21–23 **6th International Conference of IMBIC on "Mathematical Sciences for Advancement of Science and Technology" (MSAST 2012)**, Salt Lake City, Kolkata, West Bengal, India. (Sept. 2012, p. 1167)

22–24 **The International Congress on Science and Technology**, Allahabad, U.P., India. (Apr. 2012, p. 593)

26–January 1 **International Conference: Mathematical Science and Applications**, Abu Dhabi University, College of Arts and Science, Department of Applied Sciences and Mathematics, Abu Dhabi, United Arab Emirates. (Sept. 2012, p. 1167)

27–29 **International Conference on Mathematics, Trends and Development (ICMTD12)**, Cairo, Egypt. (Sept. 2012, p. 1167)

27–30 **Eighth International Triennial Calcutta Symposium on Probability and Statistics**, Department of Statistics, Calcutta University, Kolkata, West Bengal, India. (Nov. 2011, p. 1495)

28–31 **International Conference on Mathematical Sciences (ICMS2012)**, Shri Shivaji Education Society's Science College, Nagpur, Maharashtra, India. (Sept. 2012, p. 1167)

31–January 11 **Recent Advances in Operator Theory and Operator Algebras**, Indian Statistical Institute, Bangalore, India. (Sept. 2012, p. 1168)

January 2013

1–9 **VI-MSS Event: Workshop and Conference on Limit Theorems in Probability**, Bangalore, India. (Sept. 2012, p. 1168)

* 3–5 **National Workshop Computer Applications based on Modern Algebra**, Manipal Institute of Technology, Manipal University Manipal-576 104, Karnataka, India.
Description: Algebra is often described as the language of mathematics and computer science. Historically, the terms algebra and algorithm originate from the same source. Algebra is so beautiful that many people naturally possess the ability to understand and apply algebra in real life problems. The aim of the workshop is to highlight the concepts from modern algebra and demonstrate their applications in computer science. Indeed, it is encouraging to note that computer algebra has evolved as a discipline linking advanced algebra to methods of computer science and thus offering many tools. The workshop will focus on algorithms and algebraic computations, finite fields and applications, algebraic codes, data mining, soft computing techniques, algebraic cryptography, and recent developments in these areas. The workshop will provide an ideal platform for the faculty, researchers, and the students in the vari-

ous disciplines of science and engineering to reinforce their knowledge. The participants of this workshop will also benefit from recent trends of modern algebra and its applications.
Information: http://conference.manipal.edu/algebra2013.

6–8 **ACM-SIAM Symposium on Discrete Algorithms (SODA13)**, Astor Crowne Plaza Hotel, New Orleans, Louisiana. (Apr. 2012, p. 593)

* 7–11 **ANODE 2013 conference, John Butcher 80th birthday**, Auckland, New Zealand.
Description: The conference in the year in which John Butcher turns 80 marks his lifelong contributions to numerical analysis.
Plenary lectures: The following mathematicians have agreed to present lectures: Kevin Burrage (Oxford and Brisbane), John Butcher (Auckland), Rob Corless (London, Ontario), Robert McLachlan (Palmerston North), Linda Petzold (Santa Barbara), Chus Sanz-Serna (Valladolid), Zaijiu Shang (Beijing), Gerhard Wanner (Geneva). In addition, there will be a full programme of contributed lectures and offers to present contributed lectures are warmly welcomed.
Information: Registration is now open at http://jcbutcher.com/d/ANODE2013 for the ANODE 2013 conference.

7–12 **Iwasawa Theory, Representations, and the p-adic Langlands Program**, University of Münster, Münster, Germany. (Jan. 2012, p. 106)

14–18 **AIM Workshop: Modeling problems related to our environment**, American Institute of Mathematics, Palo Alto, California. (Sept. 2012, p. 1168)

14–May 24 **Noncommutative Algebraic Geometry and Representation Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Oct. 2011, p. 1325)

14–February 1 **Winter School on Mathematical Physics**, Universidad Nacional Autonoma de Mexico, Mexico City, Mexico. (Oct. 2012, p. 1302)

17–19 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program - Disease Dynamics 2013: Immunization, a True Multi-Scale Problem**, PIMS, Vancouver, British Columbia, Canada. (Sept. 2012, p. 1168)

21–25 **AIM Workshop: Online databases - from L-functions to combinatorics**, International Centre for Mathematical Sciences Edinburgh, Scotland, United Kingdom. (Sept. 2012, p. 1168)

* 21–25 **Masterclass: Recursion from matrix models to quantum algebraic geometry by Eynard and Orantin**, QGM, Aarhus University, Aarhus, Denmark.
Description: The main topics have their roots in matrix model theory, which has a universal behavior observed in many physical phenomena, such as solid state physics, quantum chaos, mesoscopic conductors, nuclear physics, quantum chromodynamics, string theory, and also in mathematics, such as the distribution of Riemann zeta function zeroes. Some important aspects of matrix model theory were further developed in the work of Eynard, and this work provided the initial impetus for a vast generalization in the seminal work of Eynard and Orantin, extending the scope of application of matrix model methods to an even greater class of theories, now called Eynard-Orantin invariants. Important examples of Eynard-Orantin invariants give intersection numbers over moduli space, simple Hurwitz numbers, lattice points in moduli space of curves, and Chern-Simons invariants of 3-manifolds, thus connecting with deep combinatorial, topological and geometrical aspects of physics and mathematics.
Information: http://qgm.au.dk/currently/events/show/artikel/masterclass-21-25-jan-2013-recursion-frem-matrix-models-to-quantum-algebraic-geometry.

24–25 **Connections for Women: Noncommutative Algebraic Geometry and Representation Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1014)

* 28–February 1 **International Conference on Fluids And Variational Methods**, University of Leipzig, Leipzig, Germany.
Description: The aim of the conference is to bring together experts from fluid dynamics and the calculus of variations. Fluid dynamics inherently involves transport and dissipation phenomena. Nevertheless, techniques that have been developed in the context of the calculus of variations have on several occasions proved to be very successful: the Scheffer-CKN partial regularity theory originates from geometric measure theory and minimal surface regularity; the generalized flow of Brenier finds its origin in the theory of Young measures and the Monge-Kantorovich displacement problem; Baire category techniques for existence were first used for variational problems from material science. Our hope is that in Leipzig, building on the tradition of Leon Lichtenstein, this conference will result in further synergies and a flow of ideas in both directions.
Information: http://www.math.uni-leipzig.de/~fluids2013/.

28–February 1 **Introductory Workshop: Noncommutative Algebraic Geometry and Representation Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1014)

* 28–February 1 **Topological recursion and quantum algebraic geometry**, QGM, Aarhus University, Aarhus, Denmark.
Information: http://qgm.au.dk/currently/events/show/artikel/uvw-knotsxtopology-combinatorics-low-and-high-algebra/.

28–May 3 **ICERM Semester Program: Automorphic Forms, Combinatorial Representation Theory and Multiple Dirichlet Series**, ICERM, Providence, Rhode Island. (Jan. 2012, p. 106)

* 30–February 1 **The Third International Conference on Digital Information Processing and Communications (ICDIPC2013)**, Islamic Azad University (IAU), Dubai, UAE.
Description: Researchers are encouraged to submit their work electronically. All papers will be fully refereed by a minimum of two specialized referees. Before final acceptance, all referees' comments must be considered.
Important dates: Submission Deadline: December 15, 2012. Notification of Acceptance: January 1, 2013. Camera Ready Submission: January 20, 2013. Registration: January 20, 2013.
Information: http://sdiwc.net/conferences/2013/dubai/index.php.

February 2013

4–5 **2nd Annual International Conference on Computational Mathematics, Computational Geometry & Statistics (CMCGS 2013)**, Hotel Fort Canning, Singapore, Singapore. (Nov. 2012, p. 1480)

4–8 **AIM Workshop: Stochastics in geophysical fluid dynamics**, American Institute of Mathematics, Palo Alto, California. (Sept. 2012, p. 1169)

4–8 **The Second Biennial International Group Theory Conference**, Dogus University, Istanbul, Turkey. (Sept. 2012, p. 1169)

4–March 15 **Doc-course on Complex Analysis and Related Areas**, Universities of Seville and Málaga, Spain. (Oct. 2012, p. 1302)

5–7 **International Conference on Mathematical Sciences and Statistics (ICMSS2013)**, Kuala Lumpur, Malaysia. (Sept. 2012, p. 1169)

6–8 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program - Models and Methods in Ecology and Epidemiology**, CRM, Montréal, Canada. (Sept. 2012, p. 1169)

11–14 **The AMSI Workshop on Graph C^*-algebras, Leavitt path algebras and symbolic dynamics**, University of Western Sydney, Australia. (Nov. 2012, p. 1480)

11–15 **ICERM Workshop: Sage Days: Multiple Dirichlet Series, Combinatorics, and Representation Theory**, ICERM, Providence, Rhode Island. (Sept. 2012, p. 1169)

11–17 (NEW DATE) **Representation Theory, Homological Algebra, and Free Resolutions**, Mathematical Sciences Research Institute, Berkeley, California. (Oct. 2012, p. 1302)

20–22 **DIMACS Workshop on Energy Infrastructure: Designing for Stability and Resilience**, DIMACS Center, CoRE Building, Rutgers University, Piscataway, New Jersey. (Sept. 2012, p. 1169)

25–March 1 **AIM Workshop - Brauer groups and obstruction problems: Moduli spaces and arithmetic**, American Institute of Mathematics, Palo Alto, California. (Sept. 2012, p. 1169)

March 2013

1–3 **2013 Spring Southeastern Section Meeting**, University of Mississippi, Oxford, Mississippi. (Sept. 2012, p. 1170)

* 2–3 **36th Annual Texas Partial Differential Equations Conference**, The University of Texas at El Paso, El Paso, Texas.
Description: This traditional meeting comes to El Paso for the first time in 2013. In keeping with tradition, there will be no registration fee, no principal speakers, and all talks will be limited to 20 minutes. Graduate students are particularly encouraged to participate. Those wishing to speak should submit title and short abstract by Friday, February 22, 2013, to the listed email address of one of the organizers.
Organizers: Please send requests for information to Behzad Djafari-Rouhani, email: behzad@utep.edu, Maria Christina Mariani, email: mcmariani@utep.edu, Osvaldo Mendez, email: osmendez@utep.edu, Indranil SenGupta, email: indranil.sengupta@ndsu.edu, Son-Young Yi, email: syi@utep.edu.
Information: http://math.utep.edu/texaspde.

* 4–6 **The First International Conference on Green Computing, Technology and Innovation (ICGCTI2013)**, The Asia Pacific University of Technology and Innovation (APU), Kuala Lumpur, Malaysia.
Description: To provide a medium for professionals, engineers, academicians, scientists, and researchers from over the world to present the result of their research activities in the field of Computer Science, Engineering and Information Technology. ICGCTI 2013 provides opportunities for the delegates to share the knowledge, ideas, innovations and problem solving techniques. Submitted papers will be reviewed by the technical program committee of the conference.
Keywords: Green computing, engineering, algorithms, interformation technology, smart grids, power aware.
Deadlines: Submission deadline: December 15, 2012. Contact: icg@sdiwc.net.
Information: http://sdiwc.net/conferences 2013/malaysia4.

* 4–6 **The Second International Conference on e-Technologies and Networks for Development (ICeND 2013)**, The Asia Pacific University of Technology and Innovation (APU), Kuala Lumpur, Malaysia.
Description: To provide a medium for professionals, engineers, academicians, scientists, and researchers from over the world to present the result of their research activities in the field of Computer Science, Engineering and Information Technology. ICeND 2013 provides opportunities for the delegates to share the knowledge, ideas, innovations and problem solving techniques. Submitted papers will be reviewed by the technical program committee of the conference.
Keywords: E-Technologies, computing, computer networks, security, internet, wireless communications.
Submission deadline: December 15, 2012. Contact: ice@sdiwc.net.
Information: http://sdiwc.net/conferences 2013/malaysia2/.

4–8 **Forty-Fourth Southeastern International Conference on Combinatorics, Graph Theory and Computing**, Florida Atlantic University, Boca Raton, Florida. (Oct. 2012, p. 1302)

4–8 **ICERM Workshop: Whittaker Functions, Schubert Calculus and Crystals**, ICERM, Providence, Rhode Island. (Sept. 2012, p. 1170)

11–14 **Interactions between Analysis and Geometry**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California. (Oct. 2011, p. 1325)

13–15 **IAENG International Conference on Operations Research 2013 (ICOR'13)**, Royal Garden Hotel, Hong Kong, China. (Sept. 2012, p. 1170)

* 15–16 **29th Southeastern Analysis Meeting (SEAM 2013)**, Virginia Tech, Blacksburg, Virginia.
Description: This is the 29th edition of an annual meeting held in the southeastern United States in Analysis.
Traditional topics: Function-theoretic operator theory—the mathematics at the intersection of operator theory, classical complex analysis, harmonic analysis, and several complex variables—and its related areas and fields of application including operator algebras, operator spaces and operator systems; systems and control theory; scattering theory and mathematical physics; algebraic and semi-algebraic geometry (both classical and noncommutative).
Featured speakers: Fritz Gesztesy (University of Missouri), Palle E.T. Jorgensen (University of Iowa), Dmitry S. Kaliuzhnyi-Verbovetskyi (Drexel University), and Anna Skripka (University of New Mexico). In addition to the featured speakers there will be contributed half-hour talks.
Funding: From the National Science Foundation for junior participants is expected.
Information: http://www.math.vt.edu/seam2013/.

18–22 **84th Annual Meeting of GAMM (The International Association of Applied Mathematics and Mechanics)**, University of Novi Sad, Novi Sad, Serbia. (Sept. 2012, p. 1170)

* 18–22 **Masterclass: Soergel bimodules and Kazhdan-Lusztig conjectures by Williamson and Elias**, QGM, Aarhus University, Aarhus, Denmark.
Description: This will be a course about Coxeter groups, their Hecke algebras, Kazhdan-Lusztig polynomials and Soergel bimodules. It will culminate in an algebraic proof of the Kazhdan-Lusztig conjecture (a character formula for highest weight modules over a complex semisimple Lie algebra, which up until recently had difficult geometric proofs) and a proof of the positivity of Kazhdan-Lusztig polynomials (a conjecture which has been open for over thirty years). Along the way ideas from categorification, higher algebra and Hodge theory play an essential role.
Information: http://qgm.au.dk/currently/events/show/artikel/masterclass-marts-2013/.

20–22 **17th International Conference on Discrete Geometry for Computer Imagery (DGCI 2013)**, Escuela Tecnica Superior de Ingenieria Informatica, Univ. de Sevilla, Seville, Spain. (Sept. 2012, p. 1170)

25–27 **7th IMA Conference on Quantitative Modelling in the Management of Health and Social Care**, Central London College, London, United Kingdom. (Sept. 2012, p. 1170)

25–29 **AIM Workshop: Mathematical problems arising from biochemical reaction networks**, American Institute of Mathematics, Palo Alto, California. (Sept. 2012, p. 1170)

April 2013

4–6 **38th Arkansas Spring Lecture Series in the Mathematical Sciences: "Extension and Interpolation of Functions"**, University of Arkansas, Fayetteville, Arkansas. (Nov. 2012, p. 1480)

* 5–6 **3rd International Conference on E-Learning and Knowledge management Technology (ICEKMT 2013)**, Hotel Ramada, Bangkok, Thailand.
Description: This conference will bring together educators, trainers, researchers, practitioners, futurists, policy makers, and users to discuss and propose how this transformation can be empowered.
Information: http://www.icekm.com.

6–7 **2013 Spring Eastern Sectional Meeting**, Boston College, Chestnut Hill, Massachusetts. (Sept. 2012, p. 1170)

8–9 **IMA Mathematics in Finance**, Edinburgh Conference Centre, Heriot-Watt University, Edinburgh, United Kingdom (Sept. 2012, p. 1170)

8–10 **Fourteenth International Conference on Numerical Combustion (NC13)**, Holiday Inn Riverwalk, San Antonio, Texas. (Sept. 2012, p. 1170)

8–12 **AIM Workshop: Geometric perspectives in mathematical quantum field theory**, American Institute of Mathematics, Palo Alto, California. (Sept. 2012, p. 1171)

8–12 **Interactions between Noncommutative Algebra, Representation Theory, and Algebraic Geometry**, Mathematical Sciences Research Institute, Berkeley, California. (Aug. 2011, p. 1014)

13–14 **2013 Spring Western Section Meeting**, University of Colorado Boulder, Boulder, Colorado. (Sept. 2012, p. 1171)

13–14 **3rd IIMA International Conference on Advanced Data Analysis, Business Analytics and Intelligence**, Indian Institute of Management, Ahmedabad, India. (Apr. 2012, p. 593)

15–17 **Geomathematics 2013**, Hotel Haus am Weinberg, Sankt Martin, Palatinate, Germany. (Nov. 2012, p. 1480)

15–19 **ICERM Workshop: Combinatorics, Multiple Dirichlet Series and Analytic Number Theory**, ICERM, Providence, Rhode Island. (Sept. 2012, p. 1171)

19–20 (NEW DATE) **New Frontiers in Numerical Analysis and Scientific Computing**, Kent State University, Kent, Ohio. (Nov. 2012, p. 1172. Formally listed under April 12–13.)

* 20 **2013 Great Lakes SIAM conference on "Computational Mathematics: Modeling, Algorithms and Applications"**, Central Michigan University, Mount Pleasant, Michigan.
Description: This conference will be a leading forum for the presentation of new advances and research in the field of computational mathematics.
Topics: Of interest for submission include, but not limited to: computational and systems biology, modeling and simulation in molecular biology, numerical and analytical partial differential equations (PDEs), applications of mathematics in material science, nanotechnology, and engineering, wavelet theory and applications, stochastic modeling techniques and applications, biomedical visualization and applications, high performance computing and simulation, simulation application in industry.
Information: http://people.cst.cmich.edu/zheng1x/GLSIAM2013.html.

26 **Philosophy of Information: The Value of Information**, American University, Washington, DC. (Oct. 2012, p. 1302)

27–28 **2013 Spring Central Section Meeting**, Iowa State University, Ames, Iowa. (Sept. 2012, p. 1171)

29–May 1 **Mathematics of Planet Earth 2013. Establishing the scientific foundation for Quantitative Public Health Decision-Making: Linking surveillance, disease modeling, and simulation at the Fields Institute**, FIELDS, Toronto, Canada. (Sept. 2012, p. 1171)

* 30–May 3 **Third Buea International Conference on the Mathematical Sciences**, University of Buea, Cameroon.
Description: The goals of the conferences are to bring together distinguished scientists whose specialties involve mathematics and neighboring disciplines, to give their perspectives on current research and directions for further research in the area of their expertise. The conference will provide a medium for the exchange of information and ideas among mathematical scientists from diverse backgrounds, and space for Mathematical Scientists outside of Cameroon to engage actively in the development of Mathematics in the Cameroon sub-region, in particular, and Africa in general. The 2013 conference will accommodate talks from all areas of Mathematics, to close an adjoining two-week summer school on Stochastic Analysis, Financial and Actuarial Mathematics with Applications.
Information: http://www.bueaconference.com.

May 2013

5–9 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program - Major and Neglected Diseases in Africa**, Ottawa, Canada. (Sept. 2012, p. 1171)

6–10 **AIM Workshop: Algorithms for lattices and algebraic automorphic forms**, American Institute of Mathematics, Palo Alto, California. (Sept. 2012, p. 1171)

6–10 **The Commutative Algebra of Singularities in Birational Geometry: Multiplier Ideals, Jets, Valuations, and Positive Characteristic Methods**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1171)

12–17 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program- Impact of climate change on biological invasions and population distributions**, BIRS, Banff, Canada. (Sept. 2012, p. 1172)

13–17 **AIM Workshop: Nonhomogeneous boundary-value problems for nonlinear waves**, American Institute of Mathematics, Palo Alto, California. (Sept. 2012, p. 1172)

19–23 **SIAM Conference on Applications of Dynamical Systems (DS13)**, Snowbird Ski and Summer Resort, Snowbird, Utah. (Oct. 2011, p. 1326)

* 19–24 **FEMTEC 2013 - 4th International Congress on Computational Engineering and Sciences**, Stratosphere Hotel, Las Vegas, Nevada.
Description: FEMTEC 2013 is the 4th event in a successful series of interdisciplineary international conferences. It promotes modern technologies and practices in scientific computing and visualization, and strengthens the interaction between researchers and practitioners in all areas of computational engineering and sciences. Main thematic areas include: Multiphysics coupled problems, Higher-order computational methods, computing with Python, GPU computing, and cloud computing. Application areas: Theoretical results as well as applications are welcome. Application areas include, but are not limited to: Computational electromagnetics, civil engineering, nuclear engineering, mechanical engineering, nonlinear dynamics, fluid dynamics, climate and weather modeling, computational ecology, wave propagation, acoustics, geophysics, geomechanics and rock mechanics, hydrology, subsurface modeling, biomechanics, bioinformatics, computational chemistry, stochastic des and others.
Information: http://femtec2013.femhub.com/.

19–25 **15th International Conference on Functional Equations and Inequalities**, Ustron (near the borders with the Czech Republic and Slovakia), Poland. (Sept. 2012, p. 1172)

19–27 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program - Summer School on Mathematics of Infectious Disease**, York University, Toronto, Canada. (Sept. 2012, p. 1172)

25–27 **10th Hstam International Congress on Mechanics**, Technical University of Crete, Chania, Crete, Greece. (Sept. 2012, p. 1172)

26–30 **The 19th International Conference on Difference Equations and Applications**, Sultan Qaboos University, Muscat, Oman. (Sept. 2012, p. 1172)

27–31 **Summer School on Topics in Space-Time Modeling and Inference**, Aalborg University, Department of Mathematical Sciences, Aalborg, Denmark. (Nov. 2012, p. 1481)

* 27–June 7 **Masterclass: (u,v,w knots)x(topology, combinatorics, low and high algebra) by Dror Bar-Natan (University of Toronto)**, QGM, Aarhus Univrsity, Aarhus, Denmark.
Description: When appropriately read using the language of "finite type invariants", "Jacobi diagrams", and "expansions", the combinatorics underlying various knot theories turns out to be the same as the combinatorics underlying various classes of Lie algebras, thus establishing a bijection between certain hard problems in knot theory and certain hard problems in Lie theory, enriching both subjects.
Information: http://qgm.au.dk/currently/events/show/artikel/masterclass-uvw-knotsxtopology-combinatorics-low-and-high-algebra/.

* 30–June 1 **Dynamical systems and statistical physics (91th Encounter between Mathematicians and Theoretical Physicists)**, Institut de Recherche Mathématique Avancée, Strasbourg, France.
Description: The 91th Encounter between Mathematicians and Theoretical Physicists will take place at Institut de Recherche Mathématique Avancée (University of Strasbourg and CNRS) on May 30–June 1st, 2013. The theme will be: "Dynamical systems and statistical physics".
Invited speakers: Viviane Baladi (Copenhagen), Jean-René Chazottes (Ecole Polytechnique), Bertrand Eynard (CEA), Vladimir Fock (Strasbourg), Giovanni Gallavotti (Rome), François Ledrappier (Paris), Rémi Monasson (ENS Paris), Samuel Petite (Amiens), Hans Rugh (Orsay), Klaus Schmidt (Vienna) and Maher Younan (Genève). Some of the talks will be survey talks intended for a general audience. Ph.D. students welcome.
Registration: Is required (and free of charge) at this link. Hotel booking can be asked for through the registration link. For practical and other questions please contact the organizers: Charles Boubel: charles.boubel@unistra.fr and Athanase Papadopoulos: papadop@math.unistra.fr.
Information and Registration: http://www-irma.u-strasbg.fr/article1321.html.

June 2013

3–7 **MEGA 2013: Effective Methods in Algebraic Geometry**, Goethe University, Frankfurt am Main, Germany. (Sept. 2012, p. 1172)

* 3–9 **Summer school on Finsler geometry with applications to low-dimensional geometry and topology**, Department of Mathematics, University of the Aegean, Karlovassi, Island of Samos, Greece.
Description: The focus of this Summer School will be on the following thematic areas: Finsler geometry, dynamics, hyperbolic geometry, projective geometry, systolic geometry, Teichmüller theory. There will be a series of short courses given by Norbert A'Campo (University of Basel), Ivan Babenko (University of Montpellier), Gilles Courtois (Ecole Polytechnique), Bertrand Deroin (University of Paris XI) and Marc Troyanov (EPFL, Lausanne). The Summer School is primarily intended for Ph.D. students but all researchers are also welcome. Besides the courses, there will be a series of specialized lectures.
Organizing committee: Athanase Papadopoulos (University of Strasbourg), Georgios Tsapogas (University of the Aegean), Muhammed Uluda (Galatasaray university, Istanbul) and Constantin Vernicos (University of Montpellier). For questions and practical details contact the organisers.
Information: http://myria.math.aegean.gr/conferences/finsler13/index.html.

3–July 12 **Nonlinear expectations, stochastic calculus under Knightian uncertainty, and related topics**, Institute for Mathematical Sciences, National University of Singapore, Singapore. (Oct. 2012, p. 1303)

3–28 **Focus Program on Noncommutative Geometry and Quantum Groups**, Fields Institute for Research in Mathematical Sciences, Toronto, Ontario, Canada. (Sept. 2012, p. 1172)

4–14 **Conference on Nonlinear Mathematical Physics: Twenty Years of JNMP**, The Sophus Lie Conference Center, Nordfjordeid, Norway. (Sept. 2012, p. 1173)

5–9 **4th Novi Sad Algebraic Conference–NSAC 2013**, Department of Mathematics and Informatics, Faculty of Science, University of Novi Sad, Novi Sad, Serbia. (Sept. 2012, p. 1173)

10–14 **AIM Workshop: Automorphic forms and harmonic analysis on covering groups**, American Institute of Mathematics, Palo Alto, California. (Nov. 2012, p. 1481)

10–14 **ApplMath13, 8th Conference on Applied Mathematics and Scientific Computing**, Sibenik, Croatia. (Sept. 2012, p. 1173)

10–14 **Computational Methods and Function Theory 2013**, Shantou University, Shantou, Guangdong, China. (Sept. 2012, p. 1173)

* 10–14 **Pde's, Dispersion, Scattering theory and Control theory**, University of Monastir, Monastir, Tunisia.
Organizers: Kais Ammari, Université de Monastir, Tunisia; email: kais.ammari@fsm.rnu.tn, Gilles Lebeau, Université Nice, Sophia Antipolis, France; email: Gilles.Lebeau@unice.fr.
Topics: Control theory, scattering theory, dispersion theory, Pde's theory.
Courses: Control theory, E. Zuazua; Dispersion, L. Robbiano.
Invited speakers: Z. Ammari, N. Burq, M. Dimassi, C. Guillarmou, L. Ignat, O. Ivanovici, L. Matthieu, F. Méhat, L. Michel, L. Miller, M. Paicu, V. Petkov, F. Planchon, P. Raphaël, L. Rosier, E. Trélat.

* 10–20 **Recent Advances in Hodge Theory: Period Domains, Algebraic Cycles, and Arithmetic**, UBC Campus, Vancouver, B.C., Canada.
Description: A four-day summer school for graduate students and postdocs, followed by a six-day research conference on the asymptotics, symmetries, and arithmetic of periods, as well as related representation theory and geometry. Each day will concentrate on a specific topic: Algebraic cycles and the Hodge conjecture, Arithmetic aspects of cycles and period maps, Period domains and their compactifications, Mumford-Tate groups and representation theory, Automorphic forms and automorphic cohomology (6) Relative completion of the fundamental group.
Confirmed speakers: S. Bloch, P. Brosnan, H. Carayol, W. Goldring, P. Griffiths, M. Green, B. Klingler, S. Kudla, R. Laza, B. Moonen, S. Mueller-Stach, M. Nori, C. Robles, C. Schnell, T. Terasoma, S. Usui, C. Voisin, V. Vologodsky, and H. Yoshida. The summer school will include lectures by the organizers and other participants.
Information: http://www.pims.math.ca/scientific-event/130610-rahtpdaca.

* 11–13 **4th International Conference on Mathematical and Computational Applications**, Celal Bayar University, Applied Mathematics and Computation Center, Manisa, Turkey.
Description: The first of these conference series was organized in Manisa (Turkey) in 1996, the second in Baku (Azerbaijan) in 1999, and the third in Konya (Turkey) in 2002. This international conference is devoted to original research in the field of engineering, natural sciences or social sciences where mathematical and/or computational techniques are necessary for solving specific problems. The aim of the conference is to provide a medium by which a wide range of experience can be exchanged among researchers from diverse fields such as engineering (electrical, mechanical, civil, industrial, aeronautical, nuclear, etc.), natural sciences (physics, mathematics, chemistry, biology, etc.) or social sciences (administrative sciences, economics, political sciences, etc.). The papers may be theoretical where mathematics is used in a nontrivial way or computational

or combination of both. Papers containing only experimental techniques and abstract mathematics without any sign of application are discouraged.
Information: http://icmca2013.cbu.edu.tr/.

* 12–14 **Tenth edition of the Advanced Course in Operator Theory and Complex Analysis**, Sevilla, Spain.
Invited speakers: Filippo Bracci, Université "Tor Vergata" (Italy); James Brennan, University of Kentucky (Kentucky); Alexander Olevskii, Tel Aviv University (Israel); Tatiana Smirnova-Nagnibeda, Université de Genève (Switzerland). Apart of attending the course, you may also have the opportunity to deliver a contributed talk. Please feel free to pass on this information to any colleague who might be interested in our conference.
Information: You can find further information about the courses at http://congreso.us.es/ceacyto/2013.

* 16–23 **51st International Symposium on Functional Equations**, Rzeszów, Poland.
Topics: Functional equations and inequalities, mean values, functional equations on algebraic structures, Hyers-Ulam stability, regularity properties of solutions, conditional functional equations, functional-differential equations, iteration theory; applications of the above, in particular to the natural, social, and behavioral sciences.
Local Organizer: Józef Tabor, Institute of Mathematics, University of Rzeszów al. Rejtana 16 A, PL-35-959 Rzeszów, Poland; email: tabor@univ.rzeszow.pl.
Scientific committee: J. Aczél (Honorary Chair; Waterloo, ON, Canada), W. Benz (Honorary Member, Hamburg, Germany), Z. Daróczy (Honorary Member, Debrecen, Hungary), L. Reich (Honorary Member, Graz, Austria), R. Ger (Chair; Kotowice, Poland), Zs. Páles (Debrecen, Hungary), J. Rätz (Bern, Switzerland), J. Schwaiger (Graz, Austria), and A. Sklar (Chicago, IL, USA).
Information: Participation at these annual meetings is by invitation only. Those wishing to be invited to this or one of the following meetings should send details of their interest and, preferably, publications (paper copies) and/or manuscripts with their postal and e-mail address to: Roman Ger, Institute of Mathematics, Silesian University, Bankowa 14, PL-40-007 Katowice, Poland, email: romanger@us.edu.pl before February 15, 2013.

17–21 **AIM Workshop: Exponential random network models**, American Institute of Mathematics, Palo Alto, California. (Sept. 2012, p. 1173)

17–28 **Algebraic Topology**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2012, p. 1481)

21–24 **"Experimental and Theoretical Methods in Algebra, Geometry and Topology". Held in the honor of Alexandru Dimca and Stefan Papadima on the occasion of their 60th birthday**, Mangalia (near Constanta), Romania. (Sept. 2012, p. 1173)

22–29 **Physics and Mathematics of Nonlinear Phenomena 2013**, Hotel Le Sirene, Gallipoli, South of Italy. (Oct. 2012, p. 1303)

* 24–July 5 **Seminaire de Mathematiques Superieures 2013: Physics and Mathematics of Link Homology**, Montreal, Canada.
Description: Homology theories of knots and links is a burgeoning field at the interface of mathematics with theoretical physics. The 2013 edition of the SMS will bring together leading researchers in mathematics and mathematical physics working in this area, with the aim to educate a new generation of scientists in this exciting subject. The school will provide a pedagogical review of the current state of the various constructions of knot homologies, and also encourage interactions between the communities in order to facilitate development of the unified picture.
Information: http://www.msri.org/web/msri/scientific/workshops/summer-graduate-workshops/show/-/event/Wm9461.

26–29 **International Symposium on Symbolic and Algebraic Computation (ISSAC)**, Northeastern University, Boston, Massachussetts. (Nov. 2012, p. 1481)

27 **5th National Dyscalculia and Maths Learning Difficulties Conference, UK**, Cumberland Hotel, London, England. (Nov. 2012, p. 1481)

28–30 **First International Conference on Smarandache Multispace and Multistructure**, Academy of Mathematics and Systems, Chinese Academy of Sciences, Beijing 100190, People's Republic of China. (Sept. 2012, p. 1173)

30–July 20 **IAS/PCMI Summer 2013: Geometric Analysis**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2012, p. 1481)

July 2013

1–4 **2nd IMA Conference on Dense Granular Flows**, Isaac Newton Institute of Mathematical Sciences, Cambridge, United Kingdom. (Oct. 2012, p. 1303)

1–5 **Erdös Centennial**, Budapest, Hungary. (Sept. 2012, p. 1173)

1–5 **International conference on Sampling Theory and Applications 2013**, Jacobs University, Bremen, Germany. (Sept. 2012, p. 1173)

1–5 **The 6th Pacific RIM Conference on Mathematics 2013**, Sapporo Convention Center, Sapporo City, Japan. (Nov. 2012, p. 1481)

1–5 **Preconditioning of Iterative Methods—Theory and Applications 2013 (PIM 2013)**, Faculty of Civil Engineering, Czech Technical University in Prague, Czech Republic. (Oct. 2012, p. 1303)

1–12 **New Geometric Techniques in Number Theory**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2012, p. 1481)

2–5 **The 4th International Conference on Matrix Analysis and Applications**, Konya, Turkey. (Nov. 2012, p. 1481)

3–5 **The 2013 International Conference of Applied and Engineering Mathematics**, Imperial College London, London, United Kingdom. (Nov. 2012, p. 1482)

8–10 **SIAM Conference on Control and Its Applications (CT13)**, Town and Country Resort and Convention Center, San Diego, California. (Sept. 2012, p. 1174)

8–12 **AIM Workshop: Generalizations of chip-firing and the critical group**, American Institute of Mathematics, Palo Alto, California. (Sept. 2012, p. 1174)

8–12 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program - Climate Change and the Ecology of Vector-borne Diseases**, Fields Institute, CDM, Toronto, Canada. (Sept. 2012, p. 1174)

* 15–19 **Finite Dimensional Integrable Systems 2013**, CIRM, Marseille, France.
Description: Non-linear ordinary and partial differential equations describe a large number of physical phenomena and geometrical problems. An effective method to handle them is associated to `integrable systems' providing means to find exact solutions or to analyse the solutions without knowing them. Our conference will deal with finite-dimensional integrable systems, the most classical part of the general theory. Recently, new methods have been developed, based on branches of mathematics (and physics) such as complex analysis, symplectic geometry, representation theory, computer algebra, general relativity, etc. The conference will bring together experts in mathematics and mathematical physics in this rapidly evolving field: integrable geodesic flows, integrable systems on Lie algebras, obstructions to integrability, symplectic and Poisson geometry, separation of variables, discrete integrable systems, quantum integrability, applications to physics.
Information: http://www.cpt.univ-mrs.fr/fdis13/.

* 15–20 **Stochasticity in Biology: Is Nature Inherently Random?**, Montreal, Canada.
Description: Although alarming news is accumulating by the day on the impact of human activities on biodiversity, ecosystems and climate change, the response by the international community has not yet been up to the faced challenges. The pursuit of self-interest has often been pointed out as a major obstacle to reach the much-needed global or regional agreements to tackle these problems. Another difficulty in dealing with these issues is that they are of the long-term variety and involve a high degree of uncertainty.
Information: http://www.crm.umontreal.ca/act/theme/theme_2013_2_en/biodiversity_environment13_e.php.

20–25 **European Meeting of Statisticians**, Eotvos Lorand University, Budapest, Hungary. (Sept. 2012, p. 1174)

22–25 **MIP2013: Mixed Integer Programming Workshop**, University of Wisconsin-Madison, Madison, Wisconsin. (Sept. 2012, p. 1174)

22–26 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program - Biodiversity in a Changing World**, CRM, Cambam, Montréal, Canada. (Sept. 2012, p. 1174)

* 22–26 **Positivity VII**, Leiden University, Leiden, The Netherlands.
Description: The seventh Positivity conference on ordered structures and their applications is jointly organized by Leiden University and Delft University of Technology. It is the Zaanen Centennial Conference, on the occasion of the 100th birthyear of Adriaan Cornelis Zaanen.
Invited speakers, all confirmed: Francesco Altomare (Bari, Italy), Wolfgang Arendt (Ulm, Germany), Qingying Bu (University, Mississippi, USA), Karim Boulabiar (Tunis, Tunisia), Guillermo Curbera (Sevilla, Spain), Julio Flores (Madrid, Spain), Yehoram Gordon (Haifa, Israel), Rien Kaashoek (Amsterdam, The Netherlands), Coenraad Labuschagne (Johannesburg, South Africa), Boris Mordukhovich (Detroit, Michigan, USA), Jan van Neerven (Delft, The Netherlands), Ioannis Polyrakis (Athens, Greece), Abdelaziz Rhandi (Salerno, Italy), Evgeny Semenov (Voronezh, Russia), Fedor Sukochev (Sydney, Australia), Jun Tomiyama (Tokyo, Japan).
Information: http://websites.math.leidenuniv.nl/positivity2013/.

29–August 2 **36th Conference on Stochastic Processes and their Applications**, Boulder, Colorado. (Sept. 2012, p. 1174)

29–August 9 **Introduction to the Mathematics of Seismic Imaging**, Mathematical Sciences Research Institute, Berkeley, California. (Nov. 2012, p. 1482)

August 2013

3–11 **Groups St. Andrews 2013**, University of St. Andrews, St. Andrews, Fife, Scotland, UK. (Sept. 2012, p. 1174)

5–9 **1st Mathematical Congress of the Americas**, Guanajuato, Mexico. (Sept. 2012, p. 1174)

5–9 **XXII Rolf Nevanlinna Colloquium**, Helsinki, Finland. (Aug. 2011, p. 1014)

* 11–17 **3rd Mile High Conference on Nonassociative Mathematics**, University of Denver, Denver, Colorado.
Description: An international conference on all aspects of nonassociative mathematics, including quasigroups, loops, latin squares, Lie algebras, Jordan algebras, octonions and nonassociative structures in physics.
Main speakers (tentative): Alberto Elduque, University of Zaragoza, Spain; Pavel Kolesnikov, Sobolev Institute of Mathematics, Russia; Peter Plaumann, University of Erlangen-Nuremberg, Germany; Susanne Pumpluen, University of Nottingham, UK; Jonathan Smith, Iowa State University, USA.
Program and organizing committee: Murray Bremner, University of Saskatchewan, Canada; John Huerta, Australian National University, Australia; Michael Kinyon (co-chair), University of Denver, USA; Eric Moorhouse, University of Wyoming, USA; Petr Vojtechovsky (co-chair), University of Denver, USA.
Information: http://www.math.du.edu/milehigh.

12–15 **International Conference on Algebra in Honour of Patrick Smith and John Clark's 70th Birthdays**, Balikesir, Turkey. (Nov. 2012, p. 1482)

* 12–16 **AIM Workshop: Computable stability theory**, American Institute of Mathematics, Palo Alto, California.
Description: This workshop, sponsored by AIM and the NSF, will be devoted to the interplay between stability theory and computable model theory.
Information: http://www.aimath.org/ARCC/workshops/computestab.html.

* 12–16 **Branching Diffusions and Random Trees**, Montreal, Canada.
Description: One of the most compelling images to result from Darwin's theory of evolution is that of the tree of life. Inherent in this picture is the idea that when members of a species are geographically separated, over time they may evolve to a point where it makes sense to view them as different species. These are the branch points in the tree of life. Probability theory has developed powerful stochastic spatial models that can be used to understand and model the behavior of such migrating and evolving populations. In particular, the theories of branching random walk and branching diffusions are fundamental in population biology and genetics.
Information: www.crm.umontreal.ca/act/theme theme_2013_2_en/branching_diffusions13_e.php.

* 19–September 13 **Infectious Disease Dynamics**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom.
Description: On January 1, 2013, it will be 20 years since Epidemic Models started as a 6-month programme in the first year of the Isaac Newton Institute for Mathematical Sciences. Since then the field has grown enormously. The complexity and non-linearity of infection dynamics, as well as effects of prevention and control, are such that mathematical and statistical analysis is essential for insight and prediction, now more than ever before. Much research is no longer devoted to generic insights into dynamics, but rather to very precise insights into focussed questions regarding specific infectious diseases. The four-week programme will: take stock of progress in the last twenty years, to assess where we are today and provide a synthesis, take a systematic look at the use of models to inform public health decisions, and to analyse where and why models fail in their predictions, set the agenda for future research and in particular determine the main challenges.
Information: http://www.newton.ac.uk/programmes/IDD/.

19–December 20 **Mathematical General Relativity**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1174)

19–December 20 **Optimal Transport: Geometry and Dynamics**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1175)

22–23 **Connections for Women on Optimal Transport: Geometry and Dynamics**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1175)

26–30 **International Conference AMMCS-2013 (Applied Mathematics, Modeling and Computational Science)**, Waterloo, Ontario, Canada. (Sept. 2012, p. 1175)

26–30 **Introductory Workshop on Optimal Transport: Geometry and Dynamics**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1175)

* 27–December 20 **Mathematical Challenges in Quantum Information**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom.
Description: Quantum information is currently one of the most dynamic and exciting areas of science and technology. Its breadth of significance ranges from deep fundamental issues of the ultimate physical limits of information processing and foundations of quantum mechanics, to the technological exploitation of quantum physics for exponentially enhanced computing power and novel possibilities for communication and information security. A notable aspect of many of the most important recent developments is the importance of increasingly sophisticated techniques from mathematics and theoretical computer science. Among the challenges addressed will be: additivity violations of capacities and minimal output entropies; weak additivity. for certain quantities? Existence of bound entanglement with non-positive partial transpose?. Is there a quantum version of the PCP theorem? A number of workshops will take place during the programme. For full details see: http://www.newton.ac.uk/programmes/MQI/ws.html.
Information: http://www.newton.ac.uk/programmes/MQI/.

September 2013

1–August 31, 2014 **Call for Research Programmes 2013-2014**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain. (Sept. 2012, p. 1175)

* 1–December 20 **Research Program on Automorphisms of Free Groups: Algorithms, Geometry and Dynamics**, Centre de Recerca Matemàtica, Bellaterra, Barcelona, Spain.
Description: The study of automorphisms of free groups is a classical subject, with more than 100 years of history. The last 25 years have witnessed the development of many interesting new tools, resulting in the subject's diversification into algorithmic, geometric and dynamical aspects. While these aspects continue to be heavily intertwined, they have meanwhile taken root in several other areas of mathematics. The purpose of the proposed program is to assemble experts from these three aspects, with the object of finding innovative approaches to the main open questions from each.
Information: http://www.crm.cat/2012/RPAutomorphisms.

3–4 **Connections for Women: Mathematical General Relativity**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1175)

* 3–6 **CAI 2013: 5th Conference on Algebraic Informatics**, ERISCS and IML, Aix-Marseille University, IGESA, Porquerolles Island, France.
Description: CAI 2011 continues the tradition established by the previous sessions: to bring together researchers from theoretical computer science and algebra. This should enhance the understanding of syntactic and semantic problems by algebraic models; and it should also propagate the application of modern techniques from informatics in algebraic computation. Authors are invited to submit papers (in PDF format) presenting original research work, electronically to cai2013@acrypta.fr. All submissions should be formatted according to the usual LNCS article style and should not exceed 12 pages. The Proceedings of CAI 2013 will be published in the Lecture Notes in Computer Science Series (LNCS) by Springer.
Important dates: Submission Due: March 1, 2013. Notification: April 25, 2013. Proceedings Version Due: May 14, 2013.
Information: http://iml.univ-mrs.fr/ati/conferences/CAI2013/.

9–13 **Introductory Workshop: Mathematical General Relativity**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1175)

9–December 6 **ICERM Semester Program on "Low-Dimensional Topology, Geometry, and Dynamics"**, Institute for Computational and Experimental Research in Mathematics (ICERM), Providence, Rhode Island. (Sept. 2012, p. 1176)

11–13 **14th IMA Conference on Mathematics of Surfaces**, University of Birmingham, United Kingdom. (Sept. 2012, p. 1176)

* 16–20 **Mathematics for an Evolving Biodiversity**, Montreal, Canada.
Description: This workshop will provide an overview of recent theoretical and methodological developments for modeling the complex evolutionary dynamics that have shaped the structure of contemporary biodiversity. Theoretical work at the interface between ecology and evolutionary studies will be presented, as well as its applications to empirical data.
Information: http://www.crm.umontreal.ca/act/theme/theme_2013_2_en/mathematics_evolving_biodiversity13_e.php

* 16–20 **MatTriad'2013 - Conference on Matrix Aanalysis and its Applications**, Herceg-Novi, Montenegro.
Description: The aim is to bring together researchers sharing an interest in a variety of aspects of matrix analysis and its applications in other fields of mathematics and offer them a possibility to discuss current developments in these subjects.
Information: http://mattriad2013.pmf.uns.ac.rs.

* 16–October 11 **Mathematics and Physics of the Holographic Principle**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom.
Description: Holographic duality relates a string theory to a quantum field theory without gravity. Currently it is an area of research located at the confluence of previously seemingly distant fields in physics and mathematics including superconductivity and other exotic phases of strongly coupled quantum matter, string theory, numerical general relativity and the theory of non-linear partial differential equations. The main aim of the programme is to tackle questions which the traditional methods within each discipline have proved inadequate to address, with special emphasis on strongly correlated condensed matter systems and non-equilibrium dynamics. Preliminary progress includes the application of the duality to concrete experimental questions about the quark-gluon plasma and the emergence of various fascinating condensed matter phenomena from the physics of AdS black holes. A number of workshops will take place during the programme. For full details see: http://www.newton.ac.uk/programmes/HOL/ws.html.
Information: http://www.newton.ac.uk/programmes/HOL/.

* 23–27 **Mathematics of Sequence Evolution: Biological Models and Applications**, Montreal, Canada.
Description: Models of evolution of biological sequences have gone a long way since Jukes and Cantor. First, it is no longer acceptable to consider that mutations of a given type occur independently and uniformly across time and space. A large number of factors affect the rate at which mutations occur. Second, selective pressure makes that the probability of fixation of a mutation depends on the fitness of the mutated individual, which sometimes places unexpected constraints on the mutational process and induces strong dependencies between positions along the sequences.
Information: http://www.crm.umontreal.ca/act/theme/theme_2013_2_en/mathematics_sequence_evolution13_e.php.

28–29 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program - Mathematical Modeling of Indigenous Population Health**, BIRS, Banff, Canada. (Sept. 2012, p. 1176)

October 2013

5–6 **2013 Fall Southeastern Section Meeting**, University of Louisville, Louisville, Kentucky. (Sept. 2012, p. 1176)

* 7–11 **Coalescent Theory: New Developments and Applications**, Montreal, Canada.
Description: Coalescent theory is one of the most elegant and powerful probabilistic approaches in mathematical population genetics.

It formalizes the backward perspective on evolution in large finite populations by considering a population evolving forward in time under the effects of various factors, conditional on genetic data observed in the current generation, providing a link between evolutionary models and empirical data.
Information: http://www.crm.umontreal.ca/act/theme/theme_2013_2_en/coalescent_theory13_e.php.

12–13 **2013 Eastern Sectional Meeting**, Temple University, Philadelphia, Pennsylvania. (Sept. 2012, p. 1176)

14–18 **Fluid Mechanics, Hamiltonian Dynamics, and Numerical Aspects of Optimal Transportation**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1176)

18–20 **2013 Fall Central Section Meeting**, Washington University, St. Louis, Missouri. (Sept. 2012, p. 1176)

21–25 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program - Sustainability of Aquatic Ecosystem Networks**, AARMS, Fredericton, New Brunswick, Canada. (Sept. 2012, p. 1176)

* 21–December 20 **Mathematics for the Fluid Earth**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom.
Description: The fluid Earth is an excellent example of a forced, dissipative non-equilibrium system dominated by nonlinear processes and featuring multi-scale interactions, so that its understanding can be approached using the tools of dynamical systems theory and non-equilibrium statistical mechanics. The purpose of this programme is to bring together scientists from very different perspectives in models of the dynamics of the fluid components of the Earth system.
Aim: This programme aims to prove that there is a close connection between "core" questions and problems of pure and applied mathematics and "core" questions of geophysical fluid dynamics relevant for the investigation of the climate system and of its component.'
Themes: The programme features three main macro-themes of interest: a) Dynamical Systems and Statistical Mechanics; b) Extreme Events; c) Partial Differential Equations. Each theme has a huge potential for future breakthroughs at the boundary between mathematics and natural science.
Information: http://www.newton.ac.uk/programmes/MFE/.

November 2013

2–3 **2013 Western Fall Section Meeting**, University of California Riverside, Riverside, California. (Sept. 2012, p. 1176)

* 4–8 **Biodiversity and Environment: Viability and Dynamic Games Perspectives**, Montreal, Canada.
Description: Although alarming news is accumulating by the day on the impact of human activities on biodiversity, ecosystems and climate change, the response by the international community has not yet been up to the faced challenges. The pursuit of self-interest has often been pointed out as a major obstacle to reach the much-needed global or regional agreements to tackle these problems. Another difficulty in dealing with these issues is that they are of the long-term variety and involve a high degree of uncertainty.
Information: http://www.crm.umontreal.ca/act/theme/theme_2013_2_en/biodiversity_environment13_e.php

10–15 **Mathematics of Planet Earth 2013 - Pan-Canadian Thematic Program - Current Challenges for Mathematical Modelling of Cyclic Populations**, BIRS, Banff, Canada. (Sept. 2012, p. 1176)

* 12–14 **The Second International Conference on Informatics Engineering & Information Science (ICIEIS2013)**, University Technology Malaysia (UTM), Kuala Lumpur, Malaysia.
Description: Researchers are encouraged to submit their work electronically. All papers will be fully refereed by a minimum of two specialized referees. Before final acceptance, all referees comments must be considered.
Important dates: Submission Deadline: August 1, 2013. Notification of Acceptance: August 20, 2013. Camera Ready Submission: August 30, 2013. Registration: September 2, 2013.
Information: http://sdiwc.net/conferences/2013/icieis2013/.

18–22 **Evolution Problems in General Relativity**, Mathematical Sciences Research Institute, Berkeley, California. (Sept. 2012, p. 1176)

26–28 **International Conference on Pure and Applied Mathematics, ICPAM-LAE 2013**, Png University of Technology, Lae, Morobe Province, Papua New Guinea. (Sept. 2012, p. 1176)

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.

January 2014

* 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.
Information: Further information on SODA14, ALENEX14 and ANALCO14 will be posted at http://www.siam.org/meetings/da14/ in April, 2013.

* 6–July 4 **Free Boundary Problems and Related Topics**, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom.
Description: Free boundary problems are today considered as one of the most important directions in the mainstream of the analysis of partial differential equations (PDEs), with an abundance of applications in various sciences and real world problems. In the last two decades, various new ideas, techniques, and methods have been developed, and new important, challenging problems in physics, engineering, industry, finance, biology, and other areas have arisen. The topics of this programme are directed towards theory, numerics and applications. The study of free boundary problems is an extremely broad topic due to the abundance of applications. This breadth presents challenges and opportunities! Many problems treated by applied scientists and numerical analysts are not well known amongst theoretical people, and vice versa. The aim of this programme is to enhance links and unifying techniques by bringing together the relevant specialists.
Information: http://www.newton.ac.uk/programmes/FRB/.

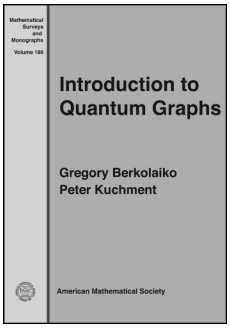
March 2014

* 31–April 3 **SIAM Conference on Uncertainty Quantification (UQ14)**, Hyatt Regency Savannah, Savannah, Georgia.
Description: The call for submissions will be available at: http://www.siam.org/meetings/uq14/ in early April, 2013.
Information: http://www.siam.org/meetings/uq14/.

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



Introduction to Quantum Graphs

Gregory Berkolaiko and **Peter Kuchment**, *Texas A&M University, College Station, TX*

A "quantum graph" is a graph considered as a one-dimensional complex and equipped with a differential operator ("Hamiltonian"). Quantum graphs arise naturally as simplified models in mathematics, physics, chemistry, and engineering when one considers propagation of waves of various nature through a quasi-one-dimensional (e.g., "meso-" or "nano-scale") system that looks like a thin neighborhood of a graph. Works that currently would be classified as discussing quantum graphs have been appearing since at least the 1930s, and since then, quantum graphs techniques have been applied successfully in various areas of mathematical physics, mathematics in general and its applications. One can mention, for instance, dynamical systems theory, control theory, quantum chaos, Anderson localization, microelectronics, photonic crystals, physical chemistry, nano-sciences, superconductivity theory, etc.

Quantum graphs present many non-trivial mathematical challenges, which makes them dear to a mathematician's heart. Work on quantum graphs has brought together tools and intuition coming from graph theory, combinatorics, mathematical physics, PDEs, and spectral theory.

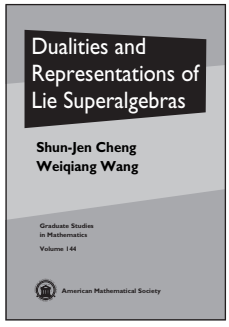
This book provides a comprehensive introduction to the topic, collecting the main notions and techniques. It also contains a survey of the current state of the quantum graph research and applications.

This item will also be of interest to those working in discrete mathematics and combinatorics and applications.

Contents: Operators on graphs. Quantum graphs; Quantum graphs–Some special topics; Spectra of quantum graphs; Spectra of periodic graphs; Spectra of quantum graphs–Special topics; Quantum chaos on graphs; Some applications and generalizations; Appendix A. Some notions of graph theory; Appendix B. Linear operators and operator-functions; Appendix C. Structure of spectra; Appendix D. Symplectic geometry and extension theory; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 186

December 2012, approximately 275 pages, Hardcover, ISBN: 978-0-8218-9211-4, 2010 *Mathematics Subject Classification:* 34B45, 35R02, 81Q35, 35Pxx, 58J50, 05C50, 82D77, 81Q50, 47N60, 82D80, 82D55, **AMS members US$68.80**, List US$86, Order code SURV/186



Dualities and Representations of Lie Superalgebras

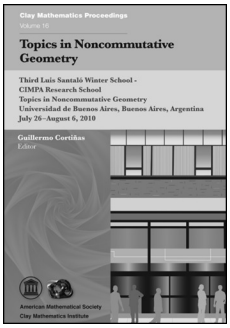
Shun-Jen Cheng, *Academia Sinica, Taipei, Taiwan*, and **Weiqiang Wang**, *University of Virginia, Charlottesville, VA*

This book gives a systematic account of the structure and representation theory of finite-dimensional complex Lie superalgebras of classical type and serves as a good introduction to representation theory of Lie superalgebras. Several folklore results are rigorously proved (and occasionally corrected in detail), sometimes with new proofs. Three important dualities are presented in the book, with the unifying theme of determining irreducible characters of Lie superalgebras. In order of increasing sophistication, they are Schur duality, Howe duality, and super duality. The combinatorics of symmetric functions is developed as needed in connections to Harish-Chandra homomorphism as well as irreducible characters for Lie superalgebras. Schur-Sergeev duality for the queer Lie superalgebra is presented from scratch with complete detail. Howe duality for Lie superalgebras is presented in book form for the first time. Super duality is a new approach developed in the past few years toward understanding the Bernstein-Gelfand-Gelfand category of modules for classical Lie superalgebras. Super duality relates the representation theory of classical Lie superalgebras directly to the representation theory of classical Lie algebras and thus gives a solution to the irreducible character problem of Lie superalgebras via the Kazhdan-Lusztig polynomials of classical Lie algebras.

Contents: Lie superalgebra ABC; Finite-dimensional modules; Schur duality; Classical invariant theory; Howe duality; Super duality; Symmetric functions; Bibliography; Index.

Graduate Studies in Mathematics, Volume 144

January 2013, 297 pages, Hardcover, ISBN: 978-0-8218-9118-6, LC 2012031989, 2010 *Mathematics Subject Classification:* 17B10, 17B20, **AMS members US$51.20**, List US$64, Order code GSM/144



Topics in Noncommutative Geometry

Guillermo Cortiñas, *Universidad de Buenos Aires, Argentina*, Editor

Luis Santaló Winter Schools are organized yearly by the Mathematics Department and the Santaló Mathematical Research Institute of the School of Exact and Natural Sciences of the University of Buenos Aires (FCEN). This volume contains the proceedings of the third Luis Santaló Winter School, which was devoted to noncommutative geometry and held at FCEN July 26–August 6, 2010.

Topics in this volume concern noncommutative geometry in a broad sense, encompassing various mathematical and physical theories that incorporate geometric ideas to the study of noncommutative phenomena. It explores connections with several areas including algebra, analysis, geometry, topology and mathematical physics.

Bursztyn and Waldmann discuss the classification of star products of Poisson structures up to Morita equivalence. Tsygan explains the connections between Kontsevich's formality theorem, noncommutative calculus, operads and index theory. Hoefel presents a concrete elementary construction in operad theory. Meyer introduces the subject of C*-algebraic crossed products. Rosenberg introduces Kasparov's KK-theory and noncommutative tori and includes a discussion of the Baum-Connes conjecture for K-theory of crossed products, among other topics. Lafont, Ortiz, and Sánchez-García carry out a concrete computation in connection with the Baum-Connes conjecture. Zuk presents some remarkable groups produced by finite automata. Mesland discusses spectral triples and the Kasparov product in KK-theory. Trinchero explores the connections between Connes' noncommutative geometry and quantum field theory. Karoubi demonstrates a construction of twisted K-theory by means of twisted bundles. Tabuada surveys the theory of noncommutative motives.

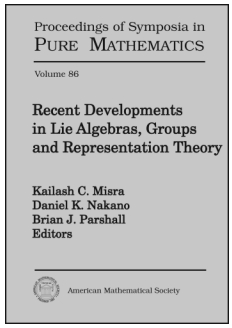
This item will also be of interest to those working in analysis, geometry and topology, and mathematical physics.

Titles in this series are co-published with the Clay Mathematics Institute (Cambridge, MA).

Contents: H. Bursztyn and **S. Waldmann**, Classifying Morita equivalent star products; **B. Tsygan**, Noncommutative calculus and operads; **E. Hoefel**, Some elementary operadic homotopy equivalences; **R. Meyer**, Actions of higher categories on C*-algebras; **J. Rosenberg**, Examples and applications of noncommutative geometry and K-theory; **J.-F. LaFont**, **I. J. Ortiz**, and **R. J. Sánchez-García**, Rational equivariant K-homology of low dimensional groups; **A. Zuk**, Automata groups; **B. Mesland**, Spectral triples and KK-theory: A survey; **R. Trinchero**, Deformations of the canonical spectral triples; **M. Karoubi**, Twisted bundles and twisted K-theory; **G. Tabuada**, A guided tour through the garden of noncommutative motives.

Clay Mathematics Proceedings, Volume 16

December 2012, 276 pages, Softcover, ISBN: 978-0-8218-6864-5, LC 2012031426, 2010 *Mathematics Subject Classification:* 14A22, 18D50, 19K35, 19L47, 19L50, 20F10, 46L55, 53D55, 58B34, 81R60, **AMS members US$63.20**, List US$79, Order code CMIP/16



Recent Developments in Lie Algebras, Groups and Representation Theory

Kailash C. Misra, *North Carolina State University, Raleigh, NC*, **Daniel K. Nakano**, *University of Georgia, Athens, GA*, and **Brian J. Parshall**, *University of Virginia, Charlottesville, VA*, Editors

This book contains the proceedings of the 2009–2011 Southeastern Lie Theory Workshop Series, held October 9–11, 2009 at North Carolina State University, May 22–24, 2010, at the University of Georgia, and June 1–4, 2011 at the University of Virginia.

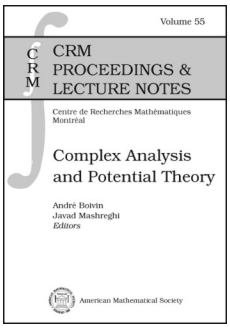
Some of the articles, written by experts in the field, survey recent developments while others include new results in Lie algebras, quantum groups, finite groups, and algebraic groups.

Contents: P. N. Achar, Perverse coherent sheaves on the nilpotent cone in good characteristic; **C. P. Bendel**, **D. K. Nakano**, and **C. Pillen**, On the vanishing ranges for the cohomology of finite groups of Lie type II; **M. Bennett** and **V. Chari**, Tilting modules for the current algebra of a simple Lie algebra; **J. F. Carlson**, Endotrivial modules; **S.-J. Cheng**, **N. Lam**, and **W. Wang**, Super duality for general linear Lie superalgebras and applications; **J. Du**, Structures and representations of affine q-Schur algebras; **A. Francis** and **L. Jones**, Multiplicative bases for the centres of the group algebra and Iwahori-Hecke algebra of the symmetric group; **R. L. Griess, Jr.**, Moonshine paths and a VOA existence proof of the Monster; **R. Guralnick** and **G. Malle**, Characteristic polynomials and fixed spaces of semisimple elements; **D.J. Hemmer**, "Frobenius twists" in the representation theory of the symmetric group; **J. Kujawa**, The generalized Kac-Wakimoto conjecture and support varieties for the Lie superalgebra $\mathfrak{osp}(m|2n)$; **S. Kumar**, An approach towards the Kollár-Peskine problem via the instanton moduli space; **G. Lusztig**, On the representations of disconnected reductive groups over F_q; **B. J. Parshall** and **L. L. Scott**, Forced gradings in integral quasi-hereditary algebras with applications to quantum groups; **B. J. Parshall** and **L. L. Scott**, A semisimple series for q-Weyl and q-Specht modules.

Proceedings of Symposia in Pure Mathematics, Volume 86

November 2012, 310 pages, Hardcover, ISBN: 978-0-8218-6917-8, LC 2012026116, 2010 *Mathematics Subject Classification:* 17B37, 17B55, 17B56, 17B65, 17B67, 20C08, 20C11, 20G05, 20G42, 20G43, **AMS members US$64**, List US$80, Order code PSPUM/86

Analysis



Complex Analysis and Potential Theory

André Boivin, *University of Western Ontario, London, ON, Canada*, and **Javad Mashreghi**, *Laval University, Québec, QC, Canada*, Editors

This is the proceedings volume of an international conference entitled *Complex Analysis and Potential Theory*, which was held to honor the important contributions of two influential analysts, Kohur N. GowriSankaran and Paul M. Gauthier, in June 2011 at the Centre de Recherches Mathématiques (CRM) in Montreal. More than fifty mathematicians from fifteen countries participated in the conference. The twenty-four surveys and research articles contained in this book are based on the lectures given by some of the most established specialists in the fields. They reflect the wide breadth of research interests of the two honorees: from potential theory on trees to approximation on Riemann surfaces, from universality to inner and outer functions and the disc algebra, from branching processes to harmonic extension and capacities, from harmonic mappings and the Harnack principle to integration formulae in $\mathbb{C}^n$ and the Hartogs phenomenon, from fine harmonicity and plurisubharmonic functions to the binomial identity and the Riemann hypothesis, and more. This volume will be a valuable resource for specialists, young researchers, and graduate students from both fields, complex analysis and potential theory. It will foster further cooperation and the exchange of ideas and techniques to find new research perspectives.

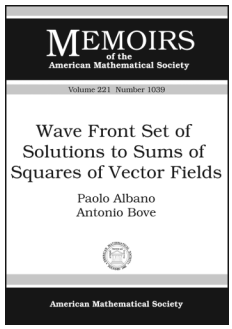
Titles in this series are co-published with the Centre de Recherches Mathématiques.

Contents: O. El-Fallah, **K. Kellay**, **J. Mashreghi**, and **T. Ransford**, A self-contained proof of the strong-type capacitary inequality for the Dirichlet space; **N. Tarkhanov**, A simple numerical approach to the Riemann hypothesis; **C. Bénéteau** and **D. Khavinson**, A survey of linear extremal problems in analytic function spaces; **L. Beznea**, **O. Lupaşcu**, and **A.-G. Oprina**, A unifying construction for measure-valued continuous and discrete branching processes; **V. Nestoridis**, Compactifications of the plane and extensions of the disc algebra; **T. Kalmes**, **M. Nieß**, and **T. Ransford**, Examples of quantitative universal approximation; **J. McDougall**, Harmonic mappings with quadrilateral image; **A. Boggess**, **R. J. Dwilewicz**, and **Z. Słodkowski**, Hartogs phenomenon on unbounded domains—Conjectures and examples; **L. M. Hernández-Pérez** and **E. S. Zeron**, Integration formulae and kernels in singular subvarieties of $\mathbb{C}^n$; **M. Stoll**, Invariant potential theory, derivatives of inner functions, and $B^{p,q}$ spaces in the unit ball of $\mathbb{C}^n$; **T. Itoh**, Logarithmic Hölder estimates of p-harmonic extension operators in a metric measure space; **N. Askaripour** and **A. Boivin**, Meromorphic approximation on noncompact Riemann surfaces; **J. Mashreghi**, On a family of outer functions; **P. V. Paramonov**, On C^m-subharmonic extension sets of Walsh-type; **A. Sadullaev**, On maximal plurisubharmonic functions; **R. Fournier** and **J.-M. Giguêre**, On universality of series in Banach spaces; **Y. Mizuta** and **T. Ohno**, Orlicz capacity of balls; **H. Aikawa**, Potential analysis on nonsmooth domains—Martin boundary and boundary Harnack principle; **D. Singman**, Potential theory on trees and mutliplication operators; **S. J. Gardiner**, Recent progress on fine differentiability and fine harmonicity; **A. G. O'Farrell**, Reversibility questions in groups arising in analysis; **V. Anandam**, Subordinate harmonic structures in an infinite network; **M. Rao**, The generalized binomial theorem; **K. Y. Fedorovskiy**, Uniform and C^m-approximation by polyanalytic polynomials.

CRM Proceedings & Lecture Notes, Volume 55

December 2012, approximately 337 pages, Softcover, ISBN: 978-0-8218-9173-5, 2010 *Mathematics Subject Classification:* 30-XX, 31-XX, 32-XX, **AMS members US$108**, List US$135, Order code CRMP/55

Differential Equations



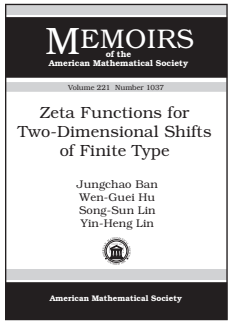
Wave Front Set of Solutions to Sums of Squares of Vector Fields

Paolo Albano and **Antonio Bove**, *Università di Bologna, Italy*

Contents: Introduction; The Poisson–Treves stratification; Standard forms for a system of vector fields; Nested strata; Bargman pseudodifferential operators; The "a priori" estimate on the FBI side; A single symplectic stratum; A single nonsymplectic stratum; Microlocal regularity in nested strata; Known cases and examples; Appendix A. A bracket lemma; Appendix B. Nonsymplectic strata do not have the reproducing bracket property; Bibliography; Index.

Memoirs of the American Mathematical Society, Volume 221, Number 1039

December 2012, 73 pages, Softcover, ISBN: 978-0-8218-7570-4, 2010 *Mathematics Subject Classification:* 35A18; 35H10, 35H20, **Individual member US$37.20**, List US$62, Institutional member US$49.60, Order code MEMO/221/1039



Zeta Functions for Two-Dimensional Shifts of Finite Type

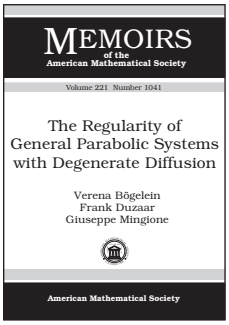
Jungchao Ban, *National Dong Hwa University, Hualien, Taiwan*, **Wen-Guei Hu** and **Song-Sun Lin**, *National Chiao Tung University, Hsinchu, Taiwan*, and **Yin-Heng Lin**, *National Central University, ChungLi, Taiwan*

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

Contents: Introduction; Periodic patterns; Rationality of ζ_n; More symbols on larger lattice; Zeta functions presented in skew coordinates; Analyticity and meromorphic extensions of zeta functions; Equations on $\mathbb{Z}^2$ with numbers in a finite field; Square lattice Ising model with finite range interaction; Bibliography.

Memoirs of the American Mathematical Society, Volume 221, Number 1037

December 2012, 60 pages, Softcover, ISBN: 978-0-8218-7290-1, 2010 *Mathematics Subject Classification:* 37B50, 37B10, 37C30; 82B20, 11M41, **Individual member US$36**, List US$60, Institutional member US$48, Order code MEMO/221/1037



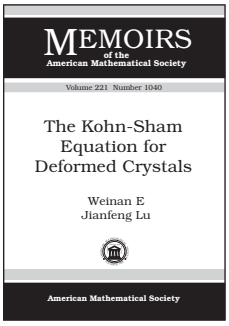
The Regularity of General Parabolic Systems with Degenerate Diffusion

Verena Bögelein and **Frank Duzaar**, *University of Erlangen Nuremberg, Germany*, and **Giuseppe Mingione**, *University of Parma, Italy*

Contents: Introduction and results; Technical preliminaries; Tools for the p-caloric approximation; The p-caloric approximation lemma; Caccioppoli and Poincaré type inequalities; Approximate $\mathcal{A}$-caloricity and p-caloricity; DiBenedetto & Friedman regularity theory revisited; Partial gradient regularity in the case $p > 2$; The case $p < 2$; Partial Lipschitz continuity of u; Bibliography.

Memoirs of the American Mathematical Society, Volume 221, Number 1041

December 2012, 143 pages, Softcover, ISBN: 978-0-8218-8975-6, 2010 *Mathematics Subject Classification:* 35K55, 35K65, 35K67, **Individual member US$45.60**, List US$76, Institutional member US$60.80, Order code MEMO/221/1041



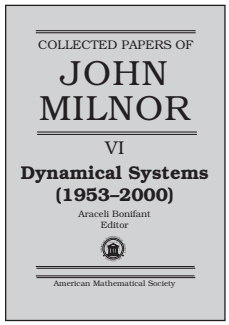
The Kohn-Sham Equation for Deformed Crystals

Weinan E, *Princeton University, NJ*, and **Jianfeng Lu**, *Duke University, Durham, NC*

Contents: Introduction; Perfect crystal; Stability condition; Homogeneously deformed crystal; Deformed crystal and the extended Cauchy-Born rule; The linearized Kohn-Sham operator; Proof of the results for the homogeneously deformed crystal; Exponential decay of the resolvent; Asymptotic analysis of the Kohn-Sham equation; Higher order approximate solution to the Kohn-Sham equation; Proofs of Lemmas 5.3 and 5.4; Appendix A. Proofs of Lemmas 9.3 and 9.9; Bibliography.

Memoirs of the American Mathematical Society, Volume 221, Number 1040

December 2012, 97 pages, Softcover, ISBN: 978-0-8218-7560-5, 2010 *Mathematics Subject Classification:* 74B20; 35Q40, **Individual member US$41.40**, List US$69, Institutional member US$55.20, Order code MEMO/221/1040



Collected Papers of John Milnor

VI. Dynamical Systems (1953–2000)

Araceli Bonifant, *University of Rhode Island, Kingston, RI*, Editor

This book, the sixth in the series "Collected Papers of John Milnor", contains all of Milnor's work on Real and Complex Dynamics from 1953 to 1999, plus one paper from 2000.

These papers provide important and fundamental material in real and complex dynamical systems. Many of them have become classics in the field. Several questions addressed in them continue to be important in current research. Having them together in the same volume gives readers a taste of all the great mathematics developed by the author in the different areas of dynamics. In some cases, there have been minor corrections or clarifications, as well as references to more recent work which answers questions raised by the author.

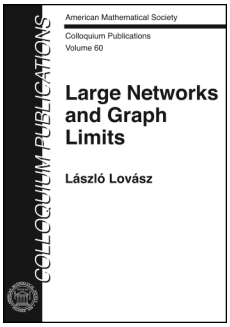
John Milnor's papers are accompanied by introductions that put them in perspective with respect to the current state of the field. There is also an index to facilitate searching the book for specific topics.

Contents: *Part I. Real dynamics:* Introduction to Part I; The characteristics of a vector field in the two-sphere (1953); On the concept of attractor (1985); On the concept of attractor: Correction and remarks (1985); Directional entropies of cellular automaton-maps (1986); On the entropy geometry of cellular automata (1988); Non-expansive Hénon maps (1988); with **W. Thurston**, On iterated maps of the interval (1988); with **S. P. Dawson, R. Galeeva, and C. Tresser**, A monotonicity conjecture for real cubic maps (1995); with **C. Tresser**, On entropy and monotonicity for real cubic maps (2000) (with an appendix by **A. Douady** and **P. Sentenac**); Fubini foiled: Katok's paradoxical example in measure theory (1997); *Part II. Complex dynamics:* Introduction to Part II; with **S. Friedland**, Dynamical properties of plane polynomial automorphisms (1989); Self-similarity and hairiness in the Mandelbrot set (1989); Remarks on iterated cubic maps (1992); Geometry and dynamics of quadratic rational maps (1993) (with an appendix by **J. Milnor** and **T. Lei**); with **M. Lyubich**, The Fibonacci unimodal map (1993); with **L. Goldberg**, Fixed points of polynomial maps. Part II. Fixed point portraits (1993); The mathematical work of Curt McMullen (1999); Index.

Collected Works, Volume 19

February 2013, 535 pages, Hardcover, ISBN: 978-0-8218-9139-1, 2010 *Mathematics Subject Classification:* 37-XX, 54H20, 26A18, 28D20, 32Hxx, 32S70, 28A35, 68Q80, 01A70, **AMS members US$87.20**, List US$109, Order code CWORKS/19.6

Discrete Mathematics and Combinatorics



Large Networks and Graph Limits

László Lovász, *Eötvös Loránd University, Budapest, Hungary*

Recently, it became apparent that a large number of the most interesting structures and phenomena of the world can be described by networks. Developing a mathematical theory of very large networks is an important challenge. This book describes one recent approach to this theory, the limit theory of graphs, which has emerged over the last decade. The theory has rich connections with other approaches to the study of large networks, such as "property testing" in computer science and regularity partition in graph theory. It has several applications in extremal graph theory, including the exact formulations and partial answers to very general questions, such as which problems in extremal graph theory are decidable. It also has less obvious connections with other parts of mathematics (classical and non-classical, like probability theory, measure theory, tensor algebras, and semidefinite optimization).

This book explains many of these connections, first at an informal level to emphasize the need to apply more advanced mathematical methods, and then gives an exact development of the theory of the algebraic theory of graph homomorphisms and of the analytic theory of graph limits.

This is an amazing book: readable, deep, and lively. It sets out this emerging area, makes connections between old classical graph theory and graph limits, and charts the course of the future.

*—**Persi Diaconis, Stanford University***

This book is a comprehensive study of the active topic of graph limits and an updated account of its present status. It is a beautiful volume written by an outstanding mathematician who is also a great expositor.

*—**Noga Alon, Tel Aviv University, Israel***

Modern combinatorics is by no means an isolated subject in mathematics, but has many rich and interesting connections to almost every area of mathematics and computer science. The research presented in Lovász's book exemplifies this phenomenon. This book presents a wonderful opportunity for a student in combinatorics to explore other fields of mathematics, or conversely for experts in other areas of mathematics to become acquainted with some aspects of graph theory.

*—**Terence Tao, University of California, Los Angeles, CA***

László Lovász has written an admirable treatise on the exciting new theory of graph limits and graph homomorphisms, an area of great importance in the study of large networks. It is an authoritative, masterful text that reflects Lovász's position as the main architect of this rapidly developing theory. The book is a must for combinatorialists, network theorists, and theoretical computer scientists alike.

*—**Bela Bollobas, Cambridge University, UK***

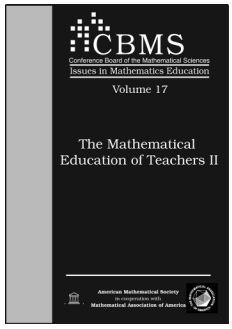
This item will also be of interest to those working in applications.

Contents: *Large graphs: An informal introduction:* Very large networks; Large graphs in mathematics and physics; *The algebra of graph homomorphisms:* Notation and terminology; Graph parameters and connection matrices; Graph homomorphisms; Graph algebras and homomorphism functions; *Limits of dense graph sequences:* Kernels and graphons; The cut distance; Szemerédi partitions; Sampling; Convergence of dense graph sequences; Convergence from the right; On the structure of graphons; The space of graphons; Algorithms for large graphs and graphons; Extremal theory of dense graphs; Multigraphs and decorated graphs; *Limits of bounded degree graphs:* Graphings; Convergence of bounded degree graphs; Right convergence of bounded degree graphs; On the structure of graphings; Algorithms for bounded degree graphs; *Extensions: A brief survey:* Other combinatorial structures; Appendix A; Bibliography; Author index; Subject index; Notation index.

Colloquium Publications, Volume 60

December 2012, 475 pages, Hardcover, ISBN: 978-0-8218-9085-1, 2010 *Mathematics Subject Classification:* 05C99; 05C25, 05C35, 05C80, 05C82, 05C85, 90B15, **AMS members US$79.20**, List US$99, Order code COLL/60

General Interest



The Mathematical Education of Teachers II

This report is a resource for those who teach mathematics and statistics to PreK–12 mathematics teachers, both future teachers and those who already teach in our nation's schools. The report makes recommendations for the mathematics that teachers should know and how they should come to know that mathematics. It urges greater involvement of mathematicians and statisticians in teacher education so that the nation's mathematics teachers have the knowledge, skills, and dispositions needed to provide students with a mathematics education that ensures high school graduates are college- and career-ready as envisioned by the Common Core State Standards.

This report draws on the experience and knowledge of the past decade to:

- Update the 2001 Mathematical Education of Teachers report's recommendations for the mathematical preparation of teachers at all grade levels: elementary, middle, and high school.
- Address the professional development of teachers of mathematics.
- Discuss the mathematical knowledge needed by teachers at different grade levels and by others who teach mathematics such as elementary mathematics specialists, special education teachers, and early childhood educators.

Each of the MET II writers is a mathematician, statistician, or mathematics educator with substantial expertise and experience in mathematics education. Among them are principal investigators for Math Science Partnerships as well as past presidents and chairs of the American Statistical Association, Association of Mathematics Teacher Educators, Association of State Supervisors of Mathematics,

Conference Board of the Mathematical Sciences, and National Council of Teachers of Mathematics.

The audience for this report includes all who teach mathematics to teachers—mathematicians, statisticians, and mathematics educators—and all who are responsible for the mathematical education of teachers—department chairs, educational administrators, and policy-makers at the national, state, school-district, and collegiate levels.

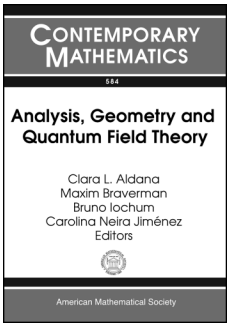
This series is published in cooperation with the Mathematical Association of America.

Contents: School mathematics and teachers' mathematics; The mathematical education of teachers: Traditions, research, current context; Recommendations: Mathematics for teachers; Roles for mathematicians; Elementary teachers; Middle grades teachers; High school teachers; Appendix A. Selected references and information sources; Appendix B. The common core state standards: Overview of content; Appendix C. The common core state standards for mathematical practice.

CBMS Issues in Mathematics Education, Volume 17

December 2012, 86 pages, Softcover, ISBN: 978-0-8218-6926-0, 2010 *Mathematics Subject Classification:* 97A99, 00-01, **AMS members US$26.40**, List US$33, Order code CBMATH/17

Geometry and Topology



Analysis, Geometry and Quantum Field Theory

Clara L. Aldana, *Max Planck Institute for Gravitational Physics, Golm, Germany*, **Maxim Braverman**, *Northeastern University, Boston, MA*, **Bruno Iochum**, *Aix-Marseille Université, France*, and **Carolina Neira Jiménez**, *Universität Regensburg, Germany*, Editors

This volume contains the proceedings of the conference "Analysis, Geometry and Quantum Field Theory" held at Potsdam University in September 2011, which honored Steve Rosenberg's 60th birthday.

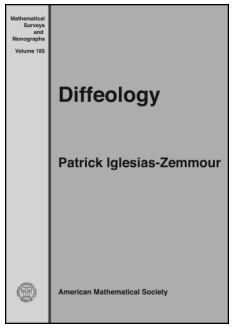
The papers in this volume cover a wide range of areas, including Quantum Field Theory, Deformation Quantization, Gerbes, Loop Spaces, Index Theory, Determinants of Elliptic Operators, K-theory, Infinite Rank Bundles and Mathematical Biology.

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

Contents: **M. G. Eastwood** and **J. A. Wolf**, A duality for the double fibration transform; **P. Hekmati** and **M. Mathai**, T-duality of current algebras and their quantization; **Y. Maeda** and **A. Sako**, Deformation quantization of instantons on $\mathbb{R}^4$; **J. Mickelsson**, The Chern character of certain infinite rank bundles arising in gauge theory; **A. Larraín-Hubach**, K-theories for classes of infinite rank bundles; **K. Waldorf**, A construction of string 2-group models using transgression-regression technique; **A. Cardona**, Extended symmetries and Poisson algebras associated to twisted Dirac structures; **S. T. Melo**, **T. Schick**, and **E. Schrohe**, C^*-algebra approach to the index theory of boundary value problems; **B. Booß–Bavnbek**, Towards a nano geometry? Geometry and dynamics on nano scale; **T. Liimatainen**, Optimal Riemannian metric for a volumorphism and a mean ergodic theorem in complete global Alexandrov nonpositively curved spaces; **C. Bär**, Renormalized integrals and a path integral formula for the heat kernel on a manifold; **S. Paycha**, Affine transformations on symbols; **C. L. Aldana**, Determinants of Laplacians on non-compact surfaces; **S. Scott**, Calculation of the variation of $\det_\zeta D$; **G. Misiołek** and **T. Yoneda**, Ill-posedness examples for the quasi-geostrophic and the Euler equations.

Contemporary Mathematics, Volume 584

December 2012, 258 pages, Softcover, ISBN: 978-0-8218-9144-5, LC 2012027493, 2010 *Mathematics Subject Classification:* 58J35, 58D17, 58B25, 19L64, 81R60, 19K56, 22E67, 32L25, 46L80, 17B69, **AMS members US$68.80**, List US$86, Order code CONM/584



Diffeology

Patrick Iglesias-Zemmour, *CNRS, Marseille, France, and The Hebrew University of Jerusalem, Israel*

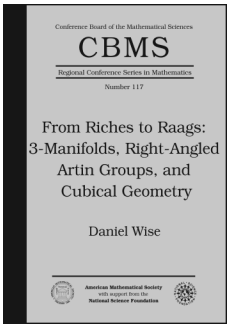
Diffeology is an extension of differential geometry. With a minimal set of axioms, diffeology allows us to deal simply but rigorously with objects which do not fall within the usual field of differential geometry: quotients of manifolds (even non-Hausdorff), spaces of functions, groups of diffeomorphisms, etc. The category of diffeology objects is stable under standard set-theoretic operations, such as quotients, products, co-products, subsets, limits, and co-limits. With its right balance between rigor and simplicity, diffeology can be a good framework for many problems that appear in various areas of physics.

Actually, the book lays the foundations of the main fields of differential geometry used in theoretical physics: differentiability, Cartan differential calculus, homology and cohomology, diffeological groups, fiber bundles, and connections. The book ends with an open program on symplectic diffeology, a rich field of application of the theory. Many exercises with solutions make this book appropriate for learning the subject.

Contents: Diffeology and diffeological spaces; Locality and diffeologies; Diffeological vector spaces; Modeling spaces, manifolds, etc.; Homotopy of diffeological spaces; Cartan-De Rham calculus; Diffeological groups; Diffeological fiber bundles; Symplectic diffeology; Solutions of exercises; Afterword; Notation and vocabulary; Bibliography.

Mathematical Surveys and Monographs, Volume 185

February 2013, approximately 449 pages, Hardcover, ISBN: 978-0-8218-9131-5, LC 2012032894, 2010 *Mathematics Subject Classification:* 53Cxx, 53Dxx, 55Pxx, 55P35, 55Rxx, 55R65, 58A10, 58A40, 58Bxx, **AMS members US$93.60**, List US$117, Order code SURV/185



From Riches to Raags: 3-Manifolds, Right-Angled Artin Groups, and Cubical Geometry

Daniel T. Wise, *McGill University, Montreal, QC, Canada*

This book presents an introduction to the geometric group theory associated with nonpositively curved cube complexes. It advocates the use of cube complexes to understand the fundamental groups of hyperbolic 3-manifolds as well as many other infinite groups studied within geometric group theory.

The main goal is to outline the proof that a hyperbolic group G with a quasiconvex hierarchy has a finite index subgroup that embeds in a right-angled Artin group. The supporting ingredients of the proof are sketched: the basics of nonpositively curved cube complexes, wallspaces and dual CAT(0) cube complexes, special cube complexes, the combination theorem for special cube complexes, the combination theorem for cubulated groups, cubical small-cancellation theory, and the malnormal special quotient theorem. Generalizations to relatively hyperbolic groups are discussed. Finally, applications are described towards resolving Baumslag's conjecture on the residual finiteness of one-relator groups with torsion, and to the virtual specialness and virtual fibering of certain hyperbolic 3-manifolds, including those with at least one cusp.

The text contains many figures illustrating the ideas.

This item will also be of interest to those working in algebra and algebraic geometry.

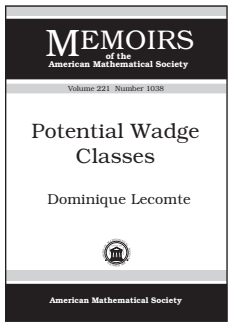
A co-publication of the AMS and CBMS.

Contents: Overview; Nonpositively curved cube complexes; Cubical disk diagrams, hyperplanes, and convexity; Special cube complexes; Virtual specialness of malnormal amalgams; Wallspaces and their dual cube complexes; Finiteness properties of the dual cube complex; Cubulating malnormal graphs of cubulated groups; Cubical small cancellation theory; Walls in cubical small-cancellation theory; Annular diagrams; Virtually special quotients; Hyperbolicity and quasiconvexity detection; Hyperbolic groups with a quasiconvex hierachy; The relatively hyperbolic setting; Applications; Bibliography; Index of notation and defined terms.

CBMS Regional Conference Series in Mathematics, Number 117

December 2012, approximately 144 pages, Softcover, ISBN: 978-0-8218-8800-1, LC 2012032056, 2010 *Mathematics Subject Classification:* 20F67, 20F06, 57M99, 20E26, **AMS members US$32.80**, **All Individuals US$32.80**, List US$41, Order code CBMS/117

Logic and Foundations



Potential Wadge Classes

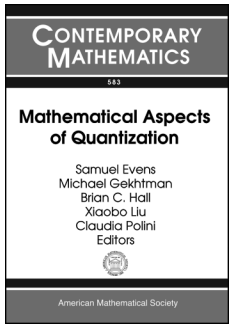
Dominique Lecomte, *Université Paris 6, France*

Contents: Introduction; A condition ensuring the existence of complicated sets; The proof of Theorem 1.10 for the Borel classes; The proof of Theorem 1.11 for the Borel classes; The proof of Theorem 1.10; The proof of Theorem 1.11; Injectivity complements; Bibliography.

Memoirs of the American Mathematical Society, Volume 221, Number 1038

December 2012, 83 pages, Softcover, ISBN: 978-0-8218-7557-5, 2010 *Mathematics Subject Classification:* 03E15; 54H05, 28A05, 26A21, **Individual member US$37.20**, List US$62, Institutional member US$49.60, Order code MEMO/221/1038

Mathematical Physics



Mathematical Aspects of Quantization

Sam Evens, **Michael Gekhtman**, **Brian C. Hall**, **Xiaobo Liu**, and **Claudia Polini**, *University of Notre Dame, IN*, Editors

This book is a collection of expository articles from the Center of Mathematics at Notre Dame's 2011 program on quantization.

Included are lecture notes from a summer school on quantization on topics such as the Cherednik algebra, geometric quantization, detailed proofs of Willwacher's results on the Kontsevich graph complex, and group-valued moment maps.

This book also includes expository articles on quantization and automorphic forms, renormalization, Berezin–Toeplitz quantization in the complex setting, and the commutation of quantization with reduction, as well as an original article on derived Poisson brackets.

The primary goal of this volume is to make topics in quantization more accessible to graduate students and researchers.

Contents: **Y. Berest** and **P. Samuelson**, Dunkl operators and quasi-invariants of complex reflection groups; **V. A. Dolgushev** and **C. L. Rogers**, Notes on algebraic operads, graph complexes, and Willwacher's construction; **E. Lerman**, Geometric quantization: A crash course; **E. Meinrenken**, Lectures on group-valued moment maps and Verlinde formulas; **T. Barron**, Quantization and automorphic forms; **Y. Berest**, **X. Chen**, **F. Eshmatov**, and **A. Ramadoss**, Noncommutative Poisson structures, derived representation schemes and Calabi-Yau algebras; **A. Kar** and **S. G. Rajeev**, Renormalization by any means necessary; **M. Schlichenmaier**, Berezin-Toeplitz quantization and star products for compact Kähler manifolds;

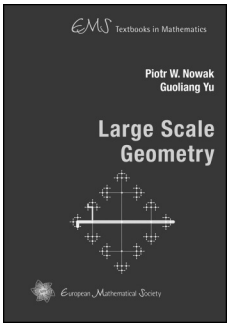
J. Śniatycki, Commutation of geometric quantization and algebraic reduction.

Contemporary Mathematics, Volume 583

December 2012, 308 pages, Softcover, ISBN: 978-0-8218-7573-5, LC 2012025701, 2010 *Mathematics Subject Classification:* 53D50, 53D55, 46L65, 81S10, **AMS members US$77.60**, List US$97, Order code CONM/583

New AMS-Distributed Publications

Geometry and Topology



Large Scale Geometry

Piotr W. Nowak, *Polish Academy of Sciences, Warsaw, Poland*, and **Guoliang Yu**, *Texas A & M University, College Station, TX*

Large scale geometry is the study of geometric objects viewed from a great distance. The idea of large scale geometry can be traced back to Mostow's work on rigidity and the work of Švarc, Milnor, and Wolf on growth of groups. In the last decades, large scale geometry has found important applications in group theory, topology, geometry, higher index theory, computer science, and large data analysis.

This book provides a friendly approach to the basic theory of this exciting and fast growing subject and offers a glimpse of its applications to topology, geometry, and higher index theory. The authors have made a conscientious effort to make the book accessible to advanced undergraduate students, graduate students, and non-experts.

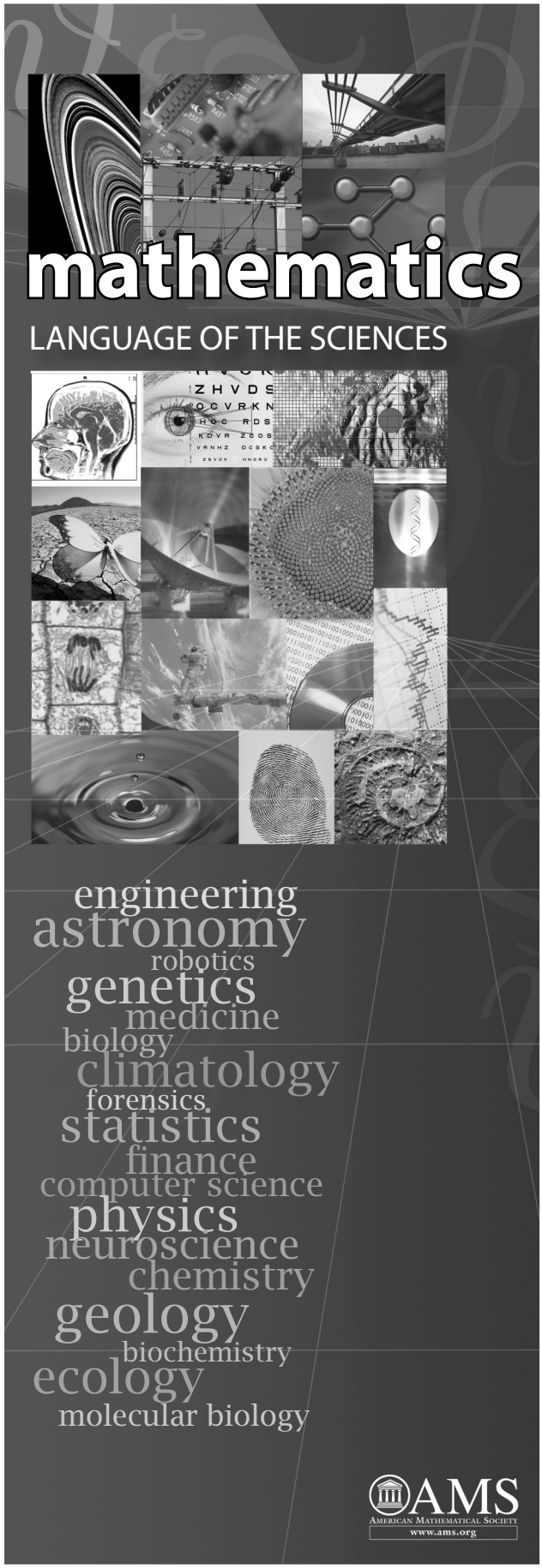
This item will also be of interest to those working in algebra and algebraic geometry.

A publication of the European Mathematical Society (EMS). Distributed within the Americas by the American Mathematical Society.

Contents: Metric spaces and large scale geometry; Asymptotic dimension and decomposition complexity; Amenability; Property A; Coarse embeddings; Group actions on Banach spaces; Coarse homology; Survey of applications; References; Index.

EMS Textbooks in Mathematics, Volume 13

October 2012, 203 pages, Hardcover, ISBN: 978-3-03719-112-5, 2010 *Mathematics Subject Classification:* 51-01, 20F69, 19K56, 57-01, 46L87, 58B34, 46L99, 53C20, **AMS members US$35.20**, List US$44, Order code EMSTEXT/13



Classified Advertisements

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

ALABAMA

UNIVERSITY OF ALABAMA
Department of Mathematics

The Department of Mathematics at the University of Alabama invites applications for a tenure-track Assistant Professor position in the area of probability/statistics with a focus on non-parametric statistics and computing. The appointment will begin on August 16, 2013. 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 at least three letters of recommendation, one of which must address teaching, to be sent to mathematics@as.ua.edu. The review process starts on December 1, 2012, 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. Hiring for this position is contingent upon funding. More information about the department and the university is available at http://math.ua.edu.

000115

CALIFORNIA

HARVEY MUDD COLLEGE
Department of Mathematics
Tenure-Track and Postdoctoral Positions

Harvey Mudd College invites applications for: (1) a tenure-track professorship, or (2) a teaching-research postdoctoral fellowship. All areas of the mathematical sciences will be considered. Successful candidates will have a Ph.D., demonstrated teaching excellence, and a strong research program that contributes to our many undergraduate research activities. As recipient of the inaugural AMS Award for Exemplary Program, the department is a recognized leader in teaching, undergraduate research mentoring, and educational outreach. Half of our graduates go to Ph.D. programs. HMC is an Equal Opportunity Employer. Apply at MathJobs.org.

000113

SAN DIEGO STATE UNIVERSITY
Department of Mathematics and Statistics
Tenure-track Assistant Professor Position in Applied and Computational Mathematics

The Department of Mathematics and Statistics at San Diego State University invites applications for a tenure-track Assistant Professor position in applied and computational mathematics, beginning in Fall 2013. Focused research areas include but are not limited to dynamical systems, nonlinear waves, applied PDEs, numerical analysis, climate science and mathematical biology.

Candidates must have a Ph.D. in mathematics or a closely related field, and demonstrate outstanding research potential. Candidates must also demonstrate enthusiasm and ability to teach undergraduate and graduate level mathematics. Preference may be given to candidates in the focused research areas described above and to those who would be able to augment or interact with existing groups within the department and the Computational Science Research Center. The successful candidate will have the opportunity to participate in our joint Ph.D. program in Computational Science, as well as in our MA and MS programs in pure and applied mathematics.

Applications should include: a cover letter, curriculum vita, a description of research program, a statement of teaching philosophy, and three letters of

Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

The 2012 rate is $3.50 per word with a minimum two-line headline. No discounts for multiple ads or the same ad in consecutive issues. For an additional $10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Headlines will be centered in boldface at no extra charge. Ads will appear in the language in which they are submitted.

There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified ads.

Upcoming deadlines for classified advertising are as follows: January 2013 issue–October 29, 2012; February 2013 issue–November 28, 2012; March 2013 issue–January 2, 2013; April 2013 issue–January 30, 2013; May 2013–February 28, 2013; June/July 2013 issue–April 26, 2013.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 1373 (vol. 44).

Situations wanted advertisements from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the U.S. and Canada or 401-455-4084 worldwide for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940; or via fax: 401-331-3842; or send email to classads@ams.org. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 20904. Advertisers will be billed upon publication.

recommendation sent directly to the search committee. Applications should be addressed to:

Professor Ricardo Carretero
Chair, Search Committee
Department of Mathematics and Statistics
San Diego State University
5500 Campanile Dr.
San Diego, CA 92182-7720

Review of applications will begin on October 15, 2012, and continue until the position is filled.

SDSU is an Equal Opportunity Employer and does not discriminate against persons on the basis of race, religion, national origin, sexual orientation, gender, gender identity and expression, marital status, age, disability, pregnancy, medical condition, or covered veteran status.

000110

UCLA
Department of Mathematics

The Department of Mathematics invites applications for temporary and visiting appointments in the categories 1-4 below. Depending on the level, candidates must give evidence of potential or demonstrated distinction in scholarship and teaching.

Temporary Positions:

(1) E.R. Hedrick Assistant Professorships. Salary is $63,000 and appointments are for three years. The teaching load is four one-quarter courses per year.

(2) Computational and Applied Mathematics (CAM) Assistant Professorships. Salary is $63,000, and appointments are for three years. The teaching load is normally reduced by research funding to two quarter courses per year.

(3) Program in Computing (PIC) Assistant Adjunct Professorships. Salary is $67,500. Applicants for these positions must show very strong promise in teaching and research in an area related to computing. The teaching load is four one-quarter programming courses each year and one additional course every two years. Initial appointments are for one year and possibly longer, up to a maximum service of four years.

(4) Assistant Adjunct Professorships and Research Postdocs. Normally appointments are for one year, with the possibility of renewal. Strong research and teaching background required. The salary range is $54,800-$61,300. The teaching load for Adjuncts is six one-quarter courses per year.

Applications and supporting documentation must be submitted electronically via www.mathjobs.org. All letters of evaluation are subject to UCLA campus policies on confidentiality. Refer potential reviewers to the UCLA Statement of Confidentiality at: http://www.math.ucla.edu/people/confidentiality.pdf.

For fullest consideration, all application materials should be submitted on or before December 7, 2012. A Ph.D. is required for all positions.

The university is an Equal Opportunity/Affirmative Action Employer. UCLA and the Department of Mathematics have a strong commitment to the achievement of excellence in teaching and research and diversity among its faculty and staff. The University of California asks that applicants complete the Equal Opportunity Employer survey for Letters and Science at the following URL: http://cis.ucla.edu/facultysurvey. Under Federal law, the University of California may employ only individuals who are legally authorized to work in the United States as established by providing documents specified in the Immigration Reform and Control Act of 1986.

000083

CONNECTICUT

UNIVERSITY OF CONNECTICUT
Department of Mathematics
Assistant Professor, Tenure-Track

The department has several positions, starting in the Fall 2013 with priority on logic, analysis, stochastic processes preferably with financial mathematics, numerical solutions of PDE's and optimization.

See http://www.mathjobs.org/jobs to retrieve information and to apply online. For questions or requests regarding additional information please email the Hiring Committee at mathhiring@uconn.edu.

000102

UNIVERSITY OF CONNECTICUT
Department of Mathematics
Professor, Tenured

The department seeks to hire a distinguished senior mathematician to hold Stuart and Joan Sidney Professorship of Mathematics, starting in the Fall 2013. Highly qualified candidates in all mathematical disciplines are encouraged to apply.

See http://www.mathjobs.org/jobs to retrieve information and to apply online. For questions or requests for additional information please email the Hiring Committee of the Department of Mathematics at sjshiring@math.uconn.edu.

000103

DISTRICT OF COLUMBIA

AMERICAN UNIVERSITY
Washington, DC

The College of Arts and Sciences at American University (Washington, DC) invites applications for a full-time, tenure-line, Assistant Professor position, beginning in August 2013, in computational neuroscience (broadly defined, including but not limited to neural networks, simulation, image processing, and bio-informatics). The appointee's tenure home and departmental affiliation will depend on his or her research background, but we are most interested in applicants who would have at least a joint affiliation with the Department of Computer Science. Applicants must have a Ph.D. in a relevant discipline. Teaching and postdoctoral experience are preferred. Responsibilities include: teaching and curriculum development; establishing an internationally recognized research program, preferably one that can involve undergraduate research participation; strengthening connections to neurosciences across campus; and service to the appointee's home department and the wider university. American University has made other recent hires in neuroscience, is presently seeking to fill other positions in computer science, and benefits from proximity to other scientific institutions in the Washington area. (For example, NIH is three metro stops from the AU campus.) The College of Arts and Sciences offers a variety of degrees at the undergraduate, masters, and doctoral levels. For more information about our programs, visit http://www.american.edu/cas/. Applicants should submit a cover letter, curriculum vitae, teaching statement, and research statement, and applicants must arrange for three letters of recommendation to be sent directly to the search committee. Materials can be submitted online (highly preferred) at http://academicjobsonline.org/ajo, or via email to CompNeuroSearch@american.edu, or in hard copy to Computational Neuroscience Search Committee, Department of Mathematics and Statistics, American University, Washington, DC 20016-8050. Applications received by December 10, 2012, will receive full consideration. American University is an EEO/AA institution, committed to a diverse faculty, staff, and student body. Women and minority candidates are strongly encouraged to apply. American University offers employee benefits to same-sex domestic partners of employees and prohibits discrimination on the basis of sexual orientation/preference and gender identity/expression.

000112

INDIANA

INDIANA UNIVERSITY BLOOMINGTON
Department of Mathematics
Zorn Research Postdoctoral Fellowships

The Department of Mathematics seeks applications for two Zorn Research Postdoctoral Fellowships beginning in the fall of 2013. These are three-year, non-tenure-track positions with reduced teaching loads. Outstanding candidates with a recent Ph.D. in any area of pure or applied mathematics are encouraged to apply; a minimum requirement is a Ph.D. in mathematics. Zorn fellows are paired with mentors with whom they have compatible research interests. The department maintains strong research groups in all of the principal fields of mathematics. Bloomington is located in the forested hills of southern Indiana and offers a rich variety of musical and cultural attractions.

Applicants should submit an AMS cover sheet, a curriculum vitae, a research statement, and a teaching statement using the online service provided by the AMS at: http://www.mathjobs.org. If unable to do so, you may send application materials to the address below. Applicants should arrange for four letters of recommendation, including one evaluating teaching experience. Please ask reference writers to submit their letters electronically through http://www.mathjobs.org. If they are unable to do so, they may also send their letters to the following address: Zorn Postdoctoral Fellowships Search Committee, Department of Mathematics, Indiana University, 831 East 3rd Street, Rawles Hall, Bloomington, IN 47405-7106. Applications should be received by December 15, 2012. Indiana University is an Equal Opportunity/Affirmative Action Employer.

000071

KANSAS

KANSAS STATE UNIVERSITY
Department of Mathematics

Applications are invited for Visiting Assistant Professorships commencing August 4, 2013. These will be term appointments with the possibility of re-appointments depending on performance, funding, and need of services. A Ph.D. in mathematics or a Ph.D. dissertation completed by December 20, 2013, is required. The department seeks candidates whose research interests mesh well with current faculty. The department has research groups in algebra, analysis, differential equations, geometry/topology, and number theory. Successful candidates are expected to participate in the department's programs during summer programs. The successful candidate should have strong research credentials as well as strong accomplishments or promise in teaching, and should value working with colleagues and students from diverse backgrounds. Applicants must submit the following: A letter of application, curriculum vita, outline of teaching philosophy, a statement of research objectives, and four letters of reference, at least one of which addresses the applicant's teaching ability or potential. All application materials must be submitted electronically via http://www.mathjobs.org. Screening of applications begins November 1, 2012, and continues until positions are closed. Kansas State University is an Equal Opportunity Employer and actively seeks diversity among its employees and encourages applications from women and minorities. A background check is required.

000107

KANSAS STATE UNIVERSITY
Visiting Assistant Professor

Subject to budgetary approval, applications are invited for a visiting assistant professorship commencing August 4, 2013. These will be term appointments with the possibility of two subsequent appointments depending on performance, funding, and need of services. Incumbent will be a Fellow of the Center for Quantitative Education and will participate in research projects addressing effective teaching in a technological environment, with particular emphasis on Calculus and Mathematics for Elementary School Teachers. The incumbent will teach in the undergraduate program and will also have time to pursue independent research in the department in either mathematics or mathematics education along with these duties. Applicants must have a commitment to excellence in teaching. A Ph.D. in mathematics or a Ph.D. dissertation completed by 12.20.13 is required. Preference will be given to applications with background in mathematics and/or teaching with technology, as well as applicants whose research interests mesh well with current department faculty. Letter of application, current vita, minimum three letters of reference, at least one of which addresses the applicant's teaching ability, and a statement of teaching philosophy must be submitted online through mathjobs.org. Screening of applications begins November 1, 2012, and continues until the position is closed. The candidate must value working with colleagues and students with diverse backgrounds. Kansas State University is an Equal Opportunity Employer and actively seeks diversity among its employees and encourages applications from women and minorities. A background check is required. For additional information about this search, please email inquiry to bennett@math.ksu.edu and reference the Q-Center position.

000108

KANSAS STATE UNIVERSITY
Department of Mathematics

Applications are invited for a tenure-track Assistant Professor position to commence August 4, 2013, with salary commensurate with qualifications. A Ph.D. in mathematics is required and preference will be given to candidates with some postdoctoral experience. The department seeks candidates whose research interests are in mathematics and its applications. The successful candidate should have strong research credentials as well as strong accomplishment or promise in teaching, should demonstrate a strong commitment to mentoring students, and should value working with colleagues and students from diverse backgrounds. Applicants must submit the following: a letter of application, curriculum vita, outline of teaching philosophy, a statement of research objectives, and four letters of reference, at least one of which addresses the applicant's teaching ability and potential. All application materials must be submitted electronically via http://www.mathjobs.org. Screening begins November 1, 2012, and continues until the position is closed. Kansas State University is an Equal Opportunity Employer and actively seeks diversity among its employees and encourages applications from women and minorities. A background check is required.

000109

UNIVERSITY OF KANSAS
Department of Mathematics

Applications are invited from exceptional candidates for a tenure-track assistant professor position in algebraic geometry and for a tenure-track assistant professor position in probability theory expected to begin as early as August 18, 2013. The University of Kansas is especially interested in hiring faculty members who can contribute to four key campus-wide strategic initiatives: (1) Sustaining the Planet, Powering the World; (2) Promoting Well-Being, Finding Cures; (3) Building Communities, Expanding Opportunities; and (4) Harnessing Information, Multiplying Knowledge. For more information, see http://www.provost.ku.edu/planning/themes. Ph.D. or ABD in math or a related field is expected by the start date of the appointment; commitment to excellence in teaching in mathematics; and commitment to excellence in research. Apply online at https://jobs.ku.edu, search for position 00061365 (algebraic geometry) or 00002395 (probability theory). In addition, reference letters should be submitted electronically to Mathjobs.org, position 3952 (algebraic geometry) or 3953 (probability theory). Review of applications will begin on November 1, 2012, and continues as long as

needed to identify a qualified pool. Equal Opportunity Employer M/F/D/V.

000104

MARYLAND

JOHNS HOPKINS UNIVERSITY
Department of Mathematics
J. J. Sylvester Assistant Professor

Subject to availability of resources and administrative approval, the Department of Mathematics invites applications for non-tenure-track two-year Assistant Professor positions beginning July 1, 2013. The J.J. Sylvester Assistant Professorship is a position offered to recent Ph.D.'s with outstanding research potential. Candidates in all areas of pure mathematics are encouraged to apply. The teaching load is three courses per academic year. To submit your application, go to http://www.mathjobs.org/jobs/jhu. Submit the AMS cover sheet, your curriculum vitae, and research and teaching statements, and ensure that at least four letters of recommendation, one of which addresses teaching, are submitted by the reference writers. If you are unable to apply online, you may send application materials to: Appointments Committee, Department of Mathematics, Johns Hopkins University, 404 Krieger Hall, Baltimore, MD 21218. If you have questions concerning this position, please write to: cpoole@jhu.edu. Preference will be given to applications received by December 1, 2012. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer. Minorities and women candidates are encouraged to apply.

000050

JOHNS HOPKINS UNIVERSITY
Department of Mathematics
Tenure-Track Assistant Professor

The Department of Mathematics invites applications for two positions at the tenure-track Assistant Professor level beginning July 1, 2013. A Ph.D. degree or its equivalent and demonstrated promise in research and commitment to teaching are required. Candidates in all areas of pure mathematics are encouraged to apply. To submit your application, go to: www.mathjobs.org/jobs/jhu. Submit the AMS cover sheet, your curriculum vitae, list of publications, and research and teaching statements, and ensure that at least four letters of recommendation, one of which addresses teaching, are submitted by the reference writers. If you are unable to apply online or do not wish to do so, you may send application materials to: Appointments Committee, Department of Mathematics, Johns Hopkins University, 404 Krieger Hall, Baltimore, MD 21218. If you have questions concerning this position, please write to: cpoole@jhu.edu. Preference will be given to applications received by October 15, 2012. The Johns Hopkins University is an Affirmative Action/Equal Opportunity Employer. Minorities and women candidates are encouraged to apply.

000051

JOHNS HOPKINS UNIVERSITY
Tenure-track Position in Financial Mathematics

The Department of Applied Mathematics and Statistics at Johns Hopkins University invites applications to fill a tenure-track position in financial mathematics. Exceptionally qualified candidates at all ranks will be considered. A successful candidate must have a doctorate in mathematics, applied mathematics, or a closely related field and will be expected to develop a successful research program in financial mathematics. The Department of Applied Mathematics and Statistics currently has ten tenure-track or tenured faculty members in the fields of probability, statistics, discrete mathematics, optimization, partial differential equations, and wavelet analysis. Electronic submission of applications to http://mathjobs.org is strongly preferred. If necessary, paper applications may be sent to:

Faculty Search Committee: Financial Mathematics
Department of Applied Mathematics and Statistics
Johns Hopkins University
100 Whitehead Hall
3400 N. Charles Street
Baltimore, MD 21218-2682 USA

Applications should include a cover letter describing the principal expertise of the applicant, a statement of teaching philosophy, a statement of research interests and experiences, and a curriculum vitae. Junior applicants should arrange to have 3-5 letters of recommendation sent. Applicants awarded a Ph.D. in June 2010 or later should provide photocopies of graduate transcripts. For full consideration, applications should be received by December 31, 2012. The department is committed to building a diverse educational environment; women and minorities are strongly encouraged to apply. The Johns Hopkins University is an EEO/AA Employer.

000101

UNIVERSITY OF MARYLAND BALTIMORE COUNTY
Department of Mathematics and Statistics

The Department of Mathematics and Statistics at the University of Maryland Baltimore County (UMBC) invites applications for two tenure-track faculty positions in Applied Mathematics at the rank of Assistant Professor, or at a higher level for exceptionally well qualified candidates, starting in the fall of 2013. The successful candidate should have a Ph.D. in mathematics or a related field, have an active, independent research program, strong potential for obtaining external funding, and a commitment to excellence in teaching. Preference will be given to candidates who are able to interact with existing groups in the Department, conduct interdisciplinary research, and strengthen connections to other research groups on campus. Applicants with postdoctoral experience are encouraged. The Department offers BS, MS and Ph.D. degrees in applied mathematics and in statistics and successful applicants should actively contribute to the success of these programs. For more information see http://www.math.umbc.edu. A complete application should include a cover letter, C.V., summary of current research program, teaching statement, and three letters of reference. All application materials should be submitted to MathJobs.org. Screening of applicants will commence December 1, 2012, and will continue until the position is filled. Applications from minorities, women and people with disabilities are especially encouraged. UMBC is an NSF-ADVANCE institution and an Affirmative Action/Equal Opportunity Employer.

000117

MASSACHUSETTS

BOSTON COLLEGE
Postdoctoral Position

The Department of Mathematics at Boston College invites applications for a postdoctoral position beginning September 2013. This position is intended for a new or recent Ph.D. with outstanding potential in research and excellent teaching. This is a 3-year Visiting Assistant Professor position, and carries a 2-1 annual teaching load. Research interests should lie within number theory, representation theory, algebraic geometry or related areas. Candidates should expect to receive their Ph.D. prior to the start of the position and have received the Ph.D. no earlier than Spring 2012. Applications must include a cover letter, description of research plans, teaching statement, curriculum vitae, and four or more letters of recommendation, with at least one addressing the candidate's teaching qualifications. Applications received no later than January 1, 2013, will be assured our fullest consideration.

Please submit all application materials through MathJobs.org. Applicants may learn more about the department, its faculty and its programs and about Boston College at http://www.bc.edu/math. Email inquiries concerning this position may be directed to postdoc-search@bc.edu. Boston College is an Affirmative Action/Equal Opportunity Employer. Applications from women, minorities and

individuals with disabilities are encouraged.

000111

WILLIAMS COLLEGE
Department of Mathematics and Statistics

Williams College invites applications for one tenure-track position in mathematics, beginning fall 2013, at the rank of assistant professor (in an exceptional case, a more advanced appointment may be considered). We are seeking a highly qualified candidate who has 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 Satyan Devadoss, 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. Evaluations 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.

000041

WILLIAMS COLLEGE
Department of Mathematics and Statistics

The Williams College Department of Mathematics and Statistics invites applications for a visiting position in mathematics for the 2013-2014 year, at the rank of assistant professor. Preference will be given to candidates who will have a Ph.D. in mathematics by September 2013. Applicants are encouraged to apply electronically at http://mathjobs.org or please send a vita and have three letters of recommendation on teaching and research sent to the Visitor Hiring Committee, Department of Mathematics and Statistics, Williams College, 18 Hoxsey Street, Williamstown, MA 01267. Teaching and research statements are also welcome. Evaluations of applications will begin on or after November 15, 2012, 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.

000079

MICHIGAN

MICHIGAN STATE UNIVERSITY
Department of Mathematics

The Department of Mathematics at Michigan State University will have two tenure-track positions to begin fall 2013. It is expected that successful applicants will be appointed at the rank of Assistant Professor, but truly outstanding candidates for appointment at higher ranks will be considered. Candidates will be evaluated on their merits in both research and teaching, and excellence is essential in both. Preference will be given to candidates with at least 2 years of experience beyond the Ph.D. Outstanding applicants from all mathematical research areas will be considered.

Applicants should send a vita, statement on research and teaching, and should arrange for at least 4 letters of recommendation to be sent, one of which must specifically address the applicant's ability to teach, and apply on-line at this link: https://www.mathjobs.org/jobs/jobs/3879.

Review of applications will begin on 10/15/2012, and will continue until the position is filled.

000106

MONTANA

MONTANA TECH
The University of Montana

The Department of Mathematical Sciences is seeking qualified applicants for two positions. Assistant Professor: Doctorate in mathematics and experience teaching a wide range of mathematical topics are required. Instructor: Master's degree in mathematics or mathematics education and experience teaching a wide range of mathematical topics are required. For more information visit http://www.mtech.edu/employment.

000116

NEW HAMPSHIRE

DARTMOUTH COLLEGE
Department of Mathematics

The Department of Mathematics anticipates a tenure-track opening with initial appointment as an Assistant Professor in the 2013-2014 academic year. The successful applicant will have a research profile with a concentration in computational or applied mathematics. Applicants should apply online at www.mathjobs.org. Position ID: APACM #3874. Applications received by December 15, 2012, will receive first consideration. For more information about this position, please visit our website: http://www.math.dartmouth.edu/activities/recruiting/. Dartmouth is committed to diversity and encourages applications from women and minorities.

000076

DARTMOUTH COLLEGE
Department of Mathematics

The Department of Mathematics anticipates a senior opening with initial appointment in the 2013-2014 academic year. The successful applicant will have a research profile with a concentration in computational or applied mathematics, will be appointed at the level of Full Professor and is expected to have an overall record of achievement and leadership consonant with such an appointment. Applicants should apply online at www.mathjobs.org. Position ID: PACM #3873. Applications received by December 15, 2012, will receive first consideration. For more information about this position, please visit our website: http://www.math.dartmouth.edu/activities/recruiting/. Dartmouth is committed to diversity and encourages applications from women and minorities.

000077

DARTMOUTH COLLEGE
Department of Mathematics

The Department of Mathematics anticipates a tenure-track opening with initial appointment in the 2013-2014 academic year, for a mathematician working in either topology or number theory. The appointment is for candidates at any rank. Applicants should apply online at www.mathjobs.org. Position ID: TTPTNT #3875. Applications received by December 15, 2012, will receive first consideration. For more information about this position, please visit our website: http://www.math.dartmouth.edu/activities/recruiting/. Dartmouth is committed to diversity and encourages applications from women and minorities.

000078

NORTH CAROLINA

THE UNIVERSITY OF NORTH CAROLINA AT GREENSBORO
Assistant/Associate Professor
Computational Mathematics

The University of North Carolina at Greensboro, Department of Mathematics and Statistics seeks applications for two tenure-track positions in computational mathematics at the Assistant Professor rank beginning 8/1/2013. Experienced candidates may also be considered for appointment at the rank of Associate Professor. Candidates must hold or anticipate a Ph.D. in mathematics or closely related area by August 1, 2013. Competitive applicants will have research that complements our Ph.D. program in computational mathematics. Preference will be given to candidates in mathematical biology and computational PDEs. Excellence in both teaching and research is expected.

Application materials should be submitted electronically to http://www.mathjobs.org. Review of applications will begin on December 15, 2012, and will be continued until filled.

UNCG is an EEO/AA employer with a strong commitment to increasing faculty diversity.

000099

TEXAS

TEXAS TECH UNIVERSITY
Department of Mathematics and Statistics

The Department of Mathematics and Statistics at Texas Tech University (M&S) invites applications for three tenure-track assistant professor positions beginning fall 2013. A Ph.D. degree at the time of appointment is required. M&S has active research groups in both pure and applied mathematics (see http://www.math.ttu.edu/FacultyStaff/research.shtml). The department fosters a spirit of interdisciplinary collaboration across areas of mathematics as well as with engineering and the physical and biological sciences. M&S is seeking candidates who will be engaged in nationally visible scholarship, establish externally-funded research programs, interact with the existing research groups in the department, involve graduate students in their research, and show excellence in teaching at the undergraduate and graduate levels.

It is anticipated that one of the positions will be in statistics, one in numerical analysis, and one in another area compatible with the department's existing research programs. Candidates with very strong records who will bring externally sponsored research to Texas Tech will be considered for associate or full professor ranks.

Please apply for position numbers T96800 for Statistics, T96232 for Numerical Analysis, and T96376 for all other areas, at http://jobs.texastech.edu. Include a completed AMS standard cover sheet and a vita.

Three letters of reference plus any material in addition to that completed online should be sent to:

Alex Wang, Hiring Committee Chair,
Department of Mathematics and Statistics,
Texas Tech University,
Lubbock, TX 79409-1042.

Review of applications will begin immediately.

Texas Tech University is committed to diversity among its faculty. We strongly encourage applications from women, minorities, persons with disabilities, and veterans, and we consider the needs of dual career couples.

Texas Tech University is an Affirmative Action/Equal Opportunity Employer.

000048

UNIVERSITY OF TEXAS AT SAN ANTONIO (UTSA)
Assistant Professor
Mathematics

The University of Texas at San Antonio (UTSA) invites applications for one tenure-track position at the rank of Assistant Professor in Mathematics starting in Fall 2013. The successful candidate will be expected to have Ph.D. degree in mathematics by the time of appointment, strong research record, and demonstrated evidence of excellent teaching ability. Information on the mathematics program, the full version of this job announcement, and details on what to include in an application can be viewed at http://math.utsa.edu. This position is pending budget approval. Applicants who are selected for interviews must be able to show proof that they will be eligible and qualified to work in the United States by time of hire. UTSA is an Affirmative Action/Equal Employment Opportunity Employer.

000114

VIRGINIA

UNIVERSITY OF VIRGINIA
Department of Mathematics
Pitts Instructorship

The Department of Mathematics at the University of Virginia invites applications for a Pitts Instructorship beginning August 25, 2013. This position carries a three-year appointment. Candidates whose research interests fit in with the strengths of the department's faculty are encouraged to apply. Preference will be given to candidates who have received their Ph.D. within the last three years. Candidates must have a Ph.D. by the time of appointment, an outstanding research record, and demonstrated teaching success. Information about the department may be found at: http://artsandsciences.virginia.edu/mathematics/index.html.

Applications should be received by January 15, 2013, to receive full consideration; however posting will remain open until filled. Early application is recommended.

To apply, submit the following required documents electronically through http://www.MathJobs.org: A cover letter, an AMS Standard Cover Sheet, a curriculum vitae, a publication list, a description of research, and a statement about teaching interests and experience. The applicant must also have four letters of recommendation submitted, of which one must support the applicant's effectiveness as a teacher.

In addition, all candidates are required to complete a Candidate Profile through the University of Virginia's employment system, which is Jobs@UVA (https://jobs.virginia.edu). Search for posting number 0611032 and follow the directions for applying to this posting to submit CV with a publication list, statement of research interest, and statement of teaching philosophy.

Questions regarding the application process for Jobs@UVa should be directed to: zk4g@virginia.edu.

For additional information about the position contact: mathematics-hiring@Virginia.EDU.

The university will perform background checks on all new faculty hires prior to making a final offer of employment.

The University of Virginia is an Equal Opportunity/Affirmative Action Employer. Women, minorities, veterans, and persons with disabilities are encouraged to apply.

000118

WISCONSIN

THE UNIVERSITY OF WISCONSIN-MADISON
Department of Mathematics

The Department of Mathematics is accepting applications to fill one position for a Faculty Associate, beginning August 26, 2013. A successful candidate will demonstrate strong qualifications in mathematics and mathematics education. A master's degree in mathematics or math education is required; preference will be given to a Ph.D. Experience with mathematics courses for pre-service and/or in-service teachers is also preferred. Duties include teaching 4 courses per year and updating courses for elementary education and special education majors. Additional information regarding this position can be found at the UW job site http://www.ohr.wisc.edu/WebListing/Unclassified/PVLSummary.aspx?pvl_num=74671.

An application packet should include a cover letter, a curriculum vitae, a statement of mathematics teaching philosophy and a detailed history of Mathematics/Mathematics Education courses taught. Application packets should be submitted electronically to http://www.mathjobs.org. Applicants should also arrange to have three to four letters of recommendation sent to mathjobs.org. To ensure full consideration, completed application packets must be received by January 2, 2013. The Department of Mathematics is committed to increasing the number of women and minority faculty. 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 applicants and nominees must be released upon request. Finalists cannot be guaranteed confidentiality. A background check may be required prior to employment. For more info about the UW Mathematics Department please see our website: http://www.math.wisc.edu.

000105

HONG KONG

THE UNIVERSITY OF HONG KONG
MR Post-doctoral Fellow in the Department of Mathematics
(Ref.: 201200919)

Applications are invited for appointment as Postdoctoral Fellow (2-3 posts) in the Department of Mathematics, from September 1, 2013, or as soon as possible thereafter, on a two-year term and with the possibility of renewal. An earlier start date can be discussed if a successful candidate finds it desirable.

Applicants should possess a Ph.D. degree. Preference will be given to those who have obtained their Ph.D. degrees within the last 6 years and whose areas of expertise fall within the following areas of concentration: algebra and number theory; geometry and lie groups; optimization, theoretical computer science and information theory; several complex variables and complex geometry; and probability theory, stochastics and mathematical finance. They are expected to show strong potential in mathematical research. The appointees will be associated with the Institute of Mathematical Research (IMR, http://www0.hku.hk/math/) and will be primarily engaged in mathematical research. They will also take active roles in the activities of IMR and contribute to the academic activities as assigned by the Head of the Department of Mathematics.

A highly competitive salary commensurate with qualifications and experience will be offered. Annual leave and medical benefits will be provided.

Applicants should send a completed application form, together with a C.V. containing information on educational experience, including the title of the thesis and the name of the thesis supervisor for the Ph.D. degree, professional experience, a list of publications, a survey of past research experience, a description of current research interests and a research plan for the next few years by e-mail to imrpostdoc@maths.hku.hk. Please indicate clearly **Ref.: 201200919** and (Post-doctoral Fellow (2-3 posts) in the Department of Mathematics) in the subject of the email. Application forms (341/1111) can be obtained at http://www.hku.hk/apptunit/form-ext.doc. Further particulars can be obtained at http://jobs.hku.hk/. Closes January 31, 2013.

The University thanks applicants for their interest, but advises that only shortlisted applicants will be notified of the application result.

The University is an Equal Opportunity Employer and is committed to a No-Smoking Policy.

000100

SINGAPORE

NATIONAL UNIVERSITY OF SINGAPORE (NUS)
Department of Mathematics

The Department of Mathematics at the National University of Singapore (NUS) invites applications for tenured, tenure-track and visiting positions at all levels, beginning in August 2013.

NUS is a research intensive university that provides quality undergraduate and graduate education. The Department of Mathematics has about 65 faculty members and teaching staff whose expertise covers major areas of contemporary mathematical research.

We seek promising scholars and established mathematicians with outstanding track records in any field of pure and applied mathematics. The department, housed in a newly renovated building equipped with state-of-the-art facilities, offers internationally competitive salary with start-up research grants, as well as an environment conducive to active research, with ample opportunities for career development. The teaching load for junior faculty is kept especially light.

The department is particularly interested in, but not restricted to, considering applicants specializing in any of the following areas:

- Analysis and Ergodic Theory
- Number Theory, Arithmetic Geometry
- Computational Science, especially Biomedical Imaging and Computational Material Sciences
- Probability, Stochastic Processes, and Financial Mathematics
- Combinatorics and Discrete Mathematics

Application materials should be sent to the Search Committee via email (as PDF files): search@math.nus.edu.sg.

Please include the following supporting documentation in the application:

1. an American Mathematical Society Standard Cover Sheet;
2. a detailed CV including publications list;
3. a statement (max. of 3 pages) of research accomplishments and plan;
4. a statement (max. of 2 pages) of teaching philosophy and methodology. Please attach evaluation on teaching from faculty members or students of your current institution, where applicable;
5. at least three letters of recommendation including one which indicates the candidate's effectiveness and commitment in teaching.

Please ask your referees to send their letters directly to search@math.nus.edu.sg.

Enquiries may also be sent to this email address. Review process will begin on 15 October, and will continue until positions are filled.

For further information about the department, please visit http://www.math.nus.edu.sg.

000069

AAAS Welcomes "Mathematics of Planet Earth" for 2013 Program

The American Association for the Advancement of Science (AAAS), founded in 1848, is the world's largest general scientific society, with over 120,000 individual and institutional members. The AAAS is divided into twenty-four disciplinary-based sections, including Section A (Mathematics). The 2013 annual meeting of the AAAS will be held in Boston on February 14–28. The theme of this year's meeting is "The Beauty and Benefits of Science", and this year's meeting features sessions that are part of Mathematics of Planet Earth 2013 (mpe2013.org).

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:

- Mathematics of Tipping Points: Framework, Applications, and Prediction, organized by Mary Lou Zeeman, Bowdoin College. (MPE 2013 symposium; scheduled speakers: Mary Silber, Sebastian Wieczorek, and Marten Scheffer.)
- Understanding and Communicating Uncertainty in Climate Change Science, organized by Richard L. Smith, University of North Carolina. (MPE 2013 symposium; scheduled speakers: Murali Haran, Leonard Smith, and Mark Berliner.)
- Compressive Sensing: Sensing Sparse Phenomena in Theory and Practice, organized by Mark Davenport, Stanford University. (Scheduled speakers: Mark Davenport, Justin Romberg, Dave Brady, Anna Gilbert, and Rachel Ward.)
- Multi-scale Study of Cancer, organized by Mark Alber, University of Notre Dame and Jill Mesirov, the Broad Institute of Harvard and MIT. (Scheduled speakers: Martin Nowak, Kathleen Wilkie, and Philip Maini.)

Other symposia that will be of interest to the mathematical community include:

- Is Beauty Truth? Mathematics in Physics from Dirac to the Higgs Boson and Beyond
- Predictability: From Physical to Data Sciences
- The Science of Uncertainty in Genomic Medicine
- Predictive Model of the Internal Combustion Engine
- Computation, Computational Efficiency, and Cognitive Science
- How Fundamental Computing Research Touches Everyday Lives
- Smart Phones, Smart Devices, Social Networks, and Smart Health Care
- Visualizing Chemistry: Seeing Another Dimension of Plants and Animals
- The 25th Anniversary of the First Collection in the History of Women in Science

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.

The AAAS Annual Meeting is the showcase of American science, and the AAAS seeks the active participation by mathematicians and mathematics educators. Looking ahead, the AAAS Program Committee is genuinely interested in offering symposia each year on topics in pure and applied mathematics. For example, in recent years there have been symposia on subjects such as the collective behavior of animals and people, the mathematics of medical imaging, quantum computing, and the changing nature of mathematical proof.

The 2014 meeting will be February 13–17, 2014 in Chicago, 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 Boston on Friday, February 15, 2013, 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 2012 to February 2013:

Chair: Jill Mesirov (Broad Institute of MIT and Harvard)
Chair-Elect: Juan Meza (University of California, Merced)
Retiring Chair: John H. Ewing (Math for America)
Secretary: Edward Aboufadel (Grand Valley State University)
Members at Large:
Tony Chan (Hong Kong University of Science and Technology)
Mary Ellen Bock (Purdue University)
Joceline Lega (University of Arizona)
Sheldon Katz (University of Illinois, Urbana-Champaign)

—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.

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 9–12, 2013

Wednesday – Saturday

Meeting #1086

Joint Mathematics Meetings, including the 119th Annual Meeting of the AMS, 96th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Georgia Benkart
Announcement issue of *Notices*: October 2012
Program first available on AMS website: November 1, 2012
Program issue of electronic *Notices*: January 2012
Issue of *Abstracts*: Volume 34, Issue 1

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Oxford, Mississippi

University of Mississippi

March 1–3, 2013

Friday – Sunday

Meeting #1087

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: December 2012
Program first available on AMS website: December 13, 2012
Program issue of electronic *Notices*: March 2013
Issue of *Abstracts*: Volume 34, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: December 4, 2012

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Patricia Hersh, North Carolina State University, *An interplay of combinatorics with topology*.

Daniel Krashen, University of Georgia, *Topology, arithmetic, and the structure of algebraic groups*.

Washington Mio, Florida State University, *Taming shapes and understanding their variation*.

Slawomir Solecki, University of Illinois at Urbana-Champaign, *An abstract approach to Ramsey theory with applications*.

Special Sessions

Algebraic Combinatorics (Code: SS 1A), **Patricia Hersh**, North Carolina State University, and **Dennis Stanton**, University of Minnesota.

Approximation Theory and Orthogonal Polynomials (Code: SS 5A), **David Benko**, University of South Alabama, **Erwin Mina-Diaz**, University of Mississippi, and **Edward Saff**, Vanderbilt University.

Banach Spaces and Operators on Them (Code: SS 4A), **Qingying Bu** and **Gerard Buskes**, University of Mississippi, and **William B. Johnson**, Texas A&M University.

Commutative Algebra (Code: SS 3A), **Sean Sather-Wagstaff**, North Dakota State University, and **Sandra M. Spiroff**, University of Mississippi.

Connections between Matroids, Graphs, and Geometry (Code: SS 10A), **Stan Dziobiak**, **Talmage James Reid**, and **Haidong Wu**, University of Mississippi.

Dynamical Systems (Code: SS 8A), **Alexander Grigo**, University of Oklahoma, and **Saša Kocić**, University of Mississippi.

Fractal Geometry and Ergodic Theory (Code: SS 2A), **Manav Das**, University of Louisville, and **Mrinal Kanti Roychowdhury**, University of Texas-Pan American.

Graph Theory (Code: SS 7A), **Laura Sheppardson** and **Bing Wei**, University of Mississippi, and **Hehui Wu**, McGill University.

Homology and Cohomology of Arithmetic Groups (Code: SS 11A), **Avner Ash**, Boston College, **Darrin Doud**, Brigham Young University, and **David Pollack**, Wesleyan University.

Modern Methods in Analytic Number Theory (Code: SS 6A), **Nathan Jones** and **Micah B. Milinovich**, University of Mississippi, and **Frank Thorne**, University of South Carolina.

Set Theory and Its Applications (Code: SS 9A), **Christian Rosendal**, University of Illinois at Chicago, and **Slawomir Solecki**, University of Illinois at Urbana-Champaign.

Session for Contributed Talks

There also will be a session for 10-minute contributed talks. Please see the abstracts submission form at http://www.ams.org/cgi-bin/abstracts/abstract.pl. The deadline for all submissions is December 4, 2012.

Accommodations

Participants should make their own arrangements directly with the properties listed below. Special rates for the meeting have been negotiated and are available at the properties shown below for the period of February 28–March 3, 2013, except where noted. When making reservations participants should state that they are with the American Mathematical Society meeting on campus. Hotels have varying cancellation or early checkout penalties; be sure to ask for details when making your reservation. The room rates listed do not include applicable taxes; the current tax rate on hotel rooms is 7%.

Inn at Ole Miss, 1 Alumni Dr. (on campus), University, MS 38677; phone: 662-234-2331 or 888-486-7666; fax: 662-536-4835. http://theinnatolemiss.com. Standard double accommodations are US$94/night and are equipped with two double beds. Deluxe accommodations are US$114/night and are equipped with two double beds, one king bed, one queen bed, or two queen beds and may also include microwaves or minirefrigerators. One-bedroom suites are the newest rooms in the hotel for US$159/night and are equipped with two queen beds, a separate living area, a kitchenette, and pull-out sofa.

Rates include free wireless Internet access, in-room coffeemaker, complimentary deluxe continental breakfast, fitness center, and complimentary shuttle service to and from Oxford Square nightly, where many restaurants are located. The McCormick Cafe on premises is open for breakfast Monday–Sunday, 7:00 a.m. to 10:00 a.m., and lunch Monday–Friday. Hotels have varying cancellation or early checkout penalties; be sure to ask for details when making your reservation. **The deadline for reservations is February 14, 2013.**

University Inn Oxford,1101 Bickerstaff Dr., Oxford, MS 38655; phone: 662-234-9500; fax: 662-234-9330. US$70 for single/double (note that no rooms are available at this rate on Thursday night, Feb. 28). Rooms are equipped with a coffee maker, microwave, and refrigerator. Rates include complimentary hot/cold breakfast buffet, free wired/wireless Internet access. There are several popular restaurants within a mile or so. Distance to the meeting site is 1.6 miles. Hotels have varying cancellation or early checkout penalties; be sure to ask for details when making your reservation. **The deadline for reservations is February 8, 2013.**

Super 8 Oxford, 2201 Jackson Ave., West, Oxford, MS 38655; phone: 662-234-7013; fax: 662-236-4378. US$72.99 for single/double. Rooms are equipped with refrigerators, microwaves, and coffee makers. Rates include complimentary continental breakfast with some hot items, free high-speed wireless, heated outdoor pool, and on-site fitness room. University Mall is across the street; a variety of restaurants and cocktail lounges are within easy walking distance. Distance to the meeting site is 1.5 mi. Hotels have varying cancellation or early checkout penalties; be sure to ask for details when making your reservation. **The deadline for reservations is February 7, 2012.**

Other options for accommodations: For other types of accommodations, please see the website maintained by the Oxford Convention and Visitors Bureau at www.oxfordcvb.com/lodging.html.

Dining on Campus

There are a number of dining options in the Student Union Food Court, open 7:00 a.m. to 9:00 p.m. on Friday, and 10:00 a.m. to 8:00 p.m. on Saturday and Sunday. There are many other options if one walks about 1/2 mile west on University Ave. out to N. Lamar Blvd.

Local Information and Maps

The University of Mississippi Department of Mathematics website is found at www.olemiss.edu/depts/mathematics/. A campus map is found at www.olemiss.edu; click on "MAP" in the links references at the top of the page.

Other Activities

AMS Book Sale: Stop by the on-site AMS bookstore and review the newest titles from the AMS, enjoy up to 25% off all AMS publications, or take home an AMS t-shirt! Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Parking

Please watch the AMS website at http://www.ams.org/meetings/sectional/sectional.html and follow

this link for this meeting for information on regulations, fees, and locations to park near the buildings where sessions will be held.

Registration and Meeting Information

The meeting will take place on the campus of the University of Mississippi. Registration will be conducted in Hume Hall (also the location of the Department of Mathematics) and sessions will be held in Hume Hall, The Ole Miss Union, and Fulton Chapel. The registration desk will be open Friday, 1:00 p.m.–5:00 p.m., and Saturday, 7:30 a.m.–4:00 p.m. Fees are US$53 for AMS members, US$74 for nonmembers; and US$5 for students, unemployed mathematicians, and emeritus members. Fees are payable on-site by cash, check, or credit card.

Travel Information

The Oxford Convention and Visitors Bureau website includes a wealth of information about the Oxford area, including maps, a restaurant guide, and a wealth of information about the sites to see. The area may be best known as the home of Nobel Prize winning author William Faulkner. Successful author John Grisham also has a home in Oxford.

The nearest large airport is Memphis International Airport (MEM) 2491 Winchester Road Suite 113 Memphis, TN 38116-3856; (901) 922-8000. The airport is about 75 miles north of Oxford, about a 1 1/4 hour drive. There are no shuttles to the campus; cab fare would be US $182.50 each way (fixed rate).

Getting to the campus by car:

From Memphis, TN (north of campus): Take I-55 south for 63 miles, then take the Batesville/Oxford exit. Merge onto MS-6 and proceed east toward Oxford for 26 miles. When you reach Oxford, take the second exit, Coliseum Drive, onto campus. Or, take US-78 for 52 miles and exit at Holly Springs/Oxford and merge onto MS-7 south for 31 miles. Once in Oxford take the 4th exit onto MS-6 and proceed west. Take the 3rd exit, Coliseum Drive, onto campus.

From Jackson, MS (south of campus): Take I-55 north for 150 miles, then take the Batesville/Oxford exit and follow as described above.

From Tupelo, MS (east of campus): Take MS-6 west for 53 miles, then take the 6th exit, Coliseum Drive, onto campus.

Car Rental

Hertz is the official car rental company for the meeting. To make a reservation accessing our special meeting rates online at www.hertz.com, click on the box "I have a discount", and type in our convention number (CV): 04N30003. You can also call Hertz directly at 800-654-2240 (U.S. and Canada) or 405-749-4434 (other countries). At the time this announcement was prepared, rates were US$28.49 to US$71.49 per day on the weekend. At the time of your reservation, the meeting rates will be automatically compared to other Hertz rates and you will be quoted the best comparable rate available.

Weather

Early March weather can be quite variable with temperatures ranging from the high 50s into the 80s, so dressing in layers is advised. Passing showers are a possibility.

Information for International Participants

Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the U.S. found at http://sites.nationalacademies.org/pga/biso/visas/ and http://travel.state.gov/visa/visa_1750.html. If you need a preliminary conference invitation in order to secure a visa, please send your request to dls@ams.org.

If you discover you do need a visa, the National Academies website (see above) provides these tips for successful visa applications:

* Visa applicants are expected to provide evidence that they are intending to return to their country of residence. Therefore, applicants should provide proof of "binding" or sufficient ties to their home country or permanent residence abroad. This may include documentation of the following:

- family ties in home country or country of legal permanent residence
- property ownership
- bank accounts
- employment contract or statement from employer stating that the position will continue when the employee returns;

* Visa applications are more likely to be successful if done in a visitor's home country than in a third country;

* Applicants should present their entire trip itinerary, including travel to any countries other than the United States, at the time of their visa application;

* Include a letter of invitation from the meeting organizer or the U.S. host, specifying the subject, location and dates of the activity, and how travel and local expenses will be covered;

* If travel plans will depend on early approval of the visa application, specify this at the time of the application;

* Provide proof of professional scientific and/or educational status (students should provide a university transcript).

This list is not to be considered complete. Please visit the websites above for the most up-to-date information.

Chestnut Hill, Massachusetts

Boston College

April 6–7, 2013

Saturday – Sunday

Meeting #1088

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2013
Program first available on AMS website: February 21, 2013
Program issue of electronic *Notices*: April 2013
Issue of *Abstracts*: Volume 34, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: December 18, 2012
For abstracts: February 12, 2013

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Roman Bezrukavnikov, Massachusetts Institute of Technology, *Title to be announced*.

Marston Conder, University of Auckland, *Title to be announced*.

Alice Guionnet, Ecole Normale Supérieure de Lyon, *Title to be announced*.

Yanir Rubinstein, Stanford University, *Title to be announced*.

Special Sessions

Algebraic and Geometric Structures of 3-manifolds (Code: SS 3A), **Ian Biringer**, **Tao Li**, and **Robert Meyerhoff**, Boston College.

Algorithmic Problems of Group Theory and Applications to Information Security (Code: SS 14A), **Delaram Kahrobaei**, City University of New York Graduate Center and New York College of Technology, and **Vladimir Shpilrain**, City College of New York and City University of New York Graduate Center.

Arithmetic Dynamics and Galois Theory (Code: SS 6A), **John Cullinan**, Bard College, and **Farshid Hajir** and **Siman Wong**, University of Massachusetts, Amherst.

Combinatorics and Classical Integrability (Code: SS 16A), **Amanda Redlich** and **Shabnam Beheshti**, Rutgers University.

Commuting Matrices and the Hilbert Scheme (Code: SS 11A), **Anthony Iarrobino**, Northeastern University, and **Leila Khatami**, Union College.

Complex Geometry and Microlocal Analysis (Code: SS 2A), **Victor W. Guillemin** and **Richard B. Melrose**, Massachusetts Institute of Technology, and **Yanir A. Rubinstein**, Stanford University.

Counting and Equidistribution on Symmetric Spaces (Code: SS 5A), **Dubi Kelmer**, Boston College, and **Alex Kontorovich**, Yale University.

Discrete Geometry of Polytopes (Code: SS 10A), **Barry Monson**, University of New Brunswick, and **Egon Schulte**, Northeastern University.

Financial Mathematics (Code: SS 18A), **Hasanjan Sayit** and **Stephan Sturm**, Worcester Polytechnic Institute.

History and Philosophy of Mathematics (Code: SS 7A), **James J. Tattersall**, Providence College, and **V. Frederick Rickey**, United States Military Academy.

Homological Invariants in Low-dimensional Topology. (Code: SS 1A), **John Baldwin**, **Joshua Greene**, and **Eli Grigsby**, Boston College.

Homology and Cohomology of Arithmetic Groups (Code: SS 13A), **Avner Ash**, Boston College, **Darrin Doud**, Brigham Young University, and **David Pollack**, Wesleyan University.

Hopf Algebras and their Applications (Code: SS 9A), **Timothy Kohl**, Boston University, and **Robert Underwood**, Auburn University Montgomery.

Moduli Spaces in Algebraic Geometry (Code: SS 4A), **Dawei Chen** and **Maksym Fedorchuk**, Boston College, and **Joe Harris** and **Yu-Jong Tzeng**, Harvard University.

Real and Complex Dynamics of Difference Equations with Applications (Code: SS 12A), **Ann Brett**, Johnson and Wales University, and **M. R. S. Kulenovic**, University of Rhode Island.

Recursion and Definability (Code: SS 15A), **Rachel Epstein**, Harvard University, **Karen Lange**, Wellesley College, and **Russell Miller**, Queens College and City University of New York Graduate Center.

Research by Undergraduates and Students in Post-Baccalaureate Programs (Code: SS 8A), **Chi-Keung Cheung**, Boston College, **David Damiano**, College of the Holy Cross, **Steven J. Miller**, Williams College, and **Suzanne L. Weekes**, Worcester Polytechnic Institute.

Topology and Generalized Cohomologies in Modern Condensed Matter Physics (Code: SS 17A), **Claudio Chamon** and **Robert Kotiuga**, Boston University.

Boulder, Colorado

University of Colorado Boulder

April 13–14, 2013

Saturday – Sunday

Meeting #1089

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: January 2013
Program first available on AMS website: February 28, 2013
Program issue of electronic *Notices*: April 2013
Issue of *Abstracts*: Volume 34, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: December 26, 2012
For abstracts: February 19, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Gunnar Carlsson, Stanford University, *Title to be announced.*

Jesus A. De Loera, University of California, Davis, *Title to be announced.*

Brendan Hassett, Rice University, *Title to be announced.*

Raphael Rouquier, University of California Los Angeles, *Title to be announced.*

Special Sessions

Advances in Mathematical Biology (Code: SS 16A), **Liming Wang**, California State University, Los Angeles, and **Jiangguo Liu**, Colorado State University.

Algebraic Geometry (Code: SS 14A), **Sebastian Casalaina-Martin**, University of Colorado, **Renzo Cavalieri**, Colorado State University, **Brendan Hassett**, Rice University, and **Jonathan Wise**, University of Colorado.

Algebras, Lattices and Varieties (Code: SS 5A), **Keith A. Kearnes** and **Ágnes Szendrei**, University of Colorado, Boulder.

Analysis of Dynamics of the Incompressible Fluids (Code: SS 18A), **Mimi Dai** and **Congming Li**, University of Colorado, Boulder.

Arithmetic Statistics and Big Monodromy (Code: SS 23A), **Jeff Achter**, Colorado State University, and **Chris Hall**, University of Wyoming.

Associative Rings and Their Modules (Code: SS 1A), **Greg Oman** and **Zak Mesyan**, University of Colorado, Colorado Springs.

Cluster Algebras and Related Combinatorics (Code: SS 6A), **Gregg Musiker**, University of Minnesota, **Kyungyong Lee**, Wayne State University, and **Li Li**, Oakland University.

Combinatorial Avenues in Representation Theory (Code: SS 21A), **Richard Green**, University of Colorado Boulder, **Anne Shepler**, University of North Texas, and **Nathaniel Thiem**, University of Colorado Boulder.

Combinatorial and Computational Commutative Algebra and Algebraic Geometry (Code: SS 7A), **Hirotachi Abo**, University of Idaho, **Zach Teitler**, Boise State University, and **Alexander Woo**, University of Idaho.

Diophantine Approximation on Manifolds and Fractals: Dynamics, Measure Theory and Schmidt Games. (Code: SS 15A), **Wolfgang Schmidt**, University of Colorado at Boulder, and **Lior Fishman**, University of North Texas.

Dynamical Systems: Thermodynamic Formalism and Connections with Geometry (Code: SS 10A), **Keith Burns**, Northwestern University, and **Dan Thompson**, The Ohio State University.

Dynamics and Arithmetic Geometry (Code: SS 2A), **Suion Ih**, University of Colorado at Boulder, and **Thomas J. Tucker**, University of Rochester.

Elliptic Systems and Their Applications (Code: SS 20A), **Wenxiong Chen**, Yeshiva University, and **Congming Li**, University of Colorado at Boulder.

Extremal Graph Theory (Code: SS 3A), **Michael Ferrara**, University of Colorado Denver, **Stephen Hartke**, University of Nebraska-Lincoln, and **Michael Jacobson**, University of Colorado Denver.

Foundations of Computational Mathematics (Code: SS 13A), **Susan Margulies**, Pennsylvania State University, and **Jesus De Loera**, University of California, Davis.

Geometric Methods in the Representation Theory of Reductive Groups (Code: SS 19A), **J. Matthew Douglass**, University of North Texas, **Gerhard Roehrle**, Ruhr-Universitaet Bochum, and **Rahbar Virk**, University of Colorado Boulder.

Harmonic Analysis of Frames, Wavelets, and Tilings (Code: SS 12A), **Veronika Furst**, Fort Lewis College, **Keri Kornelson**, University of Oklahoma, and **Eric Weber**, Iowa State University.

Noncommutative Geometry and Geometric Analysis (Code: SS 22A), **Carla Farsi** and **Alexander Gorokhovsky**, University of Colorado, Boulder.

Nonlinear Waves and Integrable Systems (Code: SS 9A), **Christopher W. Curtis**, University of Colorado, Boulder, **Anton Dzhamay**, University of Northern Colorado, **Willy Hereman**, Colorado School of Mines, and **Barbara Prinari**, University of Colorado, Colorado Springs.

Number Theory with a Focus on Diophantine Equations and Recurrence Sequences (Code: SS 8A), **Patrick Ingram**, Colorado State University, and **Katherine E. Stange**, University of Colorado, Boulder.

Set Theory and Boolean Algebras (Code: SS 17A), **Natasha Dobrinen**, University of Denver, and **Don Monk**, University of Colorado, Boulder.

Singular Spaces in Geometry, Topology, and Algebra (Code: SS 11A), **Greg Friedman**, Texas Christian University, and **Laurentiu Maxim**, University of Wisconsin, Madison.

Themes in Applied Mathematics: From Data Analysis through Fluid Flows and Biology to Topology (Code: SS 4A), **Hanna Makaruk**, Los Alamos National Laboratory, and **Robert Owczarek**, University of New Mexico, and Enfitek, Inc.

Ames, Iowa

Iowa State University

April 27–28, 2013

Saturday – Sunday

Meeting #1090

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: February 2013
Program first available on AMS website: March 14, 2013
Program issue of electronic *Notices*: April 2013

Issue of *Abstracts*: Volume 34, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: January 18, 2013
For abstracts: March 5, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Kevin Costello, Northwestern University, *Title to be announced.*

Marianne Csornyei, University of Chicago, *Title to be announced.*

Vladimir Markovic, California Institute of Technology, *Title to be announced.*

Eitan Tadmor, University of Maryland, *Title to be announced.*

Special Sessions

Algebraic and Geometric Combinatorics (Code: SS 4A), **Sung Y. Song**, Iowa State University, and **Paul Terwilliger**, University of Wisconsin-Madison.

Analysis, Dynamics and Geometry In and Around Teichmuller Spaces (Code: SS 17A), **Alistair Fletcher**, Northern Illinois University, **Vladimir Markovic**, California Institute of Technology, and **Dragomir Saric**, Queens College CUNY.

Commutative Algebra and its Environs (Code: SS 6A), **Olgur Celikbas** and **Greg Piepmeyer**, University of Missouri, Columbia.

Commutative Ring Theory (Code: SS 8A), **Michael Axtell**, University of St. Thomas, and **Joe Stickles**, Millikin University.

Computability and Complexity in Discrete and Continuous Worlds (Code: SS 11A), **Jack Lutz** and **Tim McNicholl**, Iowa State University.

Computational Advances on Special Functions and Tropical Geometry (Code: SS 14A), **Lubjana Beshaj**, Oakland University, and **Emma Previato**, Boston University.

Control Theory and Qualitative Analysis of Partial Differential Equations (Code: SS 16A), **George Avalos**, University of Nebraska-Lincoln, and **Scott Hansen**, Iowa State University.

Discrete Methods and Models in Mathematical Biology (Code: SS 18A), **Dora Matache**, University of Nebraska-Omaha, and **Stephen J. Willson**, Iowa State University.

Extremal Combinatorics (Code: SS 7A), **Steve Butler** and **Ryan Martin**, Iowa State University.

Generalizations of Nonnegative Matrices and Their Sign Patterns (Code: SS 3A), **Minerva Catral**, Xavier University, **Shaun Fallat**, University of Regina, and **Pauline van den Driessche**, University of Victoria.

Geometric Elliptic and Parabolic Partial Differential Equations (Code: SS 13A), **Brett Kotschwar**, Arizona State University, and **Xuan Hien Nguyen**, Iowa State University.

Logic and Algebraic Logic (Code: SS 9A), **Jeremy Alm**, Illinois College, and **Andrew Ylvisaker**, Iowa State University.

Multi-Dimensional Dynamical Systems (Code: SS 15A), **Jayadev Athreya**, University of Illinois at Chicago, **Jonathan Chaika**, University of Chicago, and **Joseph Rosenblatt**, University of Illinois at Urbana-Champaign.

Numerical Analysis and Scientific Computing (Code: SS 20A), **Hailiang Liu**, **Songting Luo**, **James Rossmanith**, and **Jue Yan**, Iowa State University.

Numerical Methods for Geometric Partial Differential Equations (Code: SS 22A), **Gerard Awanou**, University of Illinois at Chicago, and **Nicolae Tarfulea**, Purdue University.

Operator Algebras and Topological Dynamics (Code: SS 1A), **Benton L. Duncan**, North Dakota State University, and **Justin R. Peters**, Iowa State University.

Partial Differential Equations (Code: SS 12A), **Gary Lieberman** and **Paul Sacks**, Iowa State University, and **Mahamadi Warma**, University of Puerto Rico at Rio Piedras.

Probabilistic and Multiscale Modeling Approaches in Cell and Systems Biology (Code: SS 19A), **Jasmine Foo**, University of Minnesota, and **Anastasios Matzavinos**, Iowa State University.

Quasigroups, Loops, and Nonassociative Division Algebras (Code: SS 21A), **C. E. Ealy Jr.**, Western Michigan University, **Annegret Paul**, Westerm Michigan University, **Benjamin Phillips**, University of Michigan Dearborn, **J. D. Phillips**, Northern Michigan University, and **Petr Vojtechovsky**, University of Denver.

Ring Theory and Noncommutative Algebra (Code: SS 24A), **Victor Camillo**, University of Iowa, and **Miodrag C. Iovanov**, University of Bucharest and University of Iowa.

Stochastic Processes with Applications to Physics and Control (Code: SS 10A), **Jim Evans** and **Arka Ghosh**, Iowa State University, **Jon Peterson**, Purdue University, and **Alexander Roitershtein**, Iowa State University.

Topology of 3-Manifolds (Code: SS 23A), **Marion Campisi** and **Alexander Zupan**, University of Texas at Austin.

Zero Forcing, Maximum Nullity/Minimum Rank, and Colin de Verdiere Graph Parameters (Code: SS 2A), **Leslie Hogben**, Iowa State University and American Institute of Mathematics, and **Bryan Shader**, University of Wyoming.

Alba Iulia, Romania

June 27–30, 2013

Thursday – Sunday

Meeting #1091

First Joint International Meeting of the AMS and the Romanian Mathematical Society, in partnership with the "Simion Stoilow" Institute of Mathematics of the Romanian Academy.

Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: January 2013
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/internmtgs.html.

Invited Addresses

Viorel Barbu, Universitatea Cuza, *Title to be announced.*

Sergiu Klainerman, Princeton University, *Title to be announced.*

George Lusztig, Massachusetts Institute of Technology, *Title to be announced.*

Stefan Papadima, Institute of Mathematicsof the Romanian Academy of Sciences, *Title to be announced.*

Dan Timotin, Institute of Mathematics of the Romanian Academy of Sciences, *Title to be announced.*

Srinivasa Varadhan, New York University, *Title to be announced.*

Louisville, Kentucky

University of Louisville

October 5–6, 2013

Saturday – Sunday

Meeting #1092

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: June 2013
Program first available on AMS website: August 22, 2013
Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 33, Issue 3

Deadlines

For organizers: March 5, 2013
For consideration of contributed papers in Special Sessions: June 18, 2013
For abstracts: August 13, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Michael Hill, University of Virginia, *Title to be announced.*

Suzanne Lenhart, University of Tennessee, *Title to be announced.*

Ralph McKenzie, Vanderbilt University, *Title to be announced.*

Victor Moll, Tulane University, *Title to be announced.*

Special Sessions

Set Theory and Its Applications (Code: SS 1A), **Paul Larson**, Miami University, **Justin Moore**, Cornell University, and **Grigor Sargsyan**, Rutgers University.

Philadelphia, Pennsylvania

Temple University

October 12–13, 2013

Saturday – Sunday

Meeting #1093

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: June 2013
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 33, Issue 3

Deadlines

For organizers: March 12, 2013
For consideration of contributed papers in Special Sessions: June 25, 2013
For abstracts: August 20, 2013

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Patrick Brosnan, University of Maryland, *Title to be announced.*

Xiaojung Huang, Rutgers University, *Title to be announced.*

Barry Mazur, Harvard University, *Title to be announced* (Erdős Memorial Lecture).

Robert Strain, University of Pennsylvania, *Title to be announced.*

Special Sessions

Contact and Symplectic Topology (Code: SS 5A), **Joshua M. Sabloff**, Haverford College, and **Lisa Traynor**, Bryn Mawr College.

Geometric and Spectral Analysis (Code: SS 3A), **Thomas Krainer**, Pennsylvania State Altoona, and **Gerardo A. Mendoza**, Temple University.

Higher Structures in Algebra, Geometry and Physics (Code: SS 2A), **Jonathan Block**, University of Pennsylvania, **Vasily Dolgushev**, Temple University, and **Tony Pantev**, University of Pennsylvania.

History of Mathematics in America (Code: SS 4A), **Thomas L. Bartlow**, Villanova University, **Paul R. Wolfson**, West Chester University, and **David E. Zitarelli**, Temple University.

Recent Advances in Harmonic Analysis and Partial Differential Equations (Code: SS 1A), **Cristian Gutiérrez** and **Irina Mitrea**, Temple University.

Recent Developments in Noncommutative Algebra (Code: SS 6A), **Edward Letzter** and **Martin Lorenz**, Temple University.

St. Louis, Missouri

Washington University

October 18–20, 2013

Friday – Sunday

Meeting #1094

Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: August 2013
Program first available on AMS website: September 5, 2013
Program issue of electronic *Notices*: October 2013
Issue of *Abstracts*: Volume 33, Issue 4

Deadlines

For organizers: March 20, 2013
For consideration of contributed papers in Special Sessions: July 2, 2013
For abstracts: August 27, 2013

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Ronny Hadani, University of Texas at Austin, *Title to be announced.*

Effie Kalfagianni, Michigan State University, *Title to be announced.*

Jon Kleinberg, Cornell University, *Title to be announced.*

Vladimir Sverak, University of Minnesota, *Title to be announced.*

Special Sessions

Algebraic and Combinatorial Invariants of Knots (Code: SS 1A), **Heather Dye**, McKendree University, **Allison Henrich**, Seattle University, and **Louis Kauffman**, University of Illinois.

Computability Across Mathematics (Code: SS 2A), **Wesley Calvert**, Southern Illinois University, and **Johanna Franklin**, University of Connecticut.

Riverside, California

University of California Riverside

November 2–3, 2013

Saturday – Sunday

Meeting #1095

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2013
Program first available on AMS website: September 19, 2013
Program issue of electronic *Notices*: November 2013
Issue of *Abstracts*: Volume 33, Issue 4

Deadlines

For organizers: April 2, 2013
For consideration of contributed papers in Special Sessions: July 15, 2013
For abstracts: September 10, 2013

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Michael Christ, University of California, Berkeley, *Title to be announced.*

Mark Gross, University of California, San Diego, *Title to be announced.*

Matilde Marcolli, California Institute of Technology, *Title to be announced.*

Paul Vojta, California Institute of Technology, *Title to be announced.*

Baltimore, Maryland

Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner Harbor Hotel at Camden Y

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 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: April 1, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Knoxville, Tennessee

University of Tennessee, Knoxville

March 21–23, 2014

Friday – Sunday
Southeastern Section
Associate secretary: Robert J. Daverman
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 21, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Albuquerque, New Mexico

University of New Mexico

April 5–6, 2014

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*: April 2014
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 5, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: February 11, 2014

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Special Sessions

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.

Lubbock, Texas

Texas Tech University

April 11–13, 2014

Friday – Sunday
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 18, 2013
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Tel Aviv, Israel

Bar-Ilan University, Ramat-Gan and Tel-Aviv University, Ramat-Aviv

June 16–19, 2014

Monday – Thursday
The 2nd Joint International Meeting between the AMS and the Israel Mathematical Union.
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/internmtgs.html`.

AMS 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
Central Section
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines
For organizers: February 20, 2014
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: August 5, 2014

San Francisco, California

San Francisco State University

October 25–26, 2014
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 2014
Issue of *Abstracts*: To be announced

Deadlines
For organizers: March 25, 2014
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: September 3, 2014

San Antonio, Texas

Henry B. Gonzalez Convention Center and Grand Hyatt San Antonio

January 10–13, 2015
Saturday – Tuesday
Joint Mathematics Meetings, including the 121st Annual Meeting of the AMS, 98th Annual Meeting of the Mathematical Association of America (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 consideration of contributed papers in Special Sessions: To be announced
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 consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Porto, Portugal

University of Porto

June 11–14, 2015
Thursday – Sunday
First Joint International Meeting between the AMA and the Sociedade Portuguesa de Matemática.
Associate secretary: Georgia Benkart
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: Not applicable

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Seattle, Washington

Washington State Convention Center and the Sheraton Seattle Hotel

January 6–9, 2016

Wednesday – Saturday

Joint Mathematics Meetings, including the 122nd Annual Meeting of the AMS, 99th Annual Meeting of the Mathematical Association of America (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 consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Atlanta, Georgia

Hyatt Regency Atlanta and Marriott Atlanta Marquis

January 4–7, 2017

Wednesday – Saturday

Joint Mathematics Meetings, including the 123rd Annual Meeting of the AMS, 100th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Georgia Benkart
Announcement issue of *Notices*: October 2016
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2017
Issue of *Abstracts*: Volume 38, Issue 1

Deadlines

For organizers: April 1, 2016
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Diego, California

San Diego Convention Center and San Diego Marriott Hotel and Marina

January 10–13, 2018

Wednesday – Saturday

Joint Mathematics Meetings, including the 124th Annual Meeting of the AMS, 101st Annual Meeting of the Mathematical Association of America (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: Matthew Miller
Announcement issue of *Notices*: October 2017
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 1, 2017
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Baltimore, Maryland

Baltimore Convention Center, Hilton Baltimore, and Baltimore Marriott Inner Harbor Hotel at Camden Y

January 16–19, 2019

Wednesday – Saturday

Joint Mathematics Meetings, including the 125th Annual Meeting of the AMS, 102nd 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 2018
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 2, 2018
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

AMERICAN MATHEMATICAL SOCIETY

Math in the Media

www.ams.org/mathmedia

coverage of today's applications of mathematics and other math news

"Is That Painting Real? Ask a Mathematician"
Christian Science Monitor

"Journeys to the Distant Fields of Prime"
The New York Times

"He's Too Good at Math"
Slate Magazine

"Sensor Sensibility"
Science News

"Into the Fold"
Smithsonian

"Fast Routing in Road Networks with Transit Nodes"
Science

"Puzzle Me This"
Chronicle of Higher Education

"Added Dimensions to Grain Growth"
Nature

"Students Learn to Rhythmic Beat of Rap"
NCTimes.com

"The Science of Steadying a Wobbly Table"
National Public Radio

"Muslim Tile Patterns Show Math Prowess"
The Washington Post

"Art: Of Doilies and Disease"
Discover

"Fish Virus Spreads in Great Lakes"
National Public Radio

"Team Cracks Century-Old Math Puzzle"
Associated Press

"The Geometry of Music"
Time

"The Monty Hall Problem"
abcnews.com

"The Prosecutor's Fallacy"
The New York Times

"By the NUMB3RS"
The Baltimore Sun

See the current **Math in the Media** and explore the archive at **www.ams.org/mathmedia**

AMS
AMERICAN MATHEMATICAL SOCIETY

The 2012 *Notices* Index

January issue: 1–256
February issue: 257–360
March issue: 361–472
April issue: 473–608
May issue: 609–736
June/July issue: 737–904
August issue: 905–1048
September issue: 1049–1200
October issue: 1201–1376
November issue: 1377–1512
December issue: 1513–1648

Index Section	Page Number
The AMS	1626
Announcements	1627
Articles	1627
Authors	1629
Deaths of Members of the Society	1632
Grants, Fellowships, Opportunities	1633
Letters to the Editor	1635
Meetings Information	1635
New Publications Offered by the AMS	1635
Obituaries	1635
Opinion	1636
Prizes and Awards	1636
Prizewinners	1639
Reference and Book List	1643
Reviews	1643
Surveys	1643
Tables of Contents	1644

About the Cover

110, 346, 399, 600, 654, 801, 984, 1126, 1288, 1390, 1558

The AMS

2012–2013 AMS Centennial Fellowship Awarded, 844
2011 Election Results, 334
2012 Boston, MA, Joint Mathematics Meetings Photo Key, 555
2011 Trjitzinsky Memorial Awards Presented, 65
2012 AMS Election—Nominations by Petition, 335
2012 AMS-SIAM Birkhoff Prize, 576
2012 Award for an Exemplary Program or Achievement in a Mathematics Department, 667
2012 Cole Prize in Algebra, 567
2012 Conant Prize, 568
2012 Mathematics Programs That Make a Difference, 665
2012 Morgan Prize, 572
2012 Steele Prizes, 563
2012 Trjitzinsky Memorial Awards Presented, 1581
2012 Whiteman Prize, 572
American Mathematical Society Centennial Fellowships, 1120, 1459
American Mathematical Society—Contributions, 701
AMS–AAS Mass Media Fellow Chosen, 850
AMS-AAAS Mass Media Summer Fellowships, 1279
AMS Congressional Fellow Chosen, 974
AMS Congressional Fellowship, 1460
AMS Department Chairs Workshop, 1461
AMS Electronic Products Are Now Mobile, 974
AMS Email Support for Frequently Asked Questions, 328
AMS Epsilon Fund, 1459
AMS Fellows Selected, 1465
AMS Holds Workshop for Department Chairs, 694
AMS Hosts Congressional Briefing, 442
AMS Menger Awards at the 2012 ISEF, 1118
AMS Officers and Committee Members, 1290
AMS Presents the Book Series *Pure and Applied Undergraduate Texts*, 1125
AMS Scholarships for "Math in Moscow", 971
AMS Short Course in San Diego, CA, 1319
AMS-Simons Travel Grants for Early-Career Mathematicians, 441
AMS Sponsors Exhibit at Capitol Hill Event, 975
AMS Travel Grants for MCA 2013, August 5–9, 2013, in Guanajuato, Mexico, 1119
Annual Survey Doctoral Department Groupings, 1262
Award for Distinguished Public Service, 575
Bryn Mawr Department Receives Award, 672
Bylaws of the American Mathematical Society, 73
Call for Nominations for the 2013 Frank and Brennie Morgan AMS-MAA-SIAM Prize, 709
Call for Nominations—AMS Associate Secretary, Southeastern Section, 855
Call for Nominations for 2013 Leroy P. Steele Prizes, 447, 587
Call for Nominations for AMS Award for Mathematics Programs That Make a Difference, 711

Call for Nominations for the AMS Exemplary Program Prize, 710, 856
Call for Nominations for the David P. Robbins Prize, Oswald Veblen Prize in Geometry, and Norbert Wiener Prize in Applied Mathematics, 707
Call for Nominations for the Ruth Lyttle Satter Prize, E. H. Moore Research Article Prize, and Levi L. Conant Prize, 706
Departments Coordinate Job Offer Deadlines, 1580
Epsilon Awards for 2012, 694
Erdős Memorial Lecture, 66, 850
From the AMS Public Awareness Office, 66, 328, 442, 583, 694, 975, 1282, 1465
General Information Regarding Meetings & Conferences of the AMS, 111
Math in Moscow Scholarships Awarded, 328, 974
Mathematics Research Communities 2013, 1462
MSC/SKOS—The New Implementation of the MSC as a Linked Open Dataset, 1582
Officers of the Society, 2011 and 2012 Updates, 708
(A) Photographic Look at the Joint Mathematics Meetings, Boston, 2012, 476
Project NExT Fellows Chosen, 1582
Report of the Executive Director, State of the AMS 2012, 1013
Report of the Treasurer (2011), 1149
San Diego Meeting Registration Forms, 1373, 1509, 1645
San Diego Meeting Timetable, 1362
Special Section—2012 American Mathematical Society Elections, 1131
Statistics on Women Mathematicians Compiled by the AMS, 1289
Voting Information for 2012 AMS Elections, 1012

AMS Publications News

AMS Presents the Book Series *Pure and Applied Undergraduate Texts* (Paul Sally Jr., Sergei Gelfand), 1125
How Many Norman LLoyd Johnsons Are There in the Mathematical Reviews Database? (Norman Richert), 1466

Announcements

2012 Everett Pitcher Lectures, 582
2012 Mathematics Awareness Month: "Mathematics, Statistics, and the Data Deluge' ", 327
AMS-Simons Travel Grants for Early-Career Mathematicians, 441
Call for Nominations for Prizes of the Academy of Sciences for the Developing World, 441
Departments Coordinate Job Offer Deadlines, 1580
Heidelberg Laureate Forum, 1123
Kavli Foundation Endows Tokyo Institute, 695
Dynkin Interviews Digitized at Cornell, 441
IMU and ICIAM Request Input on Journal Rankings Report, 327
Mathematics Library Assistance for Developing Countries, 67
MSC/SKOS—The New Implementation of the MSC as a Linked Open Dataset, 1582
New PIMS Headquarters, 1580
"Transcending Tradition": Exhibition on Jewish Mathematicians in German States, 1282
Who's That Mathematician? Photos from the Halmos Collection, 582

Articles

—Features

Adventures in Teaching: A Professor Goes to High School to Learn about Teaching Math (Darryl Yong), 1408
Archimedes, Gauss, and Stein (Jim Pitman and Nathan Ross), 1416
Conformal Mappings in Geometric Algebra (Garret Sobczyk), 264
Daniel Quillen (Eric Friedlander, Daniel Grayson, Coordinating Editors), 1408
Debunking Myths about Gender and Mathematics Performance (Jonathan M. Kane and Janet E. Mertz), 10
Drowning in the Data Deluge (George E. Andrews), 933
Efficient Algorithms for Solving Partial Differential Equations with Discontinuous Solutions (Chi-Wang Shu), 615
(An) Eloquent Formula for the Perimeter of an Ellipse (Semjon Adlaj), 1094
(A) Farey Tail (Patrice Philippon), 746
Forbidden Symmetries (Frank A. Farris), 1386
(A) Fresh Look at Francesco Severi (Judith Goodstein and Donald Babbitt), 1064
Galois for 21st-Century Readers (Harold M. Edwards), 912
Glimpses of Benoît B. Mandelbrot (1924–2010) (Michael F. Barnsley, Michael Frame, Ian Stewart, David Mumford, Kenneth Falconer, Ron Eglash, Harlan Brothers, Nigel Lesmoir-Gordon, Javier Barrallo, Sir Michael Berry), 1056
(An) IMMERSE-Style Course Brings a Research Experience to Students and Faculty (Ellen Veomett), 1237
Incomputability after Alan Turing (S. Barry Cooper), 776
(The) Influence of Benoît B. Mandelbrot on Mathematics (Michael F. Barnsley and Michael Frame, Editors), 1208
Influential Mathematicians: Birth, Education, and Affiliation (John Panaretos and Chrisovalandis Malesios), 274
Interdisciplinary Research—Mathematical Interactions Viewed from Four Portrayals (Goong Chen), 1246
Interview with John Milnor (Martin Raussen and Christian Skau), 400
Is There a Crystal Lattice Possessing Five-Fold Symmetry? (Michal Křížek, Jakub Šolc, and Alena Šolcová), 22
Isoperimetric Pentagonal Tilings (Ping Ngai Chung, Miguel A. Fernandez, Yifei Li, Michael Mara, Frank Morgan, Isamar Rosa Plata, Niralee Shah, Luis Sordo Vieira, and Elena Wikner), 632
(The) Klein Bottle: Variations on a Theme (Gregorio Franzoni), 1076
Leibniz's Laws of Continuity and Homogeneity (Mikhail G. Katz, David M. Sherry), 1550
Mathematics and Home Schooling (Kathleen Ambruso Acker, Mary W. Gray, Behzad Jalali, Matthew Pascal), 513
Memories of Vladimir Arnold, (Boris Khesin, Serge Tabachnikov, Dmitry Fuchs, Yakov Eliashberg, Yulij Ilyashenko, Victor Vassiliev, Helmut Hofer), 482

Mysteries in Packing Regular Tetrahedra (Jeffrey C. Lagarias, Chuanming Zong), 1540
On Circulant Matrices (Irwin Kra and Santiago R. Simanca), 368
(A) Perspective on Wigner's "Unreasonable Effectiveness of Mathematics" (Jason Scott Nicholson), 38
Princeton Lectures in Analysis by Elias M. Stein and Rami Shakarchi—A Book Review (Reviewed by Charles Fefferman and Robert Fefferman with contributions from Paul Hagelstein, Nataša Pavlović, and Lillian Pierce), 641
(A) Revolution in Mathematics? What Really Happened a Century Ago and Why It Matters Today (Frank Quinn), 31
Remembering Herbert Federer (1920–2010) (Harold Parks, Leslie Vaaler, John Wermer, William Allard, Robert Hardt, William P. Ziemer, Wendell Fleming), 622
Remembering Jerry Marsden (1942–2010) (Tudor Ratiu, Alan Weinstein, Anthony M. Bloch, Hernan Cendra, Alexandre Chorin, Michael Dellnitz, Mathieu Desbrun, Marty Golubitsky, Barbara Keyfitz, Mark Gotay, Jim Isenberg, P. S. Krishnaprasad, Alison Marsden, Richard Montgomery, Michael Ortiz, Geneviève Raugel, Jürgen Scheurle, Hiroaki Yoshimura), 758
Right or Wrong? That Is the Question (M. Dedò and L. Sferch), 924
Srinivasa Ramanujan, Going Strong at 125, Part I (Krishnaswami Alladi, George Andrews, Bruce C. Berndt, Jonathan M. Borwein), 1522
Supporting the Next Generation of "Stewards" in Mathematics Education (Barbara and Robert Reys), 288
(A) Tribute to Nigel J. Kalton (1946–2010) (Peter G. Casazza, Aleksander Pełczyński, Joe Diestel, Roman Vershynin, Gilles Godefroy), 942
Tribute to Vladimir Arnold (Boris Khesin, Serge Tabachnikov, Alexander Givental, Yakov Sinai, Steve Smale, Mikhail Sevryuk, Askold Khovanskii, Alexander Varchenko, Michael Berry), 378
When Does Compromise Prevent More Pollution? (C. Clemons, J. Cossey, M. Ferrara, S. Forcey, T. Norfolk, G. Obeng, D. Ricciardi, and G. Young), 1223
Why Are There No 3-Headed Monsters? Mathematical Modeling in Biology (J. D. Murray), 785
Winifred Edgerton Merrill: "She Opened the Door" (Susan E. Kelly, Sarah A. Rozner), 504
Yang-Mills and Beyond (Samuel L. Marateck), 802

— Communications

2010 Annual Survey of the Mathematical Sciences in the U.S. (2009–2010 Departmental Profile Report), (Richard Cleary, James W. Maxwell, and Colleen Rose), 291
2011 Ostrowski Prize Awarded, 1110
2011–2012 Faculty Salaries Report, (Richard Cleary, James W. Maxwell, and Colleen Rose), 410
2012 AMS-SIAM Birkhoff Prize, 576
2012 Award for an Exemplary Program or Achievement in a Mathematics Department, 667
2012 Cole Prize in Algebra, 567
2012 Conant Prize. 568
2012 Mathematics Programs That Make a Difference, 665
2012 Morgan Prize, 569
2012 Steele Prizes, 563
2012 Whiteman Prize, 572
Alexander Abrosimov (Valery Beloshapka, Aleksey Kalinin, Michael Kuznetsov, Kirill Mayorov, Grigory Polotovskiy, Ivan Remizov, Yakov Sennikovskiy, George Shabat, Mikhail Tokman, Alexander Tumanov, Grigoriy Zhislin), 1569
AMS Publications News: AMS Presents the Book Series Pure and Applied Undergraduate Texts (Paul Sally Jr., Sergei Gelfand), 1125
AMS Publications News: How Many Norman LLoyd Johnsons Are There in the Mathematical Reviews Database? (Norman Richert), 1466
Annual Survey Doctoral Department Groupings (Richard Cleary and James Maxwell), 1262
Applications of Near Sets (Jim Peters, Som Naimpally), 536
Award for Distinguished Public Service, 575
AWM Awards Given in Boston (Elaine Kehoe), 686
Bourgain and Tao Awarded 2012 Crafoord Prize (Elaine Kehoe), 676
Bryn Mawr Department Receives Award (Allyn Jackson), 672
Daubechies Awarded Nemmers Prize, 962
Doceamus: Applications Wanted: NSF Graduate Research Fellowships (Meredith Berthelson and Jennifer Slimowitz Pearl), 1445
Doceamus: A Modest Proposal (Alan H. Schoenfeld), 317
Doceamus: Does Algebraic Reasoning Enhance Reasoning in General? A Response to Dudley (Peter Johnson), 1270
Doceamus: Ethics for Undergraduate Researchers (Mike Axtell and Chad Westphal), 434
Doceamus: Inquiry-Based Learning: Yesterday and Today (Ronald G. Douglas), 668
Doceamus: (Math) Teachers Are the Key (Irwin Kra), 556
Doceamus: Solutions in Search of Problems (Jeremy F. Alm and David A. Andrews), 963
Doceamus: Teaching with High-Cognitive-Demand Mathematical Tasks Helps Students Learn to Think Mathematically (Jeremy F. Strayer and Elizabeth Brown), 55
Doceamus: The University of California Cal Teach Program: Recruiting Highly Qualified Future Teachers of Mathematical Science (Edward Landesman, Gretchen Andreasen), 1571
Doceamus: Undergraduate Research in Mathematics Has Come of Age (Joseph A. Gallian), 1112
Doceamus: What Should Students Get from Calculus? (And How Can We Provide It?) (Frank Quinn), 839
Elsevier's Response to the Mathematics Community (Laura Hassink and David Clark), 833
Fall 2011 Departmental Profile Report (Richard Cleary, James W. Maxwell, and Colleen Rose), 1423
Hopkins Receives NAS Award in Mathematics (Elaine Kehoe), 676
Improvement in Survival of People Living with HIV/AIDS (Arni S. R. Srinivasa Rao, Kurien Thomas, Sudhakar Kurapati, Ramesh Bhat), 560

Jack Warga (1922–2011) (Boris Mordukhovich and Qiji Zhu), 1109
JPBM Communications Award (Elaine Kehoe), 679
Kontsevich Awarded Shaw Prize. 1261
MAA Prizes Presented in Boston (Elaine Kehoe), 680
Mathematical Aesthetics in a Beautiful Town: Bridges Coimbra 2011 (Kristóf Fenyvesi), 648
Mathematical Sciences in the FY 2013 Budget (Samuel M. Rankin III), 1449
Mathematicians Take a Stand (Douglas N. Arnold and Henry Cohn), 828
MathJax: A Platform for Mathematics on the Web (Davide Cervone), 312
One in a Million—Remembrances of Laurie Snell (1925–2011) (Dan Rockmore), 1256
Organic Mathematics: Then and Now (Jonathan M. Borwein and Veselin Jungić), 416
Preliminary Report on the 2010–2011 New Doctoral Recipients (Richard Cleary, James W. Maxwell, Colleen Rose), 522
Presidential Report Draws Criticism from Mathematicians (Allyn Jackson), 1265
Remembering Yahya Ould Hamidoune (Toka Diagana), 827
Report on the 2010–2011 New Doctoral Recipients (Richard Cleary, James W. Maxwell, and Colleen Rose), 1083
(A) Report on 2010–2011 Academic Recruitment and Hiring (James W. Maxwell and Colleen Rose), 796
Science Lives—Video Portraits of Great Mathematicians (Allyn Jackson), 1443
Scripta Manent: Copyright in Academic Writings: Yours to Have and to Hold (and From Which a Publishing Contract Need Not Make You Part) (Jane Ginsburg), 965
Scripta Manent: Do Mathematicians Get the Author Rights They Want? (Kristine K. Fowler), 436
Scripta Manent: Geometry & Topology: A Community-Based Publishing Initiative (Colin Rourke), 1574
Scripta Manent: Google Books vs. MathSciNet (Scott Guthery), 1115
Scripta Manent: Why Don't More University Presses Publish Mathematics Books? (David Tranah), 58
Scripta Manent: Publishing Computational Mathematics (Tim Daly), 320
Scripta Manent: The Future of Mathematical Publishing (Michael G. Cowling), 558
Scripta Manent: The New Publishing Scene and the Tenure Case: An Administrator's View (Daniele C. Struppa), 670
Scripta Manent: The Open Textbook Revolution (Steven E. Barkan), 1447
Scripta Manent: Shifting Editorial Boards (Susan Hezlet), 841
Scripta Manent: Whither Journals? (Rob Kirby), 1272
Szemerédi Receives 2012 Abel Prize, 836
Tapia and Varadhan Receive National Medal of Science (Elaine Kehoe), 52
Tribute to Lawrence E. Payne (Howard Levine, Philip Schaefer, and Simon Levin), 653
WHAT IS…a Biholomorphic Mapping? (Eric Bedford), 812
WHAT IS…a Fenchel Conjugate? (Heinz H. Bauschke and Yves Lucet), 44
WHAT IS…a Pseudoconvex Domain? (R. Michael Range), 301
WHAT IS…a Scissors Congruence? (Johan L. Dupont), 1242
WHAT IS…a Shimura Variety? (James S. Milne), 1560
WHAT IS…an Affine Sphere? (Daniel J. F. Fox), 420
WHAT IS…an Approximate Group? (Ben Green), 655
WHAT IS…an Octopus Decomposition? (Larry Conlon), 952
WHAT IS…Cop Number? (Anthony Bonato), 1100
WHAT IS…Data Mining? (Mauro Maggioni), 532
WHAT IS…Essential Dimension? (Zinovy Reichstein), 1432

Authors

Abe, Mari, 956
Acker, Kathleen Ambruso, 513
Adlaj, Semjon, 1094
Alladi, Krishnaswami, 1522
Allard, William, 622
Alm, Jeremy F., 963
Andreasen, Gretchen, 1571
Andrews, David A., 963
Andrews, George E., 933, 1522
Arnold, Douglas N., 828
Atiyah, Michael, 1392
Axtell, Mike, 434
Babbitt, Donald, 1064
Barkan, Steven E., 1447
Barnsley, Michael F., 1056, 1208
Barrallo, Javier, 1056
Bass, Hyman, 1392
Bauschke, Heinz H., 44
Bays, Timothy, 424
Bedford, Eric, 812
Beloshapka, Valery, 1569
Berndt, Bruce C., 1522
Berry, Michael, 378, 1056, 1208
Berthelson, Meredith, 1445
Bhat, Ramesh, 560
Blank, Brian E., 1102
Bloch, Anthony M., 758
Bonato, Anthony, 1100
Borwein, Jonathan M., 416, 1522
Brothers, Harlan, 1056
Brown, Elizabeth, 55
Brown, Ken, 1392
Casazza, Peter G., 942
Cendra, Hernan, 758
Cervone, Davide, 312
Chen, Goong, 1246
Chorin, Alexandre, 758
Chung, Ping Ngai, 632
Clark, David, 833
Cleary, Richard, 291, 410, 522, 1083, 1262, 1423
Clemens, C., 1223
Cohen, Nathan, 1208
Cohn, Henry, 828
Conlon, Larry, 952
Cooper, S. Barry, 776
Coppens, Marc-Olivier, 1208
Cossey, J., 1223

Cowling, Michael G., 558
Cuntz, Joachim, 1392
Curtis, Charles W., 1565
Dale, Andrew I., 304
Daly, Tim, 320
Dedò, M., 924
Dellnitz, Michael, 758
Desbrun, Mathieu, 758
Diagana, Toka, 827
Diestel, Joe, 942
Douglas, Ronald G., 668
Duflot, Jeanne, 1392
Dupont, Johan L., 1242
Edwards, Harold M., 912
Eglash, Ron, 1056
Eliashberg, Yakov, 482
Ewing, John, 815, 1205
Falconer, Kenneth, 1056, 1208
Faris, William G., 544
Farris, Frank A., 1386
Fefferman, Charles, 641
Fefferman, Robert, 641
Fenyvesi, Kristóf, 648
Fernandez, Miguel A. , 632
Ferrara, M., 1223
Fienberg, Stephen E., 479
Fleming, Wendell, 622
Folland, Gerald B., 553, 1562
Forcey, S., 1223
Fowler, Kristine K. , 436
Fox, Daniel J. F., 420
Frame, Michael, 1056, 1208
Franzoni, Gregorio, 1076
Friedlander, Eric M., 1205, 1392
Friedlander, Susan, 613
Fuchs, Dmitry, 482
Furstenberg, Hillel, 1208
Gallian, Joseph A., 1112
Garfunkel, Solomon, 909
Gelfand, Sergei, 1125
Ghys, Etienne, 365
Ginsburg, Jane, 965
Givental, Alexander, 378
Godefroy, Gilles, 942
Goldin, Rebecca, 1205
Golubitsky, Marty, 758
Goodstein, Judith, 1064
Gotay, Mark, 758
Gray, Mary W., 513
Grayson, Daniel, 1392
Green, Ben, 655
Green, Judy, 308
Guthery, Scott, 1115
Hagelstein, Paul, 641
Häggström, Olle, 47
Hannah, John, 661
Harris, Michael, 819
Hassink, Laura, 833
Hardt, Robert, 622
Herald, Chris, 261
Hezlet, Susan, 841
Hofer, Helmut, 482
Holm, Tara S., 1205
Howe, Roger, 1208
Ilyashenko, Yulij, 482
Isenbeg, Jim, 758
Jackson, Allyn, 672, 1265, 1278, 1443
Jaco, William H., 1205
Jaffard, Stéphane, 1208
Jaladi, Behzad, 513
Johnson, Peter, 1270
Jones, Rafe, 50
Jungić, Veselin, 416
Kalinin, Aleksey, 1569
Kane, Jonathan M., 10
Katz, Mikhail G., 1550
Kehoe, Elaine, 52, 676, 678, 679, 680, 686
Kelly, Susan E., 504
Keyfitz, Barbara, 758
Khesin, Boris, 378, 482
Khovanskii, Askold, 378
Kirby, Ron, 1272
Kobayashi, Mei, 956
Kra, Irwin, 368, 556
Krishnaprasad, P. S., 758
Křížek, Michal, 22
Kurapati, Sudhakar, 560
Kuznetsov, Michael, 1569
Lagarias, Jeffrey C., 1540
Landesman, Edward. 1571
Lesmoir-Gordon, Nigel, 1056
Levin, Simon, 653
Levine, Howard, 653
Li, Yifei, 632
Linton, Christopher, 430
Lipsman, Ronald, 1519
Loday, Jean-Louis, 1392
Lucet, Yves, 44
Maggioni, Mauro, 532
Malesios, Chrisovalandis, 274
Mara, Michael, 632
Marateck, Samuel L., 802
Marsden, Alison, 758
Maxwell, James W., 291, 410, 522, 796, 1083, 1262, 1423
Mayorov, Kirill, 1569
Mazur, Barry, 1392
McClure, Don, 1013
Mertz, Janet E., 10
Milne, James S., 1560
Montgomery, Richard, 758
Mordukhovich, Boris, 1109
Morgan, Frank, 632
Mumford, David, 1056, 1208
Murray, J. D., 785
Naimpally, Som, 536
Nicholson, Jason Scott, 38
Norfolk, T., 1223

Obeng, G., 1223
Orellana, Rosa, 1053
Ortiz, Michael, 758
Osserman, Brian, 1383
Panaretos, John, 274
Parks, Harold, 622
Pascal, Matthew, 513
Pavlović, Nataša, 641
Pearl, Jennifer Slimowitz, 1445
Pełczyński, Aleksander, 942
Peters, Jim, 536
Peters, Klaus, 741
Philippon, Patrice, 746
Phillips, Anthony, 1435
Pierce, Lillian, 641
Pitman, Jim, 1416
Plata, Isamar Rosa, 632
Polotovskiy, Grigory, 1569
Quillen, Jean, 1392
Quinn, Frank, 31, 839
Range, R. Michael, 301
Ranicki, Andrew, 1392
Rankin, Samuel M. III, 1449
Rao, Arni S. R. Srinivasa, 560
Ratiu, Tudor, 758
Raugel, Geneviève, 758
Raussen, Martin, 400
Reichstein, Zinovy, 1432
Remizov, Ivan, 1569
Reys, Barbara, 288
Reys, Robert, 288
Ricciardi, D., 1223
Richert, Norman, 1466
Rockmore, Dan, 1053, 1256
Rose, Colleen, 291, 410, 522, 796, 1083, 1423
Ross, Nathan, 1416
Rourke, Colin, 1574
Rousseau, Christiane, 5
Rozner, Sarah A., 504
Sally, Paul Jr., 1125
Schaefer, Philip, 653
Schoenfeld, Alan H., 317
Scheurle, Jürgen, 758
Segal, Graeme, 1392
Sennikovskiy, Yakov, 1569
Sevryuk, Mikhail, 378
Sferch, L., 924
Shabat, George, 1569
Shah, Niralee, 632
Sherry, David M., 1550
Shu, Chi-Wang, 615
Simanca, Santiago R., 368
Sinai, Yakov, 378
Sinclair, Nathalie, 819
Skau, Christian, 400
Smale, Steve, 378
Sobczyk, Garret, 264
Šolc, Jakub, 22
Šolcová, Alena, 22
Stevens, T. Christine, 1205
Stewart, Ian, 1056, 1208
Strayer, Jeremy F., 55
Struppa, Daniele C. , 670
Sullivan, Dennis, 1392
Tabachnikov, Sergei (Serge), 365, 378, 482
Thomas, Kurien, 560
Thompson, Abigail, 1205
Tillmann, Ulrike, 1392
Tokman, Mikhail, 1569
Tranah, David, 58
Tumanov, Alexander, 1569
Vaaler, Leslie, 622
Van Osdol, Donovan H., 960
Vassiliev, Victor, 482
Varchenko, Alexander, 378
Vershynin, Roman, 942
Viana, Marcelo, 613
Vieira, Luis Sordo, 632
Veomett, Ellen, 1237
Vogan, David A. Jr., 1205
Weinstein, Alan, 758
Wermer, John, 622
West, Bruce J., 1208
Westphal, Chad, 434
Wikner, Elena, 632
Yoshimura, Hiroaki, 758
Yong, Darryl, 1408
Young, G., 1223
Zhislin, Grigoriy, 1569
Zong, Chuanming, 1540
Zorn, Paul, 1253
Zhu, Qiji, 1109
Ziemer, William P., 622

Backlog of Mathematics Research Journals

1473

Book Reviews — *See* Reviews

Classified Advertisements

107, 347, 446, 599, 727, 881, 1029, 1183, 1310, 1488, 1606

Corrections

Correction to "Glimpses of Benoît B. Mandelbrot (1924–2010)" (September 2012), 1520
Correction to "Mathematics Opportunities" (August 2012), 1520
Correction to "Shing-Shen Chern memorial article" (October 2011), 7
Correction to "Supporting the next generation of 'stewards' in mathematics education" (February 2012), 481
Correction to "Top Secret Rosies" (February 2012), 442
Corrections to "The future of mathematical publishing" (April, 2012); The photo key for JMM 2012 photos (page 555, April 2012); the DOI (Document Object Identifier) (for Doceamus article page 668, May 2012), 744

Crossword Puzzles

Deaths of AMS Members

Ahlbrandt, Calvin D., 976
Andrews, H. Robert, 976
Arenson, Donald L., 695
Artzy, Rafael, 976
Arveson, William B., 583
Bade, William G., 1465
Baouendi, M. Salah, 695
Baumgartner, James E., 583
Bell, Stoughton, 329
Benedicty, Mario, 695
Borchers, Hans-Jürgen, 66
Buck, Ellen F., 695
Cahill, Thomas P., 976
Chidambaraswamy, Jayanthi, 1465
Choczewski, Bogdan, 583
Cohen, Haskell, 976
Corning, Steve A., 1582
Cunningham, Frederic Jr., 695
Davis, William J., 976
de Bruijn, Nicolaas G., 1465
Dekster, Boris V., 329
Dickson, Douglas G., 583
Divinsky, Nathan J., 1465
Dold, Albrecht E., 66
Ekedahl, Torsten, 695
Faber, Richard L., 1465
Fang, Pao-Hsien, 329
Flajolet, Philippe, 976
Freese, Raymond, 976
Friedman, Eugene M., 329
Furth, Dave, 329
Gaalswyk, Arie, 66
Garfin, Louis, 1123
Gehring, Frederick W., 976
Gerth, Frank E. III, 329
Gordon, Basil, 976
Green, Leon W., 976
Gu, Chaohao, 1123
Guay, Merle D., 976
Hauptman, Herbert Aaron, 329
Hearsey, Bryan V., 583
Heller, Dorothy M., 976
Hirzebruch, Friedrich E. P., 976
Hocking, John G., 66
Hornback, Joseph H., 976
Howie, John M., 695
Jackson, Lloyd K., 583
Jenkins, James A., 1582
Kellogg, R. Bruce, 976
Kim, Yun-Su, 976
Knopp, Marvin I., 695
Krynicki, Michal, 329
Lakshmikantham, Vangipuram, 976
Leader, Solomon, 695
Lehamn, Eugene H., 695
Lindenstrauss, Joram, 976
Lister, William G., 1123
Litwiller, Bonnie H., 976
Loday, Jean-Louis, 1123
Loudner, Godfrey L., 1465
Luce, R. Duncan, 1465
Mahar, Thomas J., 583
Marr, John M., 695
Maurer, Gyula I., 583
Maxwell, Charles N., 695
Mayer, Meinhard E., 695
McCarthy, John, 329
Meier, Paul, 695
Metzler, Richard, 1123
Miles, Philip E., 583
Miller, John Boris, 976
Mizrahi, Jacques A., 583
Morgan, Kathryn A., 976
Neustadter, Siegfried, 976
Oler, Norman, 695
Orloff, Leo N., 1465
Osserman, Robert, 583
Ozluk, Ali Erhan, 976
Pachpatte, Baburao Govindrao, 695
Payne, Lawrence E., 66, (Memorial article) 653
Pearce, Charles E. M., 976
Penico, Anthony J., 976
Peters, John, 1123
Pirraglia, Joseph A., 66
Pittie, Harsh V., 976
Poluikis, John A., 1123
Przeworska-Rolewicz, Danuta, 1123
Quillen, Daniel G., 66
Rogawski, Jonathan, 976
Rose, Israel H., 695
Rosenzweig, Harry L., 976
Rothblum, Uriel George, 976
Roxin, Emilio O., 1465
Schweizer, Berthold, 583
Sharma, Banwarilal, 1582
Sherburne, Frank Jr.,
Shniad, Harold, 977
Silk, Jeanne-Marie, 1123
Silverman, Robert J., 695
Simpson, James E., 329
Specht, Edward John, 695
Springer, Tonny A., 583
Starr, David W., 977
Steger, Arthur, 1123
Stokes, William G., 1465
Storvick, David A., 977
Strohl, G. Ralph, 329
Szczarba, Robert H., 329
Takenaga, Roy, 66
Taksar, Michael I., 976
Thomas, Erik G. F., 66
Thurston, William Paul, 1465
Tomiuk, Daniel B. J., 66
Trabant, Edward A., 1123
Ullery, William Davis, 976

Veneri, James M., 583
Wacker, Paul F., 695
Wakana, Kaoru, 583
Weiblen, Robert Eugene, 977
Wetzel, Marion D., 977
Wheeler, John A., 977
White, Halbert, 977
Whitton, Robert C., 329
Wilf, Herbert S., 695
Willis, Paul A., 1465
Woodbury, Max A., 329
Wrede, Robert C., 977
Yohe, Cleon R., 1582
Yushkevich, A. A., 1123

Doceamus

Applications Wanted: NSF Graduate Research Fellowships (Meredith Berthelson and Jennifer Slimowitz Pearl), 1445
Does Algebraic Reasoning Enhance Reasoning in General? A Response to Dudley (Peter Johnson), 1270
Ethics for Undergraduate Researchers (Mike Axtell and Chad Westphal), 434
Inquiry-Based Learning: Yesterday and Today (Ronald G. Douglas), 668
(Math) Teachers Are the Key (Irwin Kra), 556
(A) Modest Proposal (Alan H. Schoenfeld), 317
Solutions in Search of Problems (Heremy F. Alm and David A. Andrews), 963
Teaching with High-Cognitive-Demand Mathematical Tasks Helps Students Learn to Think Mathematically (Jeremy F. Strayer and Elizabeth Brown), 55
Undergraduate Research in Mathematics Has Come of Age (Joseph A. Gallian), 1112
(The) University of California Cal Teach Program: Recruiting Highly Qualified Future Teachers of Mathematical Science (Edward Landesman, Gretchen Andreasen), 1571
What Should Students Get from Calculus? (And How Can We Provide It?) (Frank Quinn), 839

Doctoral Degrees Conferred 2010–2011

985

Election Information (AMS)

2011 Election Results, 334
2012 AMS Election—Nominations by Petition, 335
Special Section—2012 American Mathematical Society Elections, 1131

Employment Center

Mathematical Sciences Employment Center in San Diego, 1317

Grants, Fellowships, Opportunities

AAUW Educational Foundation Fellowships and Grants, 1461
AIM Workshops, 1121
American Mathematical Society Centennial Fellowships, 1120, 1459
AMS-AAAS Mass Media Summer Fellowships, 1279
AMS Congressional Fellowship, 1460
AMS Department Chairs Workshop, 1461
AMS Epsilon Fund, 1459
AMS Scholarships for "Math in Moscow", 971
AMS-Simons Travel Grants for Early-Career Mathematicians, 441
AMS Travel Grants for MCA 2013, August 5–9, 2013, in Guanajuato, Mexico, 1119
AWM Announces Two New Research Prizes, 1578
AWM Essay Contest, 1461
AWM Gweneth Humphreys Award, 581
AWM Travel Grants for Women, 1121
CAIMS/PIMS Early Career Award, 63
Call for Applications for Workshop "How to Run a Math Camp", 1279
Call for Entries for Balaguer Prize, 849
Call for Nominations: CRM-Fields-PIMS Prize, 850
Call for Nominations for 2012 Parzen Prize for Statistical Innovations, 692
Call for Nominations for 2012 Sacks Prize, 971
Call for Nominations for Clay Research Fellowships, 1120
Call for Nominations for IMU Prizes, 1459
Call for Nominations for Otto Neugebauer Prize, 971
Call for Nominations for Sloan Fellowships, 972
Call for Nominations for Popov Prize, 849
Call for Nominations for Prizes of the Academy of Sciences for the Developing World, 441
Call for Nominations for SASTRA Ramanujan Prize, 692
Call for Nominations for the Ramanujan Prize for Young Mathematicians from Developing Countries, 581
Call for Proposals for 2013 NSF-CBMS Regional Conferences, 580
Clay Mathematics Institute Summer School, 63
Clay Mathematics Institute Workshops, 1280
CRM-PISA Junior Visiting Program, 326
Deadlines for AWM Programs 64
DMS Workforce Program in the Mathematical Sciences, 579
EDGE for Women Summer Program, 326
EDGE Summer Program 2013, 1462
Fulbright Postdoctoral Fellowships in Israel, 849
International Mathematics Competition for University Students, 693
Jefferson Science Fellows Program, 1460
Joint DMS/NIGMS Initiative to Support Research at the Interface of the Biological and Mathematical Sciences, 972
Math in Moscow Scholarship Program, 582
Math for America Early Career Fellowship, 692
Mathematical Sciences Research Institute Fall Workshops, 2012, Berkeley, CA, 849
Mathematics of Planet Earth Competition: Virtual Modules, 64
Mathematics Library Assistance for Developing Countries, 67
Mathematics Research Communities 2013, 1462
MfA Fellowship Program, 325, 1578

MSRI Call for Proposals, 1280
National Academies Research Associateship Programs, 63
NDSEG Fellowships, 1579
News from Institut Mittag-Leffler, 1464
News from IPAM, 693, 1463
News from MSRI, 1281
News from the Bernoulli Center, 1579
News from the CIRM, 1121
News from the Fields Institute, 1463
News from the IMA, 325
News from the Mathematical Sciences Research Institute, Berkeley, CA 973
News from the MSRI, 1464
NRC-Ford Foundation Fellowships, 1461
NSA Mathematical Sciences Grants and Sabbaticals Program, 972
NSF Algorithms for Threat Detection, 63
NSF CAREER Awards, 849
NSF-CBMS Regional Conferences, 2012, 580
NSF Conferences and Workshops in the Mathematical Sciences, 1280
NSF Graduate Research Fellowships, 1460
NSF Integrative Graduate Education and Research Training, 581
NSF Major Research Instrumentation Program, 62
NSF Mathematical Sciences Postdoctoral Research Fellowships, 972
NSF Postdoctoral Research Fellowships, 692
NSF Program ADVANCE, 1280
NSF Program in Computational and Data-Enabled Science and Engineering in Mathematical and Statistical Sciences, 1579
NSF Scholarships in Science, Technology, Engineering, and Mathematics, 581
NSF Support for Undergraduate Training in Biological and Mathematical Sciences, 325
PIMS Conferences and Fellowships, 1122
Project NExT: New Experiences in Teaching, 579
Proposal Due Dates at the DMS, 62
Research Experiences for Undergraduates, 973
Research Opportunities for U. S. Graduate Students in Asia and Australia, 1463
STaR Program for Early Career Mathematics Educators, 1578
Summer Program for Women Undergraduates, 325

Invited Speakers

Arous, Gerard Ben (San Diego, California), 890
Barbu, Viorel (Alba Iulia, Romania), 899
Bezrukavnikov, Roman (Chestnut Hill, Massachusetts), 897
Bourgain, Jean (San Diego, California), 890
Brosnan, Patrick (Philadelpha, Pennsylvania), 1504
Calegari, Frank (Lawrence, Kansas), 120
Carlsson, Gunnar (Boulder, Colorado), 898
Christ, Michael (Riverside, California), 900
Christiansen, Tanya (Akron, Ohio), 122
Cochran, Tim (Akron, Ohio), 122
Condon, Anne (Tampa, Florida), 114
Conder, Marston (Chestnut Hill, Massachusetts), 897
Costello, Kevin (Ames, Iowa), 898
Csornyei, Marianne (Ames, Iowa), 898
De Loera, Jesus A. (Boulder, Colorado), 898
DeMarco, Laura (San Diego, California), 890
Ellenberg, Jordan (San Diego, California), 890
Ellingham, Mark (Tampa, Florida), 114
Geelen, Jim (Washington, DC), 116
Golden, Kenneth (San Diego, California), 1324
Gonek, Steve (Rochester, New York), 121
Gross, Mark (Riverside, California), 900
Guionnet, Alice (San Diego, California), 890; (Chestnut Hill, Massachusetts), 897
Guralnick, Robert (San Diego, California), 890
Hadani, Ronny (St. Louis, Missouri), 899
Hassett, Brendan (Boulder, Colorado), 898
Hersh, Patricia (Oxford, Mississippi), 897
Hill, Michael (Louisville, Kentucky), 1043
Huang, Xiaojung (Philadelphia, Pennsylvania), 1504
Hutchings, Michael (Tucson, Arizona), 122
Kalfagianni, Effie (St. Louis, Missouri), 899
Keener, James (Rochester, New York), 121
Klainerman, Sergiu (Alba Iulia, Romania), 899
Kleinberg, Jon (St. Louis, Missouri), 899
Krashen, Daniel (Oxford, Mississippi), 897
Layton, Anita (New Orleans, Louisiana), 122
Leininger, Christopher (Lawrence, Kansas), 120
Lenhart, Suzanne (Louisville, Kentucky), 1043
Lu, Zhiqin (Honolulu, Hawaii), 112
Lusztig, George (Alba Iulia, Romania), 899
Maggioni, Mauro (Tampa, Florida), 113
Marcolli, Matilde (Riverside, California), 900
Marian, Alina (Lawrence, Kansas), 120
Markovic, Vladimir (Ames, Iowa), 898
Mazur, Barry (Philadelphia, Pennsylvania), 899
McDuff. Dusa (Rochester, New York), 121
McKenzie, Ralph (Louisville, Kentucky), 1043
McLaughlin, Kenneth (Tucson, Arizona), 122
Mio, Washington (Oxford, Mississippi), 897
Moll, Victor (Louisville, Kentucky), 1043
Ng, Lenhard (New Orleans, Louisiana), 122
Ono, Ken (Tucson, Arizona), 122
Papadima, Stefan (Alba Iulia, Romania), 899
Pemantle, Robin (San Diego, California), 890
Rouquier, Raphael (Boulder, Colorado), 898
Rubinstein, Yanir (Chestnut Hill, Massachusetts), 897
Schenck, Henry K. (New Orleans, Louisiana), 122
Shuckburgh, Emily (San Diego, California), 890
Schroder, Peter (Honolulu, Hawaii), 112
Solecki, Slawomir (Oxford, Mississippi), 897
Solomon, Ronald (Akron, Ohio), 122
Solomyak, Boris (Washington, DC), 116
Sterbenz, Jacob (Tucson, Arizona), 122
Strain, Robert (Philadelphia, Pennsylvania), 1504
Sverak, Vladimir (St. Louis, Missouri), 899
Uhlmann, Gunther (Washington, DC), 116
Tadmor, Eitan (Ames, Iowa), 898
Tiep, Pham (Honolulu, Hawaii), 112

Timotin, Dan (Alba Iulia, Romania), 899
Varadhan, Srinivasa (Alba Iulia, Romania), 899
Villani, Cedric (San Diego, California), 890
Vojta, Paul (Riverside, California), 900
Wang, Weiqiang (Tampa, Florida), 113
Wei, Goufang (Tucson, Arizona), 122
Weinkove, Ben (Akron, Ohio), 122
Wienhard, Anna (Washington, DC), 116
Williams, Lauren (Honolulu, Hawaii), 112
Winkler, Peter (Rochester, New York), 121
Yakimov, Milen (New Orleans, Louisiana), 122
Yan, Catherine (Lawrence, Kansas), 120

Letters to the Editor

Ahmed, E. (Can One Explain This?), 910
Boute, Raymond (Word Problems), 480
Cornelius, E. Frank (Not a Fond Farewell), 1384
Crone, Larry (Phase Plots of Complex Functions), 262
Darken, Betsy (Sense-making Teaching), 744
Daws, Matthew (Lack of Author/Referee Communication), 744
Dawson, Bryan (Home Schooling Rethought), 743
Dray, Tevian (No Science Here), 7
Edwards, David A. (Response to Quinn), 366
Engler, Hans (Opportunities for Mathematicians in the Startup World), 366
Eremenko, Alexandre (Uncritical Use of Citation Database), 614
Gray, Mary (More on Home Schooling), 743
Gustafson, Karl (Remembering Larry Payne), 1054
Joshi, Padmini T. (The Provenance of Zero), 1054
Kapovich, Ilya (Standards for Publishing Errata), 1384
Kelly, Susan (Consumer Alert: Mead Flashcards with Errors), 614
Koblitz, Neal (AMS Fellows), 1384
Lenihan, Stanley R. (Response to Quinn), 481
Naima, Polina (More on Norrie Everitt), 743
Okoh, Frank (A Collision with Salam), 1520
Oprea, John (AMS Fellows—Arbeit macht das Leben süss), 366
Qadir, Asghar (Mathematics in Pakistan), 262
Robinson, Margaret (Ethics for Interviewers: Location Matters), 910
Rosa, Domenico (Reformers Operating in a Vacuum), 481; (The Standards 2.0), 1384
Ryan, Thomas A. (Mathematics and Home Schooling), 1520
Saifullah, Khalid (Mathematics in Pakistan), 262
Siegmund-Schultze, Reinhard (Response to D. Bondoni), 7
Suceava, Bogdan D. (Response to Quinn), 480
Talamanca, Alessandro Figà (Severi's Last Political Creed), 1520
Tsatsanis, S. Peter (On Arnold, Thom, and Whitney), 910
Wright, David (Committee on Education Offers Qualified Endorsement of Common Core Standards), 480

Mathematics Calendar

101, 337, 448, 588, 712, 857, 1016, 1155, 1301, 1479, 1588

Meeting Announcements, Presenters of Papers, and Programs

Akron, Ohio, October 2012 (announcement), 1032
Boston, Massachusetts, January 2012 (presenters of papers and program of the sessions), 127
Lawrence, Kansas, March 2012 (announcement), 352
New Orleans, Louisiana, October, 2012 (announcement), 885
Oxford, Mississippi, March 2013 (announcement), 1614
Rochester, New York, September, 2012 (announcement), 882
San Diego, California, January 2013 (announcement), 1323
Tampa, Florida, March 2012 (announcement), 113
Tucson, Arizona, October 2012 (announcement), 1035
Washington, District of Columbia, March 2012 (announcement), 116

Meetings and Conferences*

(*Page numbers given are to the main meeting announcements. See http://www.ams.org/meetings for full details and updates.)
112, 349, 462, 601, 728, 882, 1030, 1186, 1320, 1499, 1614
AAAS Meeting in Vancouver, British Columbia, February 16–20, 2012, 255, 359
AMS Short Course in San Diego, California, 1319
Fourth International Conference on Mathematical Sciences, United Arab Emirates, March 11–14, 2012, 255, 471
International Conference on Group Theory, Combinatorics, and Computing, at Florida Atlantic University, Boca Raton, Florida, October 3–8, 2012, 903, 1047, 1199, 1375
MRC Research Communities, Snowbird, Utah, June 10–30, 2012, 255, 359, 471, 607, 735, 903
Samuel Eilenberg Centenary Conference (E100), Warsaw, Poland, July 22–26, 2013, 1511
San Diego Meeting Registration Forms, 1373, 1509, 1645
San Diego Meeting Timetable, 1362

New Publications Offered by the AMS

341, 457, 594, 720, 871, 1022, 1178, 1304, 1483, 1598

Obituaries

Alexander Abrosimov, 1569
Daniel Quillen, 1386
Glimpses of Benoît B. Mandelbrot (1924–2010), 1056
(The) Influence of Benoît B. Mandelbrot on Mathematics, 1208
Jack Warga (1922–2011), 1109
Memories of Vladimir Arnold, 482
One in a Million—Remembrances of Laurie Snell (1925–2011), 1256
Remembering Herbert Federer (1920–2010), 622
Remembering Jerry Marsden (1942–2010), 758
Remembering Yahya Ould Hamidoune, 827
Sanford Segal (1937–2010), 1278
Srinivasa Ramanujan, Going Strong at 125, Part I, 1522
Tribute to Lawrence E. Payne, 653

(A) Tribute to Nigel J. Kalton (1946–2010), 942
Tribute to Vladimir Arnold, 378
Winifred Edgerton Merrill: "She Opened the Door", 504

Opinion

Improving the Refereeing Process: A Simple Proposal (Brian Osserman), 1383
International Summer School for Students (Etienne Ghys and Sergei Tabachnikov), 365
Mathematical Congress of the Americas (Susan Friedlander and Marcelo Viana), 613
Mathematicians' Central Role in Educating the STEM Workforce, 1205
Mathematics of Planet Earth 2013 (Christiane Rousseau), 5
(The) Math Gene: A Ticket to Wealth or Nerdiness? (Ronald Lipsman), 1519
Privacy in a World of Electronic Data (Stephen E. Fienberg), 479
P_V: The Value of Publishing (Klaus Peters), 741
Sonia Kovalevsky Days and Encouraging Young Women in Mathematics (Rosa Orellana and Dan Rockmore), 1053
UNR Mathematics Dodges the Budget Axe—For Now (Chris Herald), 261
What's a Math Educator to Do (Solomon Garfunkel), 909

Prizes and Awards

2011 CAP-CRM Prize in Theoretical and Mathematical Physics (Robert Brandenberger), 323
2011 Emil Artin Junior Prize in Mathematics (Lilya Budaghyan), 322
2011 Heinz Hopf Prize (Michael Rapoport), 322
2011 IEEE Control Systems Award (Eduardo D. Sontag), 439
2011 Information-Based Complexity (IBC) Young Researcher Prize (Aicke Hinrichs), 323
2011 Loève Prize (Scott Sheffield), 60
2011 Ruth I. Michler Memorial Prize (Ling Long), 691
2011 SASTRA Ramanujan Prize (Roman Holowinsky, 60
2011 Shanti Swarup Bhatnagar Prize (Mahan Maharaj and Palash Sarkar), 322
2011 Turing Award (Judea Pearl), 837
2012 Abel Prize (Endre Szemerédi), 836
2012 AMS-SIAM Birkhoff Prize (Bjorn Engquist), 576
2012 ANZIAM Medal (Robert McKibbin), 691
2012 Award for an Exemplary Program or Achievement in a Mathematics Department, 672
2012 Award for Distinguished Public Service (William McCallum), 575
2012 Crafoord Prize in Mathematics of the Royal Swedish Academy of Sciences (Jean Bourgain and Terence Tao), 676
2012 Franklin Medal in Computer and Cognitive Science (Vladimir Vapnik), 969
2012 Information-Based Complexity (IBC) Achievement Prize (Michael Gnewuch), 969
2012 Leibniz Prize in Mathematics (Barbara Wohlmuth), 439; 578
2012 Morgan Prize (John Pardon), 569
2012 Rothschild Prize (Gil Kalai), 844
2012 SASTRA Ramanujan Prize (Zhiwei Yun), 1454
2012 Whiteman Prize (Joseph Warren Dauben), 572
AAAS Fellows, 2011 (Mark S. Alber, Ingrid Daubechies, Mark L. Green, Claudia Neuhauser, Richard A. Tapia, Roger Tamam), 440
AAAS Members. 2012 (Bonnie Berger, Joan S. Birman, Russel E. Caflisch, Ngù Bao Chu, Bjorn M. Poonen, Steven H. Strogatz, Richard L. Taylor, Louis Boutet de Monvel), 848
ACM 2011 Allen Newell Award (Stephanie Forrest), 969
Adams Prize, 2012 (Sheehan Olver, Françoise Tisseur), 968
Aisenstadt Prize, 2012 (Marco Gualtieri, Young-Heon Kim), 579
AMS Centennial Fellowship, 2012–2013 (Karin Melnick), 844
AMS-AAAS Mass Media Fellow, 2012 (Evelyn Lamb), 850
AMS Menger Awards at the 2012 ISEF (First Place—Fabian Henneke, Danial Sanusi, Xianghui Zhong; Second Place—Raman A. Birulia, Katherine Leigh Cordwell; Third Place—Danila Alexandrovich Baygushev, Sidharth Dhawan, Viachaslau I. Murashka, Anirudh Prabhu; Honorable Mention—Rashad Abdulla, Frederik Benzing, Mark Alan Holmstrom, Theresa McLaughlin, Youkow Homma, Lyndon Ji, Anita Kummamuri Rao), 1118
Australian Mathematical Society Prizes (Todd Oliynyk, Frances Y. Kuo, Peter Sarnak), 61
AWM Awards Given in Boston (2012 Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman—Fan Wei; 2012 Louise Hay Award—Bonnie Gold; M. Gweneth Humphreys Award for Mentorship of Undergraduate Women in Mathematics—Deanna Haunsperger), 686
AWM-SIAM Kovalevsky Lectureship, 2012 (Barbara Keyfitz), 845
Balaguer Prize, 2012 (Angel Cano, Juan Pablo Navarrete, Jose Seade), 844
B. H. Neumann Awards, 2012 (Janine McIntosh, Graham K. Meiklejohn, Wen-Hsien Sun), 1577
Blackwell-Tapia Prize, 2012 (Ricardo Cortez), 968
Bryn Mawr Mathematics Department (Award for an Exemplary Program or Achievement in a Mathematics Department), 672
CAREER Awards, 2011 (Mark Behrens, Hongjie Dong, Kirsten Eisentraeger, Volker Elling, Maria Emelianenko, Ibrahim Fatkullin, Ilse C. F. Ipsen, Max Lieblich, Lek-Heng Lim, Ping Ma, Mokshay Madiman, Svitlana Mayboroda, Jason Metcalfe, Irina Mitrea, Adilson Motter, Alvaro Pelayo, Zhiguang Qian, Philippe Rigollet, David Savitt, Natasa Sesum, Eric Shea-Brown, Maggy Tomova, Ignacio Uriarte-Tuero, Benedek Valko, Mariel Vazquez, Stefan Wenger, Lauren Williams, Yichao Wu, Dapeng Zhan, Qing Zhou, Andrej Zlatos), 323
CASE/Carnegie Foundation for the Advancement of Teaching Professor of the Year (Kathryn C. Wetzel), 324
CAV Award, 2012 (Sam Owre, John Rushby, Natarajan Shankar), 1276
China Girls' Mathematical Olympiad, 2012, 1457

Clay Mathematics Institute Awards, 2012 (Research Awards—Jeremy Kahn, Vladimir Markovic; Research Fellows—Ivan Corwin, Jack Thorne; Research Scholar—Roman Travkin), 690
CME/MSRI Prize, 2012 (Robert Shiller), 1577
Cole Prize in Algebra, 2012 (Alexander S. Merkurjev), 567
Conant Prize, 2012 (Persi Diaconis), 568
CRM-Fields-PIMS Prize, 2012 (Stevo Todorcevic), 578
Dirac Medal, 2012 (Duncan Haldane, Charles Kane, Shoucheng Zhang), 1456
Erdős Memorial Lecturer, 2012 (Ken Ono), 850
Fermat Prize, 2011 (Manjul Bhargava, Igor Rodnianski), 439
FoCM/Smale Prize (Snorre H. Christiansen), 61
Frederic Esser Nemmers Prize, 2012 (Ingrid Daubechies), 962
Gödel Prize, 2012 (Elias Koutsoupias, Christos H. Papadimitriou, Tim Roughgarden, Éva Tardos, Noam Nisan, Amir Ronen), 1117
Guggenheim Fellows, 2012 (Stavros Garoufalidis, Nets Katz, Alexander Kiselev, Andrea Henderson), 847
Heineman Prize, 2012 (Giovanni Jona-Lasinio), 691
Hertz Foundation Fellowships (Brian Lawrence, Yun William Yu), 846
Humboldt Professorship in Mathematics, 2011 (Michael Weiss), 969
ICM Leelavati Prize, 2010 (Simon Singh), 1456
ICMI Medals, 2011 (Felix Klein Medal for Lifetime Achievement—Alan Schoenfeld; Hans Freudenthal Medal for a major cumulative program of research—Luis Radford), 689
ICTP/IMU Ramanujan Prize, 2011 (Philibert Nang), 578
Infosys Prize in Mathematical Sciences, 2011 (Kannan Soundararajan), 323
Intel Science Talent Search Winners, 2012 (Fengning (David) Ding, Anirudh Prabhu), 847
International Mathematical Olympiad, 2012 (Ravi Jagadeesan, Mitchell Lee, Bobby Shen, Thomas Swayze, David Yang, Xiaoyu He), 1278
ISEF Mathematical Sciences Awards, 2012 (Aishwarya A. Vardhana), 1117
Jefferson Science Fellow, 2012 (Clyde Martin), 1456
John von Neumann Theory Prize, 2011 (Gerard P. Cornuejols), 846
JPBM Communications Award (Dana Mackenzie), 679
MAA Prizes Presented in Boston (Gung and Hu Award for Distinguished Service—John Ewing; Chauvenet Prize—Dennis DeTurck, Herman Gluck, Daniel Pomerleano and David Shea Vela-Vick; Euler Book Prize—Daina Taimina; Beckenbach Book Prize—Dan Kalman and Nathan Carter; Haimo Awards for Teaching—Matthew DeLong, Susan Loepp, and Cynthia Wyels; Certificates of Meritorious Service—David Kerr, Joe Yanik, Ruth Favro, Frank Ford, Hortensia Soto-Johnson and Minerva Cordero-Epperson), 680
Lichnerowicz Prize, 2012 (Thomas Willwacher), 1455
MAA Prizes Presented in Madison (Carl B. Allendoerfer Award—P. Mark Kayll, John A. Adam; Trevor Evans Award—Nathan Carter, Dan Kalman; Lester R. Ford Award—David A. Cox, Ravi Vakil, Peter Sarnak, Graham Everest, Thomas Ward; George Pólya Award—Leslie A. Cheteyan, Stewart Hengeveld, Michael A. Jones, T. S. Michael; Annie and John Selden Prize—Laura Alcock; Henry L. Alder Award for Distinguished Teaching by a Beginning College or University Mathematics Faculty Member—Kathryn Leonard, Susan Martonosi, Michael Posner), 1455
Marshall Sherfield Fellowship (Samar Malek), 439
Moody's Mega Math Challenge, 2012 (Summa Cum Laude—Vineel Chakradhar, Stephen Guo, Daniel Takash, Angela Zhou, Kevin Zhou; Magna Cum Laude—Connor Davis, Mia de los Reyes, Alyssa Ferris, Sam Magura, Vitchyr Pong; Cum Laude—Madeline Jenkins, Samuel Kirschbaum, Joel Sharin, Steven Tang Sorin Vatasoiu; Meritorious—Patrick Braga, Andrew Foster, Anthony Grebe, Kevin Griffin, Alison Lui; Exemplary—David Haswell, Michael Menz, Robert Perry, Matthew Silver, Constance Zhou; First Honorable Mention—Lindsay Gardner, Ankit Kayastha, Erik Larmore, Andrew Pellegrino, Steven Rofrano), 970
National Academy of Engineering Elections (Michael S. Waterman, Frank P. Kelly), 691
National Academy of Sciences Award in Mathematics (Michael J. Hopkins), 678
National Academy of Sciences Elections (John B. Bell, Demetrios Christodoulou, Wendell H. Fleming, Barbara H. Liskov, László Lovász, Andrei Okounkov, Robert J. Tibshirani, Ruth J. Williams), 970
National Medal of Science (Richard A. Tapia and S. R. S. Varadhan), 52
NCTM Lifetime Achievement Awards (Gail F. Burrill, Francis (Skip) Fennell), 970
NDSEG Fellowships, 1577
NSF Graduate Research Fellowships, 2012 (Lauren Bandklayder, Ashley Bell, Eva Belmont, Mario Bencomo, John Binder, Emily Butler, Frederick Campbell, Suzanne Carter, Zev Chonoles, Giulia DeSalvo, Benjamin Dozie, Sylvester Eriksson-Bique, Laure Flapan, Benjamin Fogelson, Alexander Furger, John Goes, Ryan Goh, Sherry Gong, Paul Grigas, Kelvin Gu, Boaz Haberman, Nathan Harman, Kyle Hasenstab, William Karr, Christopher Kinson, Isabel Kloumann, Brian Lawrence, Oleg Lazarev, Margaret-Rose Leung, Danika Lindsay, Xue Liu, Nicole Looper, Juan Lopez Arriaza, John Lopez, Nicholas Lowman, Eileen Martin, Michele Meisner, Victor Minden, Hilary Monaco, Connor Mooney, Robin Neumayer, Derek Olson, Suchandan Pal, Aleksandr Pankov, Joseph Paulson, Cristian Potter, Suzette Puente, Evan Randles, Robert Richardson, Larry Rolen, David Rolnick, Krishanu Sankar, Barret Schloerke, Benjamin Schweinhart, Ayon Sen, Emily Sergel, Jay Shah, Alexander Shapiro, Yiwei She, Kyler Siegel, Anthony Simms, Slater Stich, Anandh Swaminathan, Daniel Thompson, Linda Tran, Rachel Vishnepolsky, Olivia Walch, Robert Walker, Brian Williams, Cameron Williams, Dylan Wilson, Scott Yang, Qiaochu Yuan, Yi Zeng, Charles Zheng), 847

NSF Posdoctoral Fellowships, 2012 (Antonio Ache, David Aulicino, Matthew Badger, Eric Baer, David Bland, Ana Caraiani, William Cavendish, Melody Chan, Elizabeth Chen, Amee rah Chowdhury, Michael Cortez, Spencer Dowdall, Glenn Ford, Rina Foygel, James Freitag, Sheel Ganatra, Noah Giansiracusa, Wushi Goldring, Owen Gwilliam, Kenneth Ho, Jack Huizenga, Adam Jacob, Thomas Koberda, Mark Lewko, Jonathan Luk, Keerthi Shyam Madapusi Sampath, Johanna Mangahas, Andrew Marks, Jason Miller, Anatoly Preygel, Douglas Rizzolo, Ian Shipman, Steven Sivek, Susan Tolwinski-Ward, Rodrigo Trevino, Vidya Venkateswaran, Cynthia Vinzant, Alden Walker, Matthew Williams, Alexander Young, Elena Yudovina, Inna Zakharevich, Alexander Zupan), 1277

Ostrowski Prize, 2011 (Ib Madsen, Kannan Soundararajan, David Preiss), 1110

PECASE Awards (Amit Singer and Maria G. Westdickenberg), 61; (Suzanne M. Shontz, Mariel Vazquez, Brent R. Waters), 1457

PIMS Education Prize, 2012 (Mark MacLean), 846

Pi Mu Epsilon Student Paper Presentation Awards, 2012 (Beth Bjorkman, Ashley Broadwell, Nathaniel Card, Wilson Cheung, Marissa Clougher, Sarah Hellig, Erik Miller, Candice Nielsen, Mario Sracic, Sarah Wesley), 1458

Prizes of the Canadian Mathematical Society, 2012 (Coxeter-James Prize—Gregory Smith, Jeffery-Williams Prize—Roland Speicher, Krieger-Nelson Prize—Ailana Fraser), 845; 2011 Adrien Pouliot Award—Malgorzata Dubiel; 2012 Excellence in Teaching—Veselin Jungic; 2011 G. de B. Robinson Award—Hugh Thomas, Alexander Yong), 1277; 2012 Doctoral Prize—Matthew Kennedy; 2012 Adrien Pouliot Award—Melania Alvarez), 1576

Prizes of the European Mathematical Society, 2012 (Simon Brendle, Emmanuel Breuillard, Alessio Figalli, Adrian Ioana, Mathieu Lewin, Ciprian Manolescu, Grégory Miermont, Sophie Morel, Tom Sanders, Corinna Ulcigrai), 1458

Prizes of the Royal Society of London (2012 Sylvester Medal—John Toland), 1276

Project NExT Fellows Chosen (Emily Braley, Steve Butler, Neil Epstein, Joel Louwsma, Katherine Morrison, Blerta Shtylla), 1582

Putnam Prizes (Samuel S. Elder, Brian R. Lawrence, Seok Hyeong Lee, Xiaosheng Mu, Evan M. O'Dorney), 846

Rhodes Scholarships (Ishan Nath, Nabeel N. Gillani, Mohit Agrawal), 324

Rollo Davidson Prize, 2012 (Vincent Beffara, Hugo Duminil-Copin), 846

Royal Society of Canada Elections (Stephen S. Kudla, Douglas R. Stinson, Danny Summers, Louis Nirenberg), 61

Royal Society of London Elections, 2012 (Alan Bundy, Alasdair Houston, Christopher Hull, Dominic Joyce, Richard Kerswell, Chandrashekhar Khare, John McNamara, Mathukumalli Vidyasagar), 848

SACNAS Distinguished Undergraduate Mentor Award, 2012 (Erika T. Camacho), 1456

Salem Prize, 2011 (Dapeng Zhan, Julien Dubedat), 578

Shaw Prize, 2012 (Maxim Kontsevich), 1261

SIAM Fellows, 2012 (Tamer Basar, Michele Benzi, Anthony Bloch, Pavel Bochev, Richard Brualdi, Gui-Qiang Chen, G. Bard Ermentrout, Richard Falk, Lisa Fauci, David Ferguson, M. Gregory Forest, Susan Friedlander, Irene M. Gamba, Walter Gautschi, Donald Goldfarb, Sven Hammarling, Pavol Hell, Bruce Hendrickson, Kirk Jordan, Michael Jordan, James Keener, Naomi Leonard, Philip Maini, Geoffrey McFadden, Edward Ott, Tamar Schlick, David Shmoys, Mary Silber, Barry Smith, Tao Tang, Edriss Titi, Robert Vanderbei, Richard Varga, Jan Willems, Thaleia Zariphopoulou), 848

SIAM Prizes (John von Neumann Lecturer—John Ball; Richard C. DiPrima Prize—Thomas Goldstein; George Pólya Prize—Vojtěch Rödl and Mathias Schacht; W. T. and Idalia Reid Prize—Ruth F. Curtain; I. E. Block Community Lecturer—Robert Bridson; Distinguished Service to the Profession—Barbara Lee Keyfitz; Outstanding Paper Prize—Nir Ailon, Bernard Chazelle, Matthew Finn, Jean-Luc Thiffeault, Bart Vandereycken, Stefan Vandewalle; Mathematical Contest in Modeling—Cheng Fu, Hangqi Zhao, Danting Zhu, James Jones, Suraj Kannan, Joshua Mitchell; SIAM Student Paper Prizes—Brittany D. Froese, Adam Oberman, Stefanie Hollborn, Marina Moraiti), 1276

SIAM Reid Prize, 2011 (Irena Lasiecka), 440

Siemens Competition in Math, Science, and Technology, 2011 (Brian Kim, Sitan Chen, Andrew Xu, Kevin Chang, Kevin Tian), 440

Simons Foundation Investigators, 2012, (Manjul Bhargava, Alice Guionnet, Christopher D. Hacon, Paul Seidel, Amit Singer, Terence Tao, Horng-Tzer Yau, Sanjeev Arora, Shafrira Goldwasser, Russell Impagliazzo, Jon Kleinberg, Daniel Spielman, Michael Brenner, Hirosi Ooguri), 1452

Sloan Research Fellowships, 2012 (Anar Akhmedov, Margaret Beck, Grigoriy Blekherman, James Bremer, Pierre Germain, Alireza Salehi Golsefidy, Florian Herzig, Vera Mikyoung Hur, Matthew Kahle, Joel Kamnitzer, Young-Heon Kim, Tong Liu, Yi Ni, Benjamin Recht, Sebastien Roch, Marcus Roper, Karl Schwede, Allan Sly, Valentino Tosatti, Rachel A. Ward), 845

Société Mathématique de France Prizes (2010 d'Alembert Prize—A. Alvarez, E. Ghys, J. Leys; (2012 d'Alembert Prize—Robin Jamet, Shaula Fiorelli Vilmart, Pierre-Alain Chérix; 2012 Anatole Decerf Prize—Francis Loret), 1456

Steele Prizes, 2012 (Michael Aschbacher, Richard Lyons, Steve Smith, Ronald Solomon, William Thurston, Ivo Babuška), 563

Stefan Bergman Prize, 2011 (Gennadi Henkin), 688

Trjitzinsky Memorial Awards, 2011 (Maocai Wu, Jeffrey Hart, Tyler Wippel, David S. Allen, Xavier E. Garcia, Amina S. Mendez, Amanda N. Rodriguez), 65

Trjitzinsky Memorial Awards, 2012 (Anakaren Santana, Emily Mavaddat, Matthew P. Larson, Abigail M. Skelton, Ryan Uding, Benjamin Heebner, Tyler R. Billingsley), 1581

USA Mathematical Olympiad, 2012 (Andre Arslan, Joshua Brakensiek, Calvin Deng, Xiaoyu He, Ravi Jagadeesan, Mitchell Lee, Zhuo Qun Song, Thomas Swayze, Victor Wang, David Yang, Samuel Zbarsky, Alex Zhu), 969
von Kaven Prize, 2012 (Eva Viehmann), 1576
Waterman Award, 2012 (Scott Aaronson), 844
Wright Award of CMS, 2012 (Bernard Hodgson), 1117

Prizewinners

Aaronson, Scott (2012 Alan T. Waterman Award), 844
Abdulla, Rashad (2012 AMS Menger Award), 1118
Adam, John A. (MAA 2012 Carl B. Allendoerfer Award), 1455
Agrawal, Mohit (Rhodes Scholarships), 324
Ailon, Nir (SIAM Outstanding Paper Prize), 1276
Akhmedov, Anar (2012 Sloan Research Fellowships), 845
Alber, Mark S. (2011 AAAS Fellow), 440
Alcock, Laura (MAA 2012 Annie and John Selden Prize Award), 1455
Allen, David S. (2011 Trjitzinsky Memorial Award), 65
Alvarez, A. (2010 d'Alembert Prize), 1456
Alvarez, Melania (2012 Adrien Pouliot Award), 1576
Arora, Sanjeev (2012 Simons Foundation Investigator), 1452
Arslan, Andre (2012 USA Mathematical Olympiad), 969
Aschbacher, Michael (2012 Steele Prize), 563
Babuška, Ivo (2012 Steele Prize), 563
Ball, John (SIAM Prize—John von Neumann Lecturer), 1276
Basar, Tamer (2012 SIAM Fellow), 848
Baygushev, Danila Alexandrovich (2012 AMS Menger Award), 1118
Beck, Margaret (2012 Sloan Research Fellowships), 845
Beffara, Vincent (2012 Rollo Davidson Prize), 846
Benzing, Frederik (2012 AMS Menger Award), 1118
Bhargava, Manjul (2011 Fermat Prize), 439
Behrens, Mark (CAREER Awards, 2011), 323
Bell, John B. (National Academy of Sciences Elections), 970
Benzi, Michele (2012 SIAM Fellow), 848
Berger, Bonnie (2012 AAAS Member), 848
Bhargava, Manjul (2012 Simons Foundation Investigator), 1452
Billingsley, Tyler R. (2012 Trjitzinsky Memorial Award), 1581
Birman, Joan S. (2012 AAAS Member), 848
Birulia, Raman A. (2012 AMS Menger Award), 1118
Blekherman Grigoriy (2012 Sloan Research Fellowships), 845,
Bloch, Anthony (2012 SIAM Fellow), 848
Bochev, Pavel (2012 SIAM Fellow), 848
Bourgain, Jean (2012 Crafoord Prize in Mathematics of the Royal Swedish Academy of Sciences), 676
Brakensiek, Joshua (2012 USA Mathematical Olympiad), 969
Braley, Emily (Project NExT Fellow), 1582
Brandenberger, Robert (2011 CAP-CRM Prize in Theoretical and Mathematical Physics), 323
Bremer, James (2012 Sloan Research Fellowships), 845
Brendle, Simon (2012 EMS Prize), 1458
Brenner, Michael (2012 Simons Foundation Investigator), 1452
Breuillard, Emmanuel (2012 EMS Prize), 1458
Bridson, Robert (SIAM Prize—I. E. Block Community Lecturer), 1276
Brualdi, Richard (2012 SIAM Fellow), 848
Bryn Mawr Mathematics Department (Exemplary Program or Achievement in a Mathematics Department), 672
Budaghyan, Lilya (2011 Emil Artin Junior Prize in Mathematics), 322
Bundy, Alan (2012 Royal Society of London Elections), 848
Burrill, Gail F. (NCTM Lifetime Achievement Award), 970
Butler, Steve (Project NExT Fellow), 1582
Caflisch, Russel E. (2012 AAAS Member), 848
Camacho, Erika T. (2012 SACNAS Distinguished Undergraduate Mentor Award), 1456
Cano, Angel (2012 Balaguer Prize), 844
Carter, Nathan (MAA Beckenbach Book Prize), 683; (MAA 2012 Trevor Evans Award), 1455
Chang, Kevin (2011 Siemens Competition in Math, Science, and Technology), 440
Chazelle, Bernard (SIAM Outstanding Paper Prize), 1276
Chen, Gui-Qiang (2012 SIAM Fellow), 848
Chen, Sitan (2011 Siemens Competition in Math, Science, and Technology), 440
Chériz, Pierre-Alain (2012 d'Alembert Prize), 1456
Cheteyan, Leslie A. (MAA 2012 George Pólya Award Award), 1455
Christodoulou, Demetrios (National Academy of Sciences Elections), 970
Chu, Ngù Bao (2012 AAAS Member), 848
Cordero-Epperson, Minerva (MAA Certificate of Meritorious Service), 685
Cordwell, Katherine Leigh (2012 AMS Menger Award), 1118
Cornuejols, Gerard P. (2011 John von Neumann Theory Prize), 846
Cortez, Ricardo (2012 Blackwell-Tapia Prize), 968
Corwin, Ivan (2012 Clay Research Fellow), 690
Cox, David A. (MAA 2012 Lester R. Ford Award), 1455
Curtain, Ruth (SIAM Prize—W. T. and Idalia Reid), 1276
Daubechies, Ingrid (2011 AAAS Fellow), 440; (2012 Frederic Esser Nemmers Prize), 962
Dauben, Joseph Warren (2012 Whiteman Prize), 572
DeLong, Matthew (MAA Haimo Award for Teaching), 684
de Monvel, Louis Boutet (2012 AAAS Member), 848
Deng, Calvin (2012 USA Mathematical Olympiad), 969
DeTurck, Dennis (MAA Chauvenet Prize), 682
Dhawan, Sidharth (2012 AMS Menger Award), 1118
Diaconis, Persi (2012 Conant Prize), 568
Ding, (David) Fengning) (2012 Intel Science Talent Search Winner), 847
Dong, Hongjie (CAREER Awards, 2011), 323
Dubedat, Julien (2011 Salem Prize), 578
Dubiel, Malgorzata (2011 CMS Adrien Pouliot Award), 1277
Duminil-Copin, Hugo (2012 Rollo Davidson Prize), 846
Eisentraeger, Kirsten (CAREER Awards, 2011), 323
Elder, Samuel S. (Putnam Prize), 846
Elling, Volker (CAREER Awards, 2011), 323

Emelianenko, Maria (CAREER Awards, 2011), 323
Engquist, Bjorn (2012 AMS-SIAM Birkhoff Prize), 576
Epstein, Neil (Project NExT Fellow), 1582
Ermentrout, G. Bard (2012 SIAM Fellow), 848
Everest, Graham (MAA 2012 Lester R. Ford Award), 1455
Ewing, John (MAA Gung and Hu Award for Distinguished Service), 680
Falk, Richard (2012 SIAM Fellow), 848
Fatkullin, Ibrahim (CAREER Awards, 2011), 323
Fauci, Lisa (2012 SIAM Fellow), 848
Favro, Ruth (MAA Certificate of Meritorious Service), 685
Fennell, Francis (Skip) (NCTM Lifetime Achievement Award), 970
Ferguson, David Ferguson (2012 SIAM Fellow), 848
Figalli, Alessio (2012 EMS Prize), 1458
Finn, Matthew (SIAM Outstanding Paper Prize), 1276
Fleming, Wendell H. (National Academy of Sciences Elections), 970
Ford, Frank (MAA Certificate of Meritorious Service), 685
Forest, M. Gregory (2012 SIAM Fellow), 848
Forrest, Stephanie (ACM 2011 Allen Newell Award), 969
Fraser, Ailana (CMS 2012 Krieger-Nelson Prize), 845
Friedlander, Susan (2012 SIAM Fellow), 848
Froese, Brittany D. (SIAM Student Paper Prize), 1276
Fu, Cheng (SIAM Mathematical Contest in Modeling Prize), 1276
Gamba, Irene M. (2012 SIAM Fellow), 848
Garcia, Xavier E. (2011 Trjitzinsky Memorial Award), 65
Garoufalidis, Stavros (2012 Guggenheim Fellowship), 847
Gautschi, Walter (2012 SIAM Fellow), 848
Germain, Pierre (2012 Sloan Research Fellowships), 845
Ghys, E. (2010 d'Alembert Prize), 1456
Gillani, Nabeel N. (Rhodes Scholarships), 324
Gluck, Herman (MAA Chauvenet Prize), 682
Gnewuch, Michael (2012 Information-Based Complexity (IBC) Achievement Prize), 969
Gold, Bonnie (AWM 2012 Louise Hay Award), 686
Goldfarb, Donald (2012 SIAM Fellow), 848
Golsefidy, Alireza Salehi (2012 Sloan Research Fellowships), 845
Goldstein, Thomas (SIAM Prize—Richard C. DiPrima), 1276
Goldwasser, Shafrira (2012 Simons Foundation Investigator), 1452
Green, Mark L. (2011 AAAS Fellow), 440
Gualtieri, Marco (2012 Aisenstadt Prize), 579
Guionnet, Alice (2012 Simons Foundation Investigator), 1452
Hacon, Christopher D. (2012 Simons Foundation Investigator), 1452
Haldane, Duncan (2012 Dirac Medal), 1456
Hammarling, Sven (2012 SIAM Fellow), 848
Hart, Jeffrey (2011 Trjitzinsky Memorial Award), 65
Haunsperger, Deanna (AWM M. Gweneth Humphreys Award for Mentorship of Undergraduate Women in Mathematics), 686
He, Xiaoyu (2012 USA Mathematical Olympiad), 969
Heebner, Benjamin (2012 Trjitzinsky Memorial Award), 1581
Hell, Pavol (2012 SIAM Fellow), 848
Henderson, Andrea (2012 Guggenheim Fellowship), 847
Hendrickson, Bruce (2012 SIAM Fellow), 848
Hengeveld, Stewart (MAA 2012 George Pólya Award Award), 1455
Henkin, Gennadi (2011 Bergman Prize), 688
Henneke, Fabian (2012 AMS Menger Award), 1118
Herzig, Florian (2012 Sloan Research Fellowships), 845
Hinrichs, Aicke (2011 Information-Based Complexity (IBC) Young Researcher Prize), 323
Hodgson, Bernard (2012 Graham Wright Award), 1117
Hollborn, Stefanie (SIAM Student Paper Prize), 1276
Holmstrom, Mark Alan (2012 AMS Menger Award), 1118
Homma, Youkow (2012 AMS Menger Award), 1118
Houston, Alasdair (2012 Royal Society of London Elections), 848
Holowinsky, Roman (2011 SASTRA Ramanujan Prize) 60
Hopkins, Michael J. (2012 NAS Award in Mathematics), 678
Hull, Christopher (2012 Royal Society of London Elections), 848
Hur, Vera Mikyoung (2012 Sloan Research Fellowships), 845
Impagliazzo, Russell (2012 Simons Foundation Investigator), 1452
Ioana, Adrian (2012 EMS Prize), 1458
Ipsen, Ilse C. F. (CAREER Awards, 2011), 323
Jagadeesan, Ravi (2012 USA Mathematical Olympiad), 969
Jamet, Robin (2012 d'Alembert Prize), 1456
Ji, Lyndon (2012 AMS Menger Award), 1118
Jona-Lasinio, Giovanni, (2012 Heineman Prize), 691
Jones, James (SIAM Mathematical Contest in Modeling Prize), 1276
Jones, Michael A. (MAA 2012 George Pólya Award Award), 1455
Jordan, Kirk (2012 SIAM Fellow), 848
Jordan, Michael (2012 SIAM Fellow), 848
Joyce, Dominic (2012 Royal Society of London Elections), 848
Jungic, Veselin (2012 CMS Excellence in Teaching), 1277
Kahle, Matthew (2012 Sloan Research Fellowships), 845
Kahn, Jeremy (2012 Clay Research Award), 690
Kalai, Gil (2012 Rothschild Prize), 844
Kalman, Dan (MAA Beckenbach Book Prize), 683; (MAA 2012 Trevor Evans Award), 1455
Kamnitzer, Joel (2012 Sloan Research Fellowships), 845
Kane, Charles (2012 Dirac Medal), 1456
Kannan, Suraj (SIAM Mathematical Contest in Modeling Prize), 1276
Katz, Nets (2012 Guggenheim Fellowship), 847
Kayll, P. Mark (MAA 2012 Carl B. Allendoerfer Award), 1455
Kelly, Frank P. (National Academy of Engineering Elections), 691
Keener, James (2012 SIAM Fellow), 848
Kennedy, Matthew (2012 CMS Adrien Pouliot Award), 1576
Kerr, David (MAA Certificate of Meritorious Service), 685
Kerswell, Richard (2012 Royal Society of London Elections), 848

Keyfitz, Barbara (2012 AWM-SIAM Kovalevsky Lectureship), 845; (SIAM Distinguished Service to the Profession Prize), 1276
Khare, Chandrashekhar (2012 Royal Society of London Elections), 848
Kim, Brian (2011 Siemens Competition in Math, Science, and Technology), 440
Kim, Young-Heon (2012 Aisenstadt Prize), 579; (2012 Sloan Research Fellowships), 845
Kiselev, Alexander (2012 Guggenheim Fellowship), 847
Kleinberg, Jon (2012 Simons Foundation Investigator), 1452
Kontsevich, Maxim (2012 Shaw Prize), 1261
Koutsoupias, Elias (2012 Gödel Prize), 1117
Kudla, Stephen S. (Royal Society of Canada Elections), 61
Kuo, Frances Y. (Australian Mathematical Society Prize), 61
Lamb, Evelyn (2012 AMS Mass Media Fellow), 850
Larson, Matthew P. (2012 Trjitzinsky Memorial Award), 1581
Lasiecka. Irena (2011 SIAM Reid Prize), 440
Lawrence, Brian R. (Hertz Fellowship Putnam Prize), 846
Lee, Mitchell (2012 USA Mathematical Olympiad), 969
Lee, Seok Lyeong (Putnam Prize), 846
Leonard, Kathryn (MAA 2012 Henry L. Alder Award), 1455
Leonard, Naomi (2012 SIAM Fellow), 848
Lewin, Mathieu (2012 EMS Prize), 1458
Leys, J. ((2010 d'Alembert Prize), 1456
Lieblich, Max (CAREER Awards, 2011), 323
Lim, Lek-Heng (CAREER Awards, 2011), 323
Liskov, Barbara H. (National Academy of Sciences Elections), 970
Liu, Tong (2012 Sloan Research Fellowships), 845
Loepp, Susan (MAA Haimo Award for Teaching), 684
Long, Ling (2011 Ruth I. Michler Memorial Prize), 691
Loret, Francis (2012 Anatole Decerf Prize), 1456
Louwsma, Joel (Project NExT Fellow), 1582
Lovász, László (National Academy of Sciences Elections), 970
Lyons, Richard (2012 Steele Prize), 563
Ma, Ping (CAREER Awards, 2011), 323
Mackenzie, Dana (JPBM Communications Award), 679
MacLean, Mark (2012 PIMS Education Prize), 846
Madiman, Mokshay (CAREER Awards, 2011), 323
Madsen, Ib (2011 Ostrowski Prize), 1110
Maharaj, Mahan (2011 Shanti Swarup Bhatnagar Prize), 322
Maini, Philip (2012 SIAM Fellow), 848
Malek, Samar (Marshall Sherfield Fellowship), 439
Manolescu, Ciprian (2012 EMS Prize), 1458
Markovic, Vladimir (2012 Clay Research Award), 690
Martin, Clyde (2012 Jefferson Science Fellow), 1456
Martonosi, Susan (MAA 2012 Henry L. Adler Award), 1455
Mavaddat, Emily (2012 Trjitzinsky Memorial Award), 1581
Mayboroda, Svitlana (CAREER Awards, 2011), 323
McCallum, William (2012 Award for Distinguished Public Service), 575
McFadden, Geoffrey (2012 SIAM Fellow), 848
McIntosh, Janine (B. H. Neumann Award), 1577
McKibbin, Robert (2012 ANZIAM Medal), 691
McLaughlin, Theresa (2012 AMS Menger Award), 1118
McNamara, John (2012 Royal Society of London Elections), 848
Meiklejohn, Graham K. (B. H. Neumann Award), 1577
Melnick, Karin (2012–2013 AMS Centennial Fellowship), 844
Mendez, Amina S. (2011 Trjitzinsky Memorial Award), 65
Merkurjev, Alexander S. (2012 Cole Prize in Algebra), 567
Metcalfe, Jason (CAREER Awards, 2011), 323
Michael, T. S. (MAA 2012 George Pólya Award Award), 1455
Miermont, Grégory (2012 EMS Prize), 1458
Mitchell, Joshua (SIAM Mathematical Contest in Modeling Prize), 1276
Mitrea, Irina (CAREER Awards, 2011), 323
Moraiti, Marina (SIAM Student Paper Prize), 1276
Morel, Sophie (2012 EMS Prize), 1458
Morrison, Katherine (Project NExT Fellow), 1582
Motter, Adilson (CAREER Awards, 2011), 323
Mu, Xiaosheng (Putnam Prize), 846
Murashkam, Viachaslau I. (2012 AMS Menger Award), 1118
Nang, Philibert (2011 ICTP/IMU Ramanujan Prize), 578
Nath, Ishan (Rhodes Scholarships), 324
Navarrete, Juan Pablo (2012 Balaguer Prize), 844
Neuhauser, Claudia (2011 AAAS Fellow), 440
Ni, Yi (2012 Sloan Research Fellowships), 845
Nirenberg, Louis (Royal Society of Canada Elections), 61
Nisan, Noam (2012 Gödel Prize), 1117
Oberman, Adam (SIAM Student Paper Prize), 1276
O'Dorney, Evan M. (Putnam Prize), 846
Okounkov, Andrei (National Academy of Sciences Elections), 970
Oliynyk, Todd (Australian Mathematical Society Prize), 61
Olver, Sheehan (2011–2012 Adams Prize), 968
Ono, Ken (2012 Erdős Memorial Lecturer), 850
Ooguri, Hirosi (2012 Simons Foundation Investigator), 1452
Ott, Edward (2012 SIAM Fellow), 848
Owre, Sam (2012 CAV Award), 1276
Papadimitriou, Christos H. (2012 Gödel Prize), 1117
Pardon, John (2012 Morgan Prize), 569
Pearl, Judea (2011 Turing Award), 837
Pelayo, Alvaro (CAREER Awards, 2011), 323
Pomerleano, Daniel (MAA Chauvenet Prize), 682
Poonen, Bjorn M. (2012 AAAS Member), 848
Posner, Michael (MAA 2012 Henry L. Alder Award), 1455
Prabhu, Anirudh (2012 Intel Science Talent Search Winner), 847; (2012 AMS Menger Award), 1118
Preiss, David (2011 Ostrowski Prize), 1110
Qian, Zhiguang (CAREER Awards, 2011), 323
Radford, Luis (2011 ICMI Hans Freudenthal Medal for a major cumulative program of research), 689
Rao, Anita Kummamuri (2012 AMS Menger Award), 1118
Rapoport, Michael (2011 Heinz Hopf Prize), 322
Recht. Benjamin (2012 Sloan Research Fellowships), 845
Rigollet, Philippe (CAREER Awards, 2011), 323
Roch, Sebastien (2012 Sloan Research Fellowships), 845
Rodnianski, Igor (2011 Fermat Prize), 439
Rödl, Vojtěch (SIAM Prize—George Pólya), 1276

Rodriguez, Amanda N. (2011 Trjitzinsky Memorial Award), 65
Ronen, Amir (2012 Gödel Prize), 1117
Roper, Marcus (2012 Sloan Research Fellowships), 845
Roughgarden, Tim (2012 Gödel Prize), 1117
Rushby, John (2012 CAV Award), 1276
Sanders, Tom (2012 EMS Prize), 1458
Santana, Anakaren (2012 Trjitzinsky Memorial Award), 1581
Sanusi, Danial (2012 AMS Menger Award), 1118
Sarkar, Palash (2011 Shanti Swarup Bhatnagar Prize), 322
Sarnak, Peter (Australian Mathematical Society Prize), 61; (MAA 2012 Lester R. Ford Award), 1455
Savitt, David (CAREER Awards, 2011), 323
Schlick, Tamar (2012 SIAM Fellow), 848
Schoenfeld, Alan (2011 ICMI Felix Klein Medal for Lifetime Achievement), 689
Schwede, Karl (2012 Sloan Research Fellowships), 845
Seade, Jose (2012 Balaguer Prize), 844
Seidel, Paul (2012 Simons Foundation Investigator), 1452
Sesum, Natasa (CAREER Awards, 2011), 323
Shankar, Natarajan (2012 CAV Award), 1276
Shea-Brown, Eric (CAREER Awards, 2011), 323
Sheffield, Scott (2011 Loève Prize), 60
Shiller, Robert (2012 CME/MSRI Prize), 1577
Shmoys, David (2012 SIAM Fellow), 848
Shontz, Suzanne M. (PECASE Awards), 1457
Shtylla, Blerta (Project NExT Fellow), 1582
Silber, Mary (2012 SIAM Fellow), 848
Singer, Amit (PECASE Awards), 61; (2012 Simons Foundation Investigator), 1452
Singh, Simon (2010 ICM Leelavati Prize), 1456
Skelton, Abigail M. (2012 Trjitzinsky Memorial Award), 1581
Sly, Allan (2012 Sloan Research Fellowships), 845
Smith, Barry (2012 SIAM Fellow), 848
Smith, Gregory (CMS 2012 Coxeter-James Prize), 845
Smith, Steve (2012 Steele Prize), 563
Solomon, Ronald (2012 Steele Prize), 563
Song, Zhuo Qun (2012 USA Mathematical Olympiad), 969
Sontag, Eduardo D. (2011 IEEE Control Systems Award), 439
Soto-Johnson, Hortensia (MAA Certificate of Meritorious Service), 685
Soundararajan, Kannan (Infosys Prize in Mathematical Sciences, 2011), 323; (2011 Ostrowski Prize), 1110
Speicher, Roland (CMS 2012 Jeffery-Williams Prize), 845
Spielman, Daniel (2012 Simons Foundation Investigator), 1452
Stinson, Douglas R. (Royal Society of Canada Elections), 61
Strogatz, Steven H. (2012 AAAS Member), 848
Summers, Danny (Royal Society of Canada Elections), 61
Sun, Wen-Hsien (2012 B. H. Neumann Award), 1577
Swayze, Thomas (2012 USA Mathematical Olympiad), 969
Szemerédi, Endre (2012 Abel Prize), 836
Taimina, Daina (MAA Euler Book Prize), 682
Tang, Tao (2012 SIAM Fellow), 848
Tao, Terence (2012 Crafoord Prize in Mathematics of the Royal Swedish Academy of Sciences), 676; (2012 Simons Foundation Investigator), 1452
Tapia, Richard A. (National Medal of Science), 52; (2011 AAAS Fellow), 440
Tardos, Éva (2012 Gödel Prize), 1117
Taylor, Richard L. (2012 AAAS Member), 848
Temam, Roger (2011 AAAS Fellow), 440
Thiffeault, Jean-Luc (SIAM Outstanding Paper Prize), 1276
Thomas, Hugh (2011 CMS G. de B. Robinson Award), 1277
Thorne, Jack (2012 Clay Research Fellow), 690
Thurston, William (2012 Steele Prize), 563
Tian, Kevin (2011 Siemens Competition in Math, Science, and Technology), 440
Tibshirani, Robert J. (National Academy of Sciences Elections), 970
Tisseur, Françoise (2011–2012 Adams Prize), 968
Titi, Edriss (2012 SIAM Fellow), 848
Todorcevic, Stevo (2012 CRM-Fields-PIMS Prize), 578
Toland, John (2012 Royal Society of London Sylvester Medal), 1276
Tomova, Maggy (CAREER Awards, 2011), 323
Tosatti, Valentino (2012 Sloan Research Fellowships), 845
Travkin, Roman (2012 Clay Research Scholar), 690
Uding, Ryan (2012 Trjitzinsky Memorial Award), 1581
Ulcigrai, Corinna (2012 EMS Prize), 1458
Uriarte-Tuero, Ignacio (CAREER Awards, 2011), 323
Vakil, Ravi (MAA 2012 Lester R. Ford Award), 1455
Valko, Benedek (CAREER Awards, 2011), 323
Vanderbei, Robert (2012 SIAM Fellow), 848
Vandereycken, Bart (SIAM Outstanding Paper Prize), 1276
Vandewalle, Stefan (SIAM Outstanding Paper Prize), 1276
Vapnik, Vladimir (2012 Franklin Medal in Computer and Cognitive Science), 969
Varadhan, S. R. S. (National Medal of Science), 52
Vardhana, Aishwarya A. (2012 ISEF Mathematical Sciences Awards), 1117
Varga, Richard (2012 SIAM Fellow), 848
Vazquez, Mariel (CAREER Awards, 2011), 323; (PECASE Awards), 1457
Vela-Vick, David Shea (MAA Chauvenet Prize), 682
Vidyasagar, Mathukumalli (2012 Royal Society of London Elections), 848
Viehmann, Eva (2012 von Kaven Prize), 1576
Vilmart, Shaula Fiorelli (2012 d'Alembert Prize), 1456
Wang, Victor (2012 USA Mathematical Olympiad), 969
Ward, Rachel A. (2012 Sloan Research Fellowships), 845
Ward, Thomas (MAA 2012 Lester R. Ford Award), 1455
Waterman, Michael S. (National Academy of Engineering Elections), 691
Waters, Brent R. (PECASE Awards), 1457
Wei, Fan (AWM 2012 Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman), 686
Weiss, Michael (2011 Humboldt Professorship in Mathematics), 969
Wenger, Stefan (CAREER Awards, 2011), 323
Westdickenberg, Maria G. (PECASE Awards), 61

Wetzel, Kathryn C. (CASE/Carnegie Foundation for the Advancement of Teaching Professor of the Year), 324
Willems, Jan (2012 SIAM Fellow), 848
Williams, Lauren (CAREER Awards, 2011), 323
Williams, Ruth J. (National Academy of Sciences Elections), 970
Willwacher, Thomas (2012 André Lichnerowicz Prize), 1455
Wippel, Tyler (2011 Trjitzinsky Memorial Award), 65
Wohlmuth, Barbara (2012 Leibniz Prize), 439, 578
Wu, Maocai (2011 Trjitzinsky Memorial Award), 65
Wu, Yichao (CAREER Awards, 2011), 323
Wyels, Cynthia (MAA Haimo Award for Teaching), 684
Xu, Andrew (2011 Siemens Competition in Math, Science, and Technology), 440
Yau, Horng-Tzer (2012 Simons Foundation Investigator), 1452
Yang, David (2012 USA Mathematical Olympiad), 969
Yanik, Joe (MAA Certificate of Meritorious Service), 685
Yong, Alexander (2011 CMS G. de B. Robinson Award), 1277
Yu, Yun William (Hertz Fellowship), 846
Yun, Zhiwei (2012 SASTRA Ramanujan Prize), 1454
Zariphopoulou, Thaleia (2012 SIAM Fellow), 848
Zbarsky, Samuel (2012 USA Mathematical Olympiad), 969
Zhan, Dapeng (CAREER Awards, 2011), 323; (2011 Salem Prize), 578
Zhang, Shoucheng (2012 Dirac Medal), 1456
Zhao, Hangqi (SIAM Mathematical Contest in Modeling Prize), 1276
Zhong, Xianghui (2012 AMS Menger Award), 111
Zhou, Qing (CAREER Awards, 2011), 323
Zhu, Alex (2012 USA Mathematical Olympiad), 969
Zhu, Danting (SIAM Mathematical Contest in Modeling Prize), 1276
Zlatos, Andrej (CAREER Awards, 2011), 323

Reciprocity Agreements

1477

Reference and Book List

67, 330, 443, 584, 696, 851, 978, 1127, 1283, 1468, 1583

Reviews

(The) Beginning of Infinity—A Book Review (Reviewed by William G. Faris), 544
(The) Calculus of Selfishness—A Book Review (Reviewed by Olle Häggström), 47
Chasing Shadows: Mathematics, Astronomy, and the Early History of Eclipse Reckoning—A Book Review (Reviewed by Christopher Linton), 430
Galileo's Muse: Renaissance Mathematics and the Arts—A Book Review (Reviewed by Anthony Phillips), 1435
(The) Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe—A Book Review (Reviewed by Brian E. Blank), 1102
Magical Mathematics—A Book Review (Reviewed by Donovan H. Van Osdol), 960
(The) Man of Numbers: Fibonacci's Arithmetic Revolution—A Book Review (Reviewed by John Hannah), 661
*(The) Mathematical Writings of Évariste Galois—A Book Review (*Reviewd by Charles W. Curtis), 1565
Math Girls—A Book Review (Reviewed by Mari Abe, Mei Kobayashi), 956
Mathématiques, un dépaysement soudain (A Little More Mad Ophelia, Please)—Exhibit Review (Reviewed by Nathalie Sinclair), 819
Numbers: A Very Short Introduction—A Book Review (Reviewed by Rafe Jones), 50
Our Days are Numbered: How Mathematics Orders Our Lives and *The Big Questions: Mathematics—Review of Two Books* (Reviewed by Paul Zorn), 1253
(The) Philosophy of Mathematical Practice—A Book Review (Reviewed by Timothy Bays), 424
(The) Theory That Would Not Die—A Book Review (Reviewed by Andrw I. Dale), 657
Top Secret Rosies—A Film Review (Reviewed by Judy Green), 308
Sudden Disorientation in a Paris Museum—Exhibit Review (Reviewed by Michael Harris), 822
Uneducated Guesses: Using Evidence to Uncover Misguided Education Policies—A Book Review (Reviewed by John Ewing), 815
(The) Universe in Zero Words and *In Pursuit of the Unknown—Review of Two Books* (Reviewed by Gerald B. Folland), 1562
What's Luck Got to Do with It?—A Book Review (Reviewed by Andrew I. Dale), 304
Why Beliefs Matter—A Book Review (Reviewed by Gerald B. Folland), 553

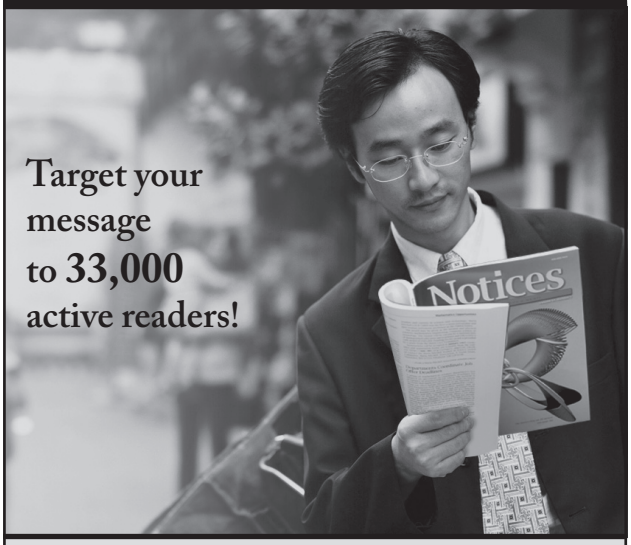
Scripta Manent

Copyright in Academic Writings: Yours to Have and to Hold (and From Which a Publishing Contract Need Not Make You Part) (Jane Ginsburg), 965
Do Mathematicians Get the Author Rights They Want? (Kristine K. Fowler), 436
(The) Future of Mathematical Publishing (Michael G. Cowling), 558
Geometry & Topology: A Community-Based Publishing Initiative (Colin Rourke), 1574
Google Books vs. MathSciNet (Scott Guthery), 1115
(The) New Publishing Scene and the Tenure Case: An Administrator's View (Daniele C. Struppa), 670
(The) Open Textbook Revolution (Steven E. Barkan), 1447
Publishing Computational Mathematics (Tim Daly), 320
Shifting Editorial Boards (Susan Hezlet), 841
Whither Journals? (Rob Kirby), 1272
Why Don't More University Presses Publish Mathematics Books? (David Tranah), 58

Surveys

Annual Survey Doctoral Department Groupings, 1262
2010 Annual Survey of the Mathematical Sciences in the U.S. (2009–2010 Departmental Profile Report), 291
2011–2012 Faculty Salaries Report, 410
Doctoral Degrees Conferred 2010–2011, 985
Fall 2011 Departmental Profile Report, 1423

Advertise in the **Notices**
of the American Mathematical Society



Target your message to 33,000 active readers!

Make an impact through Display Advertising

Increase your sales and connect with new customers.

The Notices of the AMS has the largest circulation of any publication in the field.

Select premium positions are available.

Target your audience through Classified Advertising

An effective and economical way to get the most applicants for your open position.

"We have been a long-time advertiser in the Notices *and consider it a highly effective way to reach our customers in the mathematical community."* *—Cambridge University Press*

Please contact Anne Newcomb to create a program that will address your advertising needs.

Anne Newcomb
Phone: 401-455-4084
Email: aen@ams.org

Please visit our online media kit:
http://www.ams.org/notices/adnot.html

(A) Report on 2010—2011 Academic Recruitment and Hiring, 796
Report on the 2010–2011 New Doctoral Recipients, 1083

Table of Contents

3, 259, 363, 473, 611, 739, 907, 1051, 1263, 1379, 1515

WHAT IS

WHAT IS…an Affine Sphere? (Daniel J. F. Fox), 420
WHAT IS…an Approximate Group? (Ben Green), 655
WHAT IS…a Biholomorphic Mapping? (Eric Bedford), 812
WHAT IS…a Fenchel Conjugate? (Heinz H. Bauschke and Yves Lucet), 44
WHAT IS…a Pseudoconvex Domain? (R. Michael Range), 301
WHAT IS…a Scissors Congruence? (Johan L. Dupont), 1242
WHAT IS…a Shimura Variety? (James S. Milne), 1560
WHAT IS…an Octopus Decomposition? (Larry Conlon), 952
WHAT IS…Cop Number? (Anthony Bonato), 1100
WHAT IS…Data Mining? (Mauro Maggioni), 532
WHAT IS…Essential Dimension? (Zinovy Reichstein), 1432

2013 Joint Mathematics Meetings Advance Registration/Housing Form

JOINT MATHEMATICS MEETINGS
SAN DIEGO • JAN 9-12, 2013
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 _____

Acknowledgment of this registration and any hotel reservations will be sent to the email address given here, unless you check this box: *Send by U.S. Mail* ☐

Affiliation for badge _____ Nonmathematician guest badge name: _____
(company/university) (Note fee of US$15)

☐ **I DO NOT want my program and badge to be mailed to me on 12/07/12. (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 17**	**at mtg**	**Subtotal**
☐ Member AMS, MAA, ASL, CMS, SIAM	US$ 235	US$ 309	
☐ Nonmember	US$ 367	US$ 476	
☐ Graduate Student (Mem. of AMS or MAA)	US$ 52	US$ 62	
☐ Graduate Student (Nonmember)	US$ 80	US$ 91	
☐ Undergraduate Student	US$ 52	US$ 62	
☐ High School Student	US$ 5	US$ 10	
☐ Unemployed	US$ 52	US$ 62	
☐ Temporarily Employed	US$ 191	US$ 220	
☐ Developing Countries Special Rate	US$ 52	US$ 62	
☐ Emeritus Member of AMS or MAA	US$ 52	US$ 62	
☐ High School Teacher	US$ 52	US$ 62	
☐ Librarian	US$ 52	US$ 62	
☐ Press	US$ 0	US$ 0	
☐ Nonmathematician Guest	US$ 15	US$ 15	

$_____

AMS Short Course: *Random Matrices (1/7–1/8)*			
☐ Member of AMS or MAA	US$ 104	US$ 138	
☐ Nonmember	US$ 150	US$ 180	
☐ Student, Unemployed, Emeritus	US$ 52	US$ 73	

$_____

MAA Short Course: *Conceptual Climate Models (1/7–1/8)*			
☐ Member of MAA or AMS	US$ 156	US$ 166	
☐ Nonmember	US$ 225	US$ 235	
☐ Student, Unemployed, Emeritus	US$ 78	US$ 88	

$_____

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$ 70 US$ 70
(includes table, posterboard & electricity)

$_____

Employment Center *Please go to http://ams.org/profession/employment-services/employment-center/employment-center to register.*
For further information, contact Steve Ferrucci at emp-info@ams.org.

Events with Tickets
☐ Graduate Student/First Time Attendee Reception (1/9) (no charge)
☐ MER/IME Banquet (1/10) US$ 65 # ___Chicken #___Fish
#___Kosher #___Vegan
☐ NAM Banquet (1/11) US$ 62 #___Chicken #___Fish
#___Kosher #___Vegan
☐ AMS 125th Anniversary Gala (1/12) 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.

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, we will contact you at the phone number provided on this form. For questions, contact the MMSB at mmsb@ams.org.

Signature: _____

☐ **Purchase Order #** _____(please enclose copy)

Other Information

Mathematical Reviews field of interest # _____

How did you hear about this meeting? Check one:
☐ Colleague(s) ☐ Internet ☐ *Notices* ☐ *Focus* ☐ Other _____

☐ This is my first Joint Mathematics Meetings.
☐ I am a mathematics department chair.
☐ For planning purposes for the MAA Two-year College Reception, please check if you are a faculty member at a two-year college.
☐ I would like to receive promotions for future JMM meetings.
☐ Please do not include my name on any promotional mailing lists.
☐ Please do not include my name on any list of participants distributed or displayed at the meeting.
☐ 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: 401-455-4143 or 1-800-321-4267 x4143 or x4144

Deadlines

To be eligible for the complimentary room drawing:	**Nov. 5, 2012**
For housing reservations, badges/programs mailed:	**Nov. 19, 2012**
For housing changes/cancellations through MMSB:	**Dec. 10, 2012**
For advance registration for the Joint Meetings, short courses, minicourses, and tickets:	**Dec. 17, 2012**
For 50% refund on banquets, cancel by:	**Dec. 27, 2012***
For 50% refund on advance registration, minicourses & short courses, cancel by:	**Jan. 04, 2013***

***no refunds issued after this date**

2013 Joint Mathematics Meetings Hotel Reservations – San Diego, CA

(Please see the hotel page in the announcement or on the web for detailed information on each hotel.) To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc. in the column on the left and by circling the requested room type and rate. If the rate or the hotel requested is no longer available, you will be assigned a room at the next available comparable rate. Please call the MMSB for details on suite configurations, sizes, availability, etc. All reservations, including suite reservations, must be made through the MMSB to receive the JMM rates. Reservations made directly with the hotels before **December 19** may be changed to a higher rate. All rates are subject to a 12.5% 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** _____

Name of Other Room Occupant _____ **Arrival Date** _____ **Departure Date** _____ **Child (give age(s)** _____

Order of choice	Hotel	Single	Double 1 bed	Double 2 beds	Triple 2 beds	Triple 2 beds w/cot	Triple - king or queen w/cot	Quad 2 beds	Quad 2 beds w/cot	Suites Starting rates
	San Diego Marriott Hotel & Marina (hdqtrs)									
	City View	US$ 184	US$ 184	US$ 184	US$ 204	US$204*	US$ 204*	US$ 224	US$ 224*	US$ 750
	Bay View	US$ 199	US$ 199	US$ 199	US$ 219	US$219*	US$ 219*	US$ 239	US$ 239*	N/A
	Student Rate (City View)	US$ 147	US$ 147	US$ 147	US$ 167	US$167*	US$ 167*	US$ 187	US$ 187*	N/A
	Omni San Diego	US$ 171	US$ 194	US$ 194	US$ 214	N/A	N/A	US$ 234	N/A	US$ 350
	Student Rate	US$ 154	US$ 174	US$ 174	US$ 194	N/A	N/A	US$ 214	N/A	N/A
	Embassy Suites San Diego Bay	US$ 155	US$ 155	US$ 155	US$ 175	N/A	N/A	US$ 195	N/A	(all suites)
	Student Rate	US$ 135	US$ 135	US$ 135	US $145	N/A	N/A	US$ 155	N/A	(all suites)
	Horton Grand Hotel	US$ 155	US$ 155	US$ 155	N/A	N/A	N/A	N/A	N/A	US$ 259
	Student Rate	US$ 145	US$ 145	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Residence Inn by Marriott Gaslamp District	US$ 152	US$ 152	US$ 152	N/A	N/A	N/A	N/A	N/A	(all suites)
	Student Rate	US$ 145	US$ 145	US$ 145	N/A	N/A	N/A	N/A	N/A	N/A
	Hard Rock Hotel San Diego	US$ 149	US$ 149	US$ 149	US$169	N/A	N/A	US$189	N/A	US$ 199
	Student Rate	US$ 129	US$ 129	US$ 129	US$149	N/A	N/A	US$ 169	N/A	N/A
	Best Western Plus Bayside Inn	US$ 129	US$ 129	US$ 129	US$ 139	US$ 149	US$ 149	US$ 139	US$ 149	N/A
	Student Rate	US$ 119	US$ 119	US$ 119	US$ 129	US$ 139	US$ 139	US$ 129	US$ 139	N/A
	Residence Inn by Marriott Downtown (1-bedroom studio suites. Bedroom has 1 queen bed. Living room has a single sofa sleeper)	US$ 129	US$ 129	US$ 129 **	N/A	N/A	US$144 **	N/A	N/A	(all suites)
	Student Rate (1 bed. studio suite)	US$ 119	US$ 119	US$ 119 **	N/A	N/A	US$134 **	N/A	N/A	(all suites)
	Residence Inn by Marriott Downtown (2-bedroom suites. Each bedroom has 1 queen bed. Living room has a single sofa sleeper.) Limited quantity.	N/A	N/A	US $239	US$ 254	US$ 254 **	N/A	US$ 269	US$ 269 **	(all suites)
	Four Points by Sheraton Downtown	US$ 125	US$ 125	US$ 125	US$ 135	N/A	US$ 145	US$ 145	N/A	N/A
	Student Rate	US$ 115	US$ 115	US$ 115	US$ 125	N/A	US$ 135	US$ 135	N/A	N/A
	Holiday Inn on the Bay	US$ 124	US$ 124	US$ 124	US$ 139	N/A	US$ 149	US$ 154	N/A	US$ 274
	Student Rate	US$ 114	US$ 114	US$ 114	US$ 129	N/A	US$ 139	US$ 144	N/A	N/A
	Hampton Inn San Diego Downtown	US$ 109	US$ 109	US$ 109	US$ 119	N/A	N/A	US $139	N/A	N/A
	Student Rate	US$ 99	US$ 99	US$ 99	US$ 119	N/A	N/A	US $129	N/A	N/A

* The San Diego Marriott has a one-time fee of US$ 20 for a rollaway cot. Rooms with 2 beds are limited. A king with a sleeper sofa may be substituted for the second bed.

** The sleeper sofa is the additional bed. Rollaway cots are not available.

Special Housing Requests:.

☐ I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are:_____

_____

☐ Other requests:_____

☐ I am a member of a hotel frequent-travel club and would like to receive appropriate credit.
The hotel chain and card number are:_____

Only email confirmations will be sent by the hotels, if an email address is provided.

If you are not making a reservation, please check one of the following:

☐ I plan to make a reservation at a later date.

☐ I will be making my own reservations at a hotel not listed. Name of hotel:_____

☐ I live in the area or will be staying privately with family or friends.

☐ I plan to share a room with_____, who is making the reservations.

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

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.

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: **Robert J. Daverman,** Department of Mathematics, University of Tennessee, Knoxville, TN 37996-6900, e-mail: daverman@math.utk.edu; telephone: 865-974-6900.

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:

2013

January 9–12	San Diego, California Annual Meeting	p. 1614
March 1–3	Oxford, Mississippi	p. 1614
April 6–7	Chestnut Hill, Massachusetts	p. 1617
April 13–14	Boulder, Colorado	p. 1617
April 27–28	Ames, Iowa	p. 1618
June 27–30	Alba Iulia, Romania	p. 1619
October 5–6	Louisville, Kentucky	p. 1620
October 12–13	Philadelphia, Pennsylvania	p. 1620
October 18–20	St. Louis, Missouri	p. 1621
November 2–3	Riverside, California	p. 1621

2014

January 15–18	Baltimore, Maryland Annual Meeting	p. 1621
March 21–23	Knoxville, Tennessee	p. 1622
April 5–6	Albuquerque, New Mexico	p. 1622
April 11–13	Lubbock, Texas	p. 1622
June 16–19	Tel Aviv, Israel	p. 1622
September 20–21	Eau Claire, Wisconsin	p. 1623
October 25–26	San Francisco, California	p. 1623

2015

January 10–13	San Antonio, Texas Annual Meeting	p. 1623
June 11–14	Porto, Portugal	p. 1623

2016

January 6–9	Seattle, Washington	p. 1624

2017

January 4–7	Atlanta, Georgia Annual Meeting	p. 1624

2018

January 10–13	San Diego, California Annual Meeting	p. 1624

2019

January 16–19	Baltimore, Maryland Annual Meeting	p. 1624

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 111 in the the January 2012 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.)

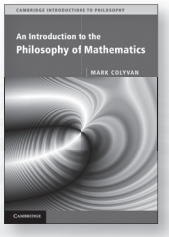
July 22–26, 2013: Samuel Eilenberg Centenary Conference (E100), Warsaw, Poland.

CAMBRIDGE

E-books Available for most titles!

NEW TITLES IN MATHEMATICS *from* CAMBRIDGE UNIVERSITY PRESS!

An Introduction to the Philosophy of Mathematics

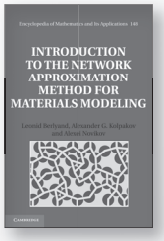


Mark Colyvan

Cambridge Introductions to Philosophy

$85.00: Hb: 978-0-521-82602-0: 198 pp.
$28.99: Pb: 978-0-521-53341-6

Introduction to the Network Approximation Method for Materials Modeling

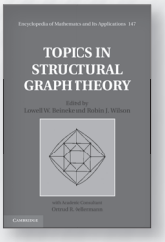


Leonid Berlyand, Alexander G. Kolpakov, *and* Alexei Novikov

Encyclopedia of Mathematics and its Applications

$80.00: Hb: 978-1-107-02823-4: 256 pp.

Topics in Structural Graph Theory

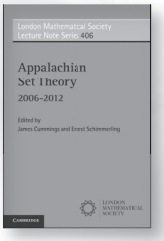


Edited by Lowell W. Beineke *and* Robin J. Wilson
Edited in consultation with Ortrud R. Oellermann

Encyclopedia of Mathematics and its Applications

$95.00: Hb: 978-0-521-80231-4: 344 pp.

Appalachian Set Theory



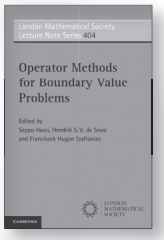
2006–2012

Edited by James Cummings *and* Ernest Schimmerling

London Mathematical Society Lecture Note Series

$70.00: Pb: 978-1-107-60850-4: 430 pp.

Operator Methods for Boundary Value Problems

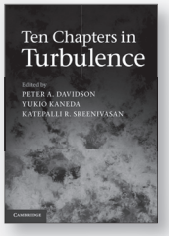


Edited by Seppo Hassi, Hendrik S. V. de Snoo, *and* Franciszek Hugon Szafraniec

London Mathematical Society Lecture Note Series

$65.00: Pb: 978-1-107-60611-1: 309 pp.

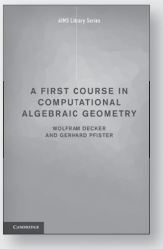
Ten Chapters in Turbulence



Edited by Peter A. Davidson, Yukio Kaneda, *and* Katepalli R. Sreenivasan

$99.00: Hb: 978-0-521-76944-0: 448 pp.

A First Course in Computational Algebraic Geometry

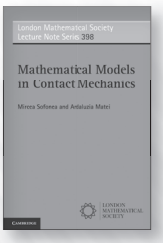


Wolfram Decker *and* Gerhard Pfister

AIMS Library of Mathematical Sciences

$25.99: Pb: 978-1-107-61253-2: 128 pp.

Mathematical Models in Contact Mechanics

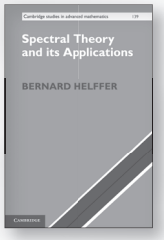


Mircea Sofonea *and* Andaluzia Matei

London Mathematical Society Lecture Note Series

$70.00: Pb: 978-1-107-60665-4: 293 pp.

Spectral Theory and its Applications

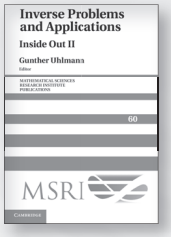


Bernard Helffer

Cambridge Studies in Advanced Mathematics

$65.00: Hb: 978-1-107-03230-9: 250 pp.

Inverse Problems and Applications



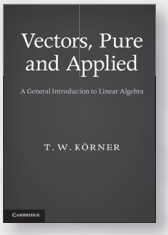
Inside Out II

Edited by Gunther Uhlmann

Mathematical Sciences Research Institute Publications

$110.00: Hb: 978-1-107-03201-9: 592 pp.

Vectors, Pure and Applied



A General Introduction to Linear Algebra

T. W. Körner

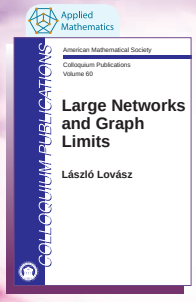
$119.00: Hb: 978-1-107-03356-6: 464 pp.
$55.00: Pb: 978-1-107-67522-3

Prices subject to change.

www.cambridge.org/us/mathematics
800.872.7423
@cambUP_maths

CAMBRIDGE UNIVERSITY PRESS

PUBLISHING HIGHLIGHTS 2012



Large Networks and Graph Limits

László Lovász, *Eötvös Loránd University, Budapest, Hungary*

This is an amazing book: readable, deep, and lively. It sets out this emerging area, makes connections between old classical graph theory and graph limits, and charts the course of the future.

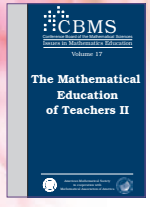
—Persi Diaconis, Stanford University

László Lovász has written an admirable treatise on the exciting new theory of graph limits and graph homomorphisms, an area of great importance in the study of large networks. It is an authoritative, masterful text that reflects Lovász's position as the main architect of this rapidly developing theory. The book is a must for combinatorialists, network theorists, and theoretical computer scientists alike.

—Bela Bollobas, Cambridge University, UK

Authored by a leading expert in the subject, this coherent and accessible book describes one recent approach to the study of large networks, the limit theory of graphs, which has emerged over the past decade and bears rich connections to other approaches to the study of large networks.

Colloquium Publications, Volume 60; 2012; 475 pages; Hardcover; ISBN: 978-0-8218-9085-1; List US$99; AMS members US$79.20; Order code COLL/60

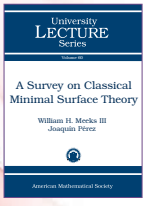


The Mathematical Education of Teachers II

An important guide to the mathematics and statistics that schoolteachers should know and to how they should come to know that mathematics, taking full consideration of the Common Core State Standards for mathematics.

This series is published in cooperation with the Mathematical Association of America.

CBMS Issues in Mathematics Education, Volume 17; 2012; 86 pages; Softcover; ISBN: 978-0-8218-6926-0; List US$33; AMS members US$26.40; Order code CBMATH/17



A Survey on Classical Minimal Surface Theory

William H. Meeks III, *University of Massachusetts, Amherst, MA*, and **Joaquín Pérez**, *Universidad de Granada, Spain*

A survey of recent spectacular successes in classical minimal surface theory, allowing the general mathematician a glimpse of the intrinsic beauty of this theory and the authors' perspective of what is happening at this historical moment in a very classical subject.

University Lecture Series, Volume 60; 2012; approximately 182 pages; Softcover; ISBN: 978-0-8218-6912-3; List US$48; AMS members US$38.40; Order code ULECT/60

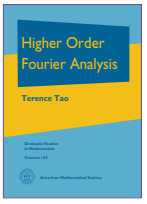
Foundations of Analysis

Joseph L. Taylor, *University of Utah, Salt Lake City, UT*

. . . [W]ell-written, clear, and concise, and supplies the students with very good introductory discussions of the various topics, correct and well-thought-out proofs, and appropriate, helpful examples.

— Robert Brooks, University of Utah

Pure and Applied Undergraduate Texts, Volume 18; 2012; 398 pages; Hardcover; ISBN: 978-0-8218-8984-8; List US$74; AMS members US$59.20; Order code AMSTEXT/18

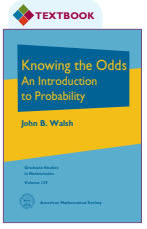


Higher Order Fourier Analysis

Terence Tao, *University of California, Los Angeles, CA*

This latest title from Tao is an introduction to higher order Fourier analysis that covers various topics in the area in a unified manner and surveys some of the most recent developments.

Graduate Studies in Mathematics, Volume 142; 2012; 187 pages; Hardcover; ISBN: 978-0-8218-8986-2; List US$54; AMS members US$43.20; Order code GSM/142



Knowing the Odds
An Introduction to Probability

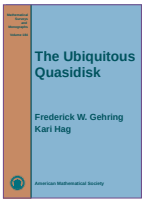
John B. Walsh, *University of British Columbia, Vancouver, BC, Canada*

John Walsh, one of the great masters of the subject, has written a superb book on probability. It covers at a leisurely pace all the important topics that students need to know, and provides excellent examples. I regret his book was not available when I taught such a course myself, a few years ago.

– Ioannis Karatzas, Columbia University

A leisurely introduction to all of the standard material that one would want in a full year probability course, with a slant towards applications in financial analysis.

Graduate Studies in Mathematics, Volume 139; 2012; 421 pages; Hardcover; ISBN: 978-0-8218-8532-1; List US$75; AMS members US$60; Order code GSM/139



The Ubiquitous Quasidisk

Frederick W. Gehring, and **Kari Hag**, *Norwegian University of Science and Technology, Trondheim, Norway*

In clean, clear, and elegant expository fashion, this authoritative text focuses on gathering the numerous properties and many different connections to various topics in geometric function theory that quasidisks possess.

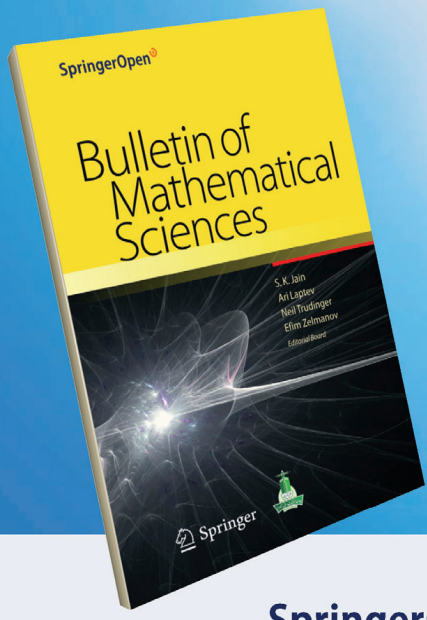
Mathematical Surveys and Monographs, Volume 184; 2012; 171 pages; Hardcover; ISBN: 978-0-8218-9086-8; List US$74; AMS members US$59.20; Order code SURV/184

AMS
American Mathematical Society
BOOKSTORE
www.ams.org/bookstore

facebook.com/amermathsoc
twitter: @amermathsoc

Springer
the language of science

springer.com



Bulletin of Mathematical Sciences

Launched by King Abdulaziz University, Jeddah, Saudi Arabia

SpringerOpen

Bulletin of Mathematical Sciences

Launched by King Abdulaziz University, Jeddah, Saudi Arabia

OPEN ACCESS

Aims and Scope

The *Bulletin of Mathematical Sciences*, a peer-reviewed open access journal, will publish original research work of highest quality and of broad interest in all branches of mathematical sciences. The *Bulletin* will publish well-written expository articles (40–50 pages) of exceptional value giving the latest state of the art on a specific topic, and short articles (about 10 pages) containing significant results of wider interest. Most of the expository articles will be invited.

Editorial Board

S. K. Jain (Algebra, Pure Mathematics), **Ari Laptev** (Analysis, Applied Mathematics), **Neil Trudinger** (Differential Equations, Applied Mathematics), **Efim Zelmanov** (Algebra, Pure Mathematics)

Executive Editors

Efim Zelmanov, San Diego, USA, **S. K. Jain**, Ohio, USA and Jeddah, Saudi Arabia

Associate Editors

Franco Brezzi, Pavia, Italy and Jeddah, Saudi Arabia, **Hitoshi Ishii**, Tokyo, Japan and Jeddah, Saudi Arabia, **Paul Nevai**, Jeddah, Saudi Arabia, **Claus Michael Ringel**, Bielefeld, Germany and Jeddah, Saudi Arabia, **Neil Robertson**, Ohio, USA and Jeddah, Saudi Arabia

Forthcoming articles include:

- **Loewy decomposition of linear differential equations**, by Fritz Schwarz
- **Optimal and isodual ternary cyclic codes of rate 1/2**, by Cherif Mihoubi und Patrick Sole
- **Negative spectra of elliptic operators**, by Stanislav Molchanov und Oleg Safronov
- **Direct-sum decompositions of modules with semilocal endomorphism rings**, by Alberto Facchini
- **Finite rank Bargmann-Toeplitz operators with non-compactly supported symbols**, by Grigori Rozenblum

For more information, please visit ► www.bullmathsci.com

American Mathematical Society Distribution Center
35 Monticello Place, Pawtucket, RI 02861 USA

0002-9920(2012)59:1;1-W