The Proof of Fermat's Last Theorem by R. Taylor and A. Wiles page 743


Jerusalem Meeting (May 24–26, 1995) page 823
FUNCTIONAL ANALYSIS
ON THE EVE OF THE
21ST CENTURY
In Honor of I.M. Gelfand’s 80th Birthday
S. Gindikin, J. Lepowsky, R. Wilson,
Rutgers University, New Brunswick, NJ
(Eds.)
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From the Editor

Should children still be forced to learn to read? Most of the information that we obtain from print media can now be communicated using videotapes, audiotapes, recorded messages, computer graphics, etc. With computer scanners and voice synthesizers, even material stored only in printed word form can be communicated orally. Some information, such as instructions for assembling toys and household paraphernalia, might be more effectively conveyed by videos or computer graphics than by printed words.

Despite the legitimacy of the claim that technology does provide alternatives to the printed word, no widespread movement to denigrate the value of literacy has yet emerged. Why then do so many people think that the development of computers and calculators has diminished the importance of mathematics in basic education? In part, this is a consequence of the misconception that identifies mathematics with numerical computations. But that is not the whole story.

The utility of literacy is rarely used as the sole justification for teaching children to read. Even if technology were to make reading nonessential, advocates would readily cite the value of exposing children to the beauty of poetry and literature. Nor have I heard anyone suggest that schools develop separate reading classes for girls in which cookbooks and child care manuals are used to motivate them.

Despite the influence of detractors like M. Smith (whose book, *Humble Pie*, is reviewed elsewhere in this issue), it is easy to make a convincing case for the pragmatic importance of providing quality mathematics education for all. However, expecting that children will learn mathematics just because it’s useful makes about as much sense as imagining that they will eat vegetables just because vitamins are good for them. Adults and children are more likely to eat vegetables that are prepared in genuinely tasty ways than overcooked mushy peas. Nor is covering them with gooey chocolate sauce likely to provide more than a temptation to lick the sauce off.

Students will be receptive to mathematics only if it is enjoyable as well as relevant. Is this possible? I think so, provided that by “enjoyment” we mean the kind of genuine pleasure that comes from solving challenging puzzles rather than “chocolate syrup” games to promote rote learning of arithmetic.

Suppose that our educational system required all students to learn to tune instruments very precisely but never allowed them to listen to music. Most of them would grow up hating music. Only a talented or lucky few would discover that one could use these same instruments to make beautiful sounds. This group might even become a powerful elite in a “world dominated by [musicians]” and become the subject of a diatribe by M. Smith! Is it really impossible, as some claim, for the average person to appreciate mathematical beauty? Certainly not everyone—perhaps not even all mathematicians—will appreciate the beauty of the Seiberg-Witten breakthrough in 4-dimensional topology. But most young children do enjoy puzzles and games of strategy. What is less widely appreciated is that such nonnumerical games are also mathematics.

True appreciation for, and enjoyment of, mathematics will not come from making it easy—any more than riding up in a cable car can replace the pleasure and achievement of a strenuous hike up a mountain. But good training and guidance are essential if mountain-climbing is to be truly enjoyable rather than unpleasantly arduous and terrifying. This is why we must strive to ensure that those teachers who guide children into the mathematical world are themselves well-qualified enthusiasts. Only then can we hope that children learn and enjoy the genuine mathematics associated with hard “problem-solving” rather than the rote formula memorization that is so often misrepresented as “mathematics”.

Does this mean that we should abandon all efforts to also give students a facility with some of the “basic” formulas and algorithms that most of us learned? No more than suggesting that musicians do not need to practice scales and learn techniques in order to be able to play beautiful music.

But why, you may ask, am I “preaching” to the “converted” readers of the Notices? When the real challenge is to convince educators and the general public? Because I think that we need to reevaluate the arguments we have been putting forth. It may well be necessary to emphasize eventual applications to secure funding for mathematics research. Applications can also make mathematics more interesting; they can even provide the insight to make it more comprehensible or intuitive. But we do our best work when we find pleasure, as well as purpose, in our activity. We cannot hope that many children will learn mathematics unless we find a way to share our enjoyment and show them its beauty as well as its utility.

Mary Beth Ruskai
Call Me Irresponsible...

It is likely that Stuart Hastings speaks for a majority of the membership (in Letters to the Editor, April). You have underlined his point with your snotty caption heading his letter: "Doesn't Like Chaotic Behavior of the Dollar". Neither the behavior of the dollar nor the behavior of any theory involving dollars has anything to do with Hastings's protest. You evidently don't like to hear it. Here it is again: WHAT POSSIBLE POINT IS THERE TO THE DESIGN USING $$$ SIGNS ON PAGE 229?

The answer is none. Second question: Why is the design there? Answer: Because we have an irresponsible editor.

John Isbell
State University of New York at Buffalo
(Received March 17, 1995)

P.S. Of course you are not going to print this; the most I can hope for is that you may read it. You are probably thinking, "What killjoys these guys are!" If so, you are wrong. I have been reproached by real killjoys for publishing papers under pseudonyms such as M. G. Stanley (from Pirates of Penzance) and H. C. Enos (a relative of Joyce's Humphrey Chimpden Earwicker). I have made joke citations of Marshall McLuhan in Trans. Amer. Math. Soc. and of John Barth in J. Algebra. What these things have in common is that they do not get in the reader's way. Can't you get your damned artists out of the way? (And stop insulting members who write in with serious complaints.)

Donald Saari's Response: It is Hastings's and Isbell's personal business whether they appreciate the editor's choice of graphics for the Notices. But I was surprised by their inability to see the relevance of tumbling dollar signs in reference to my (February) article. To remind you, I described how mathematics casts serious doubt on basic perceptions and assumptions about price dynamics. Indeed, we now know that even elementary models from a first course in economics can cause the price changes to exhibit any desired kind of chaos! So, by comparing the article with Hastings's and Isbell's complaints, I can only assume they are jesting! If not... (The paper has an editorial error: the reference Waving Invisible Hand remains in manuscript form.)

Don Saari
Northwestern University
(Received April 9, 1995)

I must agree with Stuart Hastings (letter in the April edition) that the new style of article design is disconcerting.

Take the article on Norbert Wiener in the April edition. It is nine pages long, and contains no less than six photographs of Wiener. On the four pages on which no photograph appears, there is a half-page header on the first, and the other three contain a central box with a quote from the text (the quote on p. 433 coming from p. 430, the quote on p. 436 from p. 431, the quote on p. 438 actually coming from that page).

The following article, "An Interview with Fred Wan", continues the execrable trend of excising boxes from the display and putting a quote from the article in them. It also contains two fairly unenlightening pictures—the crest of the NSF and a dollar bill made into a jigsaw puzzle.

Figures can be very valuable when they illustrate something that is easier to see than to read a description of—a good example is Figure 2 in the article "Geometric Tomography". But the belief that a page of text cannot remain unadorned, no matter how inane the image that breaks the text up may be, is best reserved for children's books.

John E. McCarthy
Young Fogy
Washington University
(Received March 27, 1995)
Letters to the Editor

Editor's Note: Before they are sent to the printer, the Editor reviews the composition of articles, including the graphics, for relevance. The Editor is sympathetic to the view expressed above that graphics should enhance and not divert attention from the text, and will pay closer attention to the composition for this reason. The Notices is in an experimental stage, and—like all good periodicals—will probably always be experimenting. We appreciate and take seriously all criticisms, corrections, and suggestions. We wonder, however, at the origins and significance of the outrage expressed in some of these letters.

All mathematicians engaged in pointless basic research have surely taken heart in the latest issue of the Notices, where Fred Wan assures that our curiosity-driven labors may unwittingly find strategic vindication in the design of better soft drink containers. A sterner inspiration is found in the article about Norbert Weiner, who apparently relished the direct practical application of mathematics to the killing of humans, bearing moral responsibility all the while.

From now on, I shall wear a red, white and blue kerchief while toiling in the $p$-adic fields, to symbolize my hope of contributing to the glorious production of garbage and death.

mark Reeder
University of Oklahoma
(Received March 27, 1995)

Response to Blackburn

The British algebraist N. Blackburn has published a vigorous attack (Notices, v. 42, pp. 325–326) against a letter of which I was among the signers (Notices, v. 41, pp. 571–572, p. 1101). I do not have time to compose a full reply.

There is, however, one point on which I cannot be silent. He denounces us for protesting the reference (in a recent obituary in the Jahresbericht der Deutschen Mathematiker Vereinigung) to the 1944 liberation of Strasbourg from the Nazis as an occupation (Besetzung) by Allied troops.

For a Frenchman of my generation it is very surprising to read what he says about the term "occupation". According to him, "to demand the use of a word with emotive significance instead of 'occupation' is pure political correctness." For us, most of the time of the war was "le temps de l'occupation". It is true that "liberation" has also an emotive significance. However, speaking of the liberation of Strasbourg does not involve using a word with emotive significance instead of the word "occupation", considered as factual and neutral.

To consider "occupation" of Strasbourg by the Allied forces as the right term has an emotional value, especially coming from a British citizen. In 1944 and 1945, British soldiers in France were regarded as liberators, not as occupying forces.

Jean-Pierre Kahane
Université de Paris-Sud (Orsay)
(Received March 27, 1995)

I just read the letter of Norman Blackburn (Notices, 42, no. 3, March 1995) replying to Kahane–Krickeberg–Lorch about Bieberbach. I would like to point out that Kahane–Krickeberg–Lorch were historically right in being incensed by the words "occupation of Strasbourg by Allied forces".

In fact Strasbourg, a French city, was liberated on November 23, 1944, by Free French forces under General Leclerc (his famous "2 e éme D.B.", "2e Armoured Division"). The French administration was immediately reestablished. American forces (the 7th Army of General Patch) cooperated in this liberation and also later, in January 1945, and despite the early misgivings of General Eisenhower, in the defense of Strasbourg against German counter-attacks. This was a normal military cooperation between allied forces, but Strasbourg never was under "Allied rule": General de Gaulle was adamant about it.

Pierre Samuel
Université de Paris-Sud (Orsay)
(Received March 27, 1995)

In his comments (Notices, 42, pp. 325–326) on the letter by Kahane, Lorch, and me (Notices, 41, pp. 571–572 and p. 1101) Norman Blackburn asserts that our letter was "...an...attack on the DMV..." and "...an example of...anti-German xenophobia...". In fact, there was nothing of the sort in it. The content of the letter was summarized in its first sentence: it was a critique of the editorial policy of the Jahresbericht as observed with respect to a specific issue, viz. articles on Bieberbach, Strubecker, and Teichmueller. As a German and as a member of the DMV since 1950, I would certainly not have signed a letter attacking the DMV indiscriminately or inciting to anti-German xenophobia. We even pointed out the formal motion of the DMV at its meeting in September 1934 regretting Bieberbach's abuse of the JDMV, which was a courageous action. One can of course judge the incriminated articles in various ways, and further discussion might be useful, but Blackburn's polemic comments distort our letter more than they discuss it.

Klaus Krickeberg
University of Paris V
(Received March 29, 1995)

Errata

Due to a typesetting production error, an incorrect e-mail address was given for Charles Yeomans of the Young Mathematicians Network on page 554 in the May issue of the Notices. The sentence should have read, "To become a member of the YMN, send e-mail to Charles Yeomans cyeomans@ms.uky.edu".

Anne Roberts, author of the article on pages 547–553 in the May issue of the Notices was incorrectly listed as associate professor of mathematics at the University of Utah. Her correct title is adjunct professor of mathematics. The Notices regrets these errors.
The proof of the conjecture mentioned in the title was finally completed in September of 1994. A. Wiles announced this result in the summer of 1993; however, there was a gap in his work. The paper of Taylor and Wiles does not close this gap but circumvents it. This article is an adaptation of several talks that I have given on this topic and is by no means about my own work. I have tried to present the basic ideas to a wider mathematical audience, and in the process I have skipped over certain details, which are in my opinion not so much of interest to the non-specialist. The specialists can then alleviate their boredom by finding those mistakes and correcting them.

Elliptic Curves
For our purposes an elliptic curve $E$ is given as the set of solutions $\{x, y\}$ of an equation $y^2 = f(x)$, where $f(x) = x^3 + \ldots$ is a polynomial of degree three. Usually $E$ is defined over the rational numbers $\mathbb{Q}$; that is, the coefficients of $f$ are in $\mathbb{Q}$. We also demand that all three zeros of $f$ are distinct ($E$ is "nonsingular"). We may consider $E$ as those solutions in $\mathbb{Q}$, $\mathbb{R}$, or $\mathbb{C}$, denoted, respectively, $E(\mathbb{Q})$, $E(\mathbb{R})$, and $E(\mathbb{C})$. One usually includes in this set an infinitely distant point, denoted $\infty$. With this addition, the solution set has the structure of an abelian group, with $\infty$ as the neutral element. The inverse of $(x, y)$ is $(x, -y)$, and the sum of three points vanishes if they lie on a line. The group addition is given by algebraic functions. As a group $E(\mathbb{Q})$ is finitely generated (Mordell's Theorem), $E(\mathbb{R})$ is isomorphic to $\mathbb{R}/\mathbb{Z}$ or to $\mathbb{R}/\mathbb{Z} \times \mathbb{Z}/2\mathbb{Z}$, and $E(\mathbb{C}) \cong \mathbb{C}/\text{lattice}$ (for example, $y^2 = x^3 - x$ yields the lattice $\mathbb{Z} \oplus \mathbb{Z}i$). For an integer $n$ let $E[n]$ denote the $n$-division points, that is, the kernel of multiplication by $n$. Over $\mathbb{C}$ these are isomorphic to $(\mathbb{Z}/n\mathbb{Z})^2$, and the coordinates are algebraic numbers. For example, the 2-division points are exactly $\infty$ and the three zeros of $f$ (where $y = 0$). The absolute Galois group $\text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q})$ acts on

Gerd Faltings is affiliated with the Max-Planck-Institute für Mathematik in Bonn, Germany.

Translated from Testausdruck DMV Mitteilungen 27. März 1995 für 2/95 by Uwe F. Mayer, University of Utah.
they, since the determining equations have coefficients in \( Q \). This yields Galois representations \( \text{Gal}(\bar{Q}/Q) \to \text{GL}_2(\mathbb{Z}/n\mathbb{Z}) \). Using a change of coordinates, one can arrange that \( f \) has integer coefficients. If one then reduces modulo a prime number \( p \), one obtains a polynomial over the finite field \( F_p \). If the zeros of the reduced polynomial are distinct then this yields an elliptic curve over \( F_p \). This is true for all prime numbers \( p \) except for the finitely many prime divisors of the discriminant of \( f \). Also the choice of \( f \) is not unique, but we do say that \( E \) has good reduction at \( p \) if we can find an \( f \) such that the zeros modulo \( p \) are distinct. (These observations are not completely true at \( p = 2 \) because of the term \( y^2 \)). Otherwise \( E \) has bad reduction at \( p \). If in this case only two zeros of \( f \) modulo \( p \) coincide, one says \( E \) has semistable bad reduction. \( E \) is called semistable if at all \( p \) it has either good or semistable reduction. The curve \( y^2 = x^3 - x \) is not semistable at \( p = 2 \) (no CM-curve is semistable).

An example (which in the end will not exist) of a semistable curve is the Frey curve. To a solution of Fermat’s equation \( a^l + b^l = c^l \) (where \( a, b, c \) are relatively prime, and \( l \geq 3 \) is prime) one associates the curve 

\[
E : y^2 = x(x - a^l)(x - c^l).
\]

This curve has bad reduction exactly at the prime divisors of \( abc \). It has the following noteworthy property: Consider the associated Galois representation \( \text{Gal}(\bar{Q}/Q) \to \text{GL}_2(\mathbb{F}_l) \). This representation is unramified (the analog of “good reduction”) at all prime numbers \( p \) at which \( E \) has good reduction. Here one might have to say “crystalline” for “unramified” if \( p = l \). Because of the particular form of the equation for \( E \), this is also true at all prime divisors \( p > 2 \) of \( abc \). Therefore the \( l \)-division points behave as if \( E \) had good reduction at all \( p > 2 \). However, as we shall see, there are no semistable elliptic curves over \( Q \) with this property, and this is the desired contradiction.

In order to reach the goal this way, one has to replace elliptic curves by modular forms. That this can be done follows from the conjecture of Taniyama-Weil (which essentially is due to Shimura). If \( E \) satisfies the conclusion of this conjecture, that is, if \( E \) is “modular”, then according to a theorem of K. Ribet one can find a modular form for \( \Gamma_0(2) \) which corresponds to the representation of \( E[l] \). However, there are no such modular forms. The content of the papers by R. Taylor and A. Wiles is exactly the proof of the Taniyama-Weil conjecture for semistable elliptic curves over \( Q \). To explain this we need a few basic facts about modular forms.

**Modular Forms**

Let \( H = \{ \tau \in \mathbb{C} | \text{Im}(\tau) > 0 \} \) be the upper half plane, on which \( \text{SL}(2, \mathbb{R}) \) acts by the usual \((a\tau + b)/(c\tau + d)\)-rule. The subgroup \( \Gamma_0(N) \) of \( \text{SL}(2, \mathbb{Z}) \) consists of those matrices

\[
\begin{pmatrix}
a & b \\
c & d
\end{pmatrix}
\]

with \( c \equiv 0 \mod N \). A modular form (of weight \( 2 \)) for \( \Gamma_0(N) \) is a holomorphic function \( f(\tau) \) on \( H \) with

\[
f((a\tau + b)/(c\tau + d)) = (c\tau + d)^2 f(\tau)
\]

for

\[
\begin{pmatrix}
a & b \\
c & d
\end{pmatrix} \in \Gamma_0(N)
\]

and \( f(\tau) \) “holomorphic at the cusps”. This last statement means in particular for the Fourier series (since \( f(\tau + 1) = f(\tau) \))

\[
f(\tau) = \sum_{n \in \mathbb{Z}} a_n \cdot e^{2\pi in\tau}
\]

that all \( a_n \) vanish for \( n < 0 \). If additionally \( a_0 = 0 \), then \( f \) is called a cusp form. The Hecke algebra \( T \) acts on the space of cusp forms. It is generated by Hecke operators \( T_p \) (for \( p \) \( \equiv \) \( N \) prime) and \( U_p \) (for \( p \) \( \mid N \)). For the Fourier coefficients one has

\[
a_n(T_pf) = a_{np}(f) + p a_{n/p}(f),
a_n(U_pf) = a_{np}(f).
\]

An eigenform is a common eigenform of all Hecke operators. One can always normalize it so that \( a_0(f) = 1 \); then \( a_p(f) \) is the corresponding eigenvalue of \( T_p \) or \( U_p \). The above equations allow one to determine all \( a_n \) recursively, and therefore one can determine the eigenform \( f \). Conversely, one can construct for a given sys-
tem \{a_p\} of eigenvalues a Fourier series
\[ f(T) = \sum a_n e^{2\pi i nT}. \]
According to a theorem of A. Weil this is a modular form if and only if the
L-series
\[ L(s, f) = \sum_{n=1}^{\infty} a_n n^{-s} \]
has a holomorphic extension to the full \(s\)-plane and satisfies a suitable
functional equation. (This also must be true for twists by Dirichlet characters.)

In case all \(a_p\) are in \(\mathbb{Q}\), the eigenform \(f\) has an associated
elliptic curve \(E\) with good reduction outside the prime divisors of \(N\). For \(p \nmid N\)
the number of the \(\mathbb{F}_p\)-rational points \(E(\mathbb{F}_p)\) is equal to \#\(E(\mathbb{F}_p) = p + 1 - a_p\). Conversely one can
define for each elliptic curve \(E\) over \(\mathbb{Q}\) a Hasse-Weil L-series \(L(s, E)\), and it is conjectured that
it has the nice properties from above. According to the theorem of A. Weil it should thus be­
long to an eigenform with rational eigenvalues. This is the content of the Taniyama-Weil con­
tecture outside the prime divisors of \(N\).

One can construct a Galois representation asso­
ciated to the eigenform.

An eigenform with rational eigenvalues yie ld s a
homomorphism
\[ \rho : \text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \to \text{GL}_2(\mathbb{R}) \]
which is unramified (or crystalline, respectively)
at \(p \nmid N\), with
\[ \begin{align*}
\text{trace}(\rho(Frob_p)) &= T_p \\
\text{det}(\rho(Frob_p)) &= p.
\end{align*} \]

An eigenform with rational eigenvalues yields a
homomorphism \(\hat{T} \to \mathbb{Z}_3\), and \(\rho\) induces the
\(l\)-adic representation that is given by the associated
elliptic curve \(E\), describing the Galois action
on all \(l^n\)-division points of \(E\). Conversely, it is possible to show that \(E\) is modular if and only if the associated \(l\)-adic representation can be constructed in this manner.

Deformations

The \(l\)-adic representation is constructed for \(l = 3\), starting with the representation on the
3-division points. This is known to be congruent to a modular representation, and then the universal
lifting of this representation is proven modular, which is the core of the proof. The prime 3 is very special here. So one starts with the consideration of \(l = 3\).

One can restrict to the case that the 3-division points yield a surjective map
\[ \text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \to \text{GL}_2(\mathbb{F}_3) \]
(in this argument 5-division points are also used once). As \(\text{PGL}_2(\mathbb{F}_3) \cong S_4\) (the symmetric group
on the four elements of \(\mathbb{P}^1(\mathbb{F}_3)\)) is solvable, the
representation on the 3-division points is already modular according to ("lifting") theorems
by Langlands and Tunnell. This uses intensively the special properties of the prime number \(l = 3\).
For \(l = 2\) the general theory does not work well
for various reasons, and for \(l \geq 5\) this beginning is impossible. We now look for a deformation
argument for the representations modulo 9, 27, 81, 243, 729, etc., to be successively rec­
ognized as being modular. For this one uses the universal deformation of the representation
modulo 3: There is a \(\mathbb{Z}_3\)-algebra \(\mathcal{R}\) of the form
\[ \mathcal{R} = \mathbb{Z}_3[[T_1, \ldots, T_r]]/(I(\text{I is an ideal}), \text{and a \"universal\" Galois representation}\]

\[ \rho : \text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \to \text{GL}_2(\mathcal{R}) \]

with these properties:

1. \(\rho\) is unramified (or crystalline, respectively)
   for \(p \nmid N\) (that is, \(E\) has good reduction at \(p\));
2. \(\rho\) has certain local properties at \(p \mid N\) ("cer­
tain" will not be discussed here);
3. \(\text{det}(\rho(Frob_p)) = p\) for \(p \nmid N\);
4. \(\rho\) mod \((3, T_1, \ldots, T_r)\) is our given repre­
sentation on \(E[3]\);
5. any other representation \(\text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \to \text{GL}_2(\mathcal{A})\)
   with the properties 1)-4) arises in a
   unique way via a homomorphism \(\mathcal{R} \to \mathcal{A}\).

The construction of \(\mathcal{R}\) follows general prin­
ciples. Basically, one takes a set of generators \(\{\sigma_1, \ldots, \sigma_3\}\) of the Galois group, and considers
the ring of power series in \(4s\) variables and di­
vides by the smallest ideal \(I\) such that modulo
\(I\) one obtains a representation with 1), \ldots, 4), pro­
vided one assigns to \(\sigma_i\) the \(2 \times 2\)-matrix which
has the four unknowns corresponding to \(\sigma_i\) as coefficients.

After the construction we get the following commutative
diagram

\[ \begin{array}{c}
\text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \\
\downarrow \rho \\
\text{GL}_2(\mathcal{R}) \\
\downarrow \text{Hom} \ \\
\mathbb{Z}_3 \\
\downarrow \subseteq \\
\mathbb{F}_3
\end{array} \]

where the two left mappings arise from the modu­
lar Galois representation and from the one of
\(E\). Wiles's idea is now to show that \(\mathcal{R}\) is iso­
morphic to \(\hat{T}\), because then the elliptic Galois
representation is automatically modular.

For this, naturally, one needs information on
\(\mathcal{R}\) that is not supplied by the general construction.
Let \(W_n\) denote the adjoint Galois representa­
tion of \(sl(2, \mathbb{Z}/3^n\mathbb{Z})\) \((2 \times 2\)-matrices with
trace zero). Then, for example, the minimal number of generators \( r(R = \mathbb{Z}_3[[T_1, \ldots, T_r]]/I) \) is given by \( \dim_{\mathbb{F}} H^1_f(Q, W_n) \), where \( H^1_f \) denotes a cohomology group satisfying certain local conditions corresponding to 1), 2) from above. This is also called a Selmer group. One sees this by setting \( A = \mathbb{F}_3[T]/(T^2) \) in the definitions. One can show (M. Flach) that the orders of \( H^1_f(Q, W_n) \) are uniformly bounded in \( n \). These orders occur in the following numerical criterion for the equality \( R = \hat{T} \): there is a \( \mathbb{Z}_3 \)-homomorphism \( \hat{T} \to \mathbb{Z}_3 \) satisfying certain local conditions corresponding to 1), 2) from above. This is also called a Selmer group.

One sees this by setting \( \mathbb{F}_3 = \mathbb{F}_3[T]/(T^2) \) in the definitions.

One can show (M. Flach) that the orders of \( H^1_f(Q, W_n) \) are uniformly bounded in \( n \). These orders occur in the following numerical criterion for the equality \( R = \hat{T} \): there is a \( \mathbb{Z}_3 \)-homomorphism \( \hat{T} \to \mathbb{Z}_3 \), where \( \hat{T} \) is the integral closure of \( \mathbb{Z}_3 \) in a finite extension of \( \mathbb{Q}_3 \). For simplicity we will assume that \( \hat{T} = \mathbb{Z}_3 \). It is known that \( \hat{T} \) is Gorenstein; that is, \( \text{Hom}_{\hat{T}}(\hat{T}, \mathbb{Z}_3) \) is a free \( \hat{T} \)-module. The surjection \( \hat{T} \to \mathbb{Z}_3 \) then has an adjoint \( \mathbb{Z}_3 \to \hat{T} \), and the composition of these two maps is multiplication by an element \( \eta \in \mathbb{Z}_3 \), which is well defined up to a unit. Furthermore, \( \eta \neq 0 \). On the other hand, let \( p \subseteq R \) be the kernel of the surjection \( R \to \mathbb{Z}_3 \). Then one has \( \#p/p^2 \geq \#\mathbb{Z}_3/\eta \cdot \mathbb{Z}_3 \) and equality if and only if \( R = \hat{T} \) and this is also a complete intersection (\( I \) can be generated by \( r \) elements). The left-hand side \( \#p/p^2 \) is identical to the order of the Selmer group \( H^1_f(Q, W_n) \), for \( n > 0 \). The first attempt tried to establish equality by using Euler systems (invented by Kolyvagin). However, it was only possible to show that \( p/p^2 \) is annihilated by \( \eta \). This is the content of the theorem of M. Flach. The higher levels of the Euler system, however, could not be constructed.

The Proof

One first shows the minimal case and then reduces to it. By the minimal case we mean that all primes of bad reduction occur already modulo 3 (and not only modulo higher powers). According to the theorem of Ribet and others (used for \( l = 3 \) and not for \( l \) the exponent of Fermat's equation), the Galois representation belonging to the curve modulo 3 is modular of level 3. In the minimal case the computation of Euler characteristics (Poitou-Tate) shows that \( H^1_f(Q, W_1) \) and \( H^2_f(Q, W_1) \) have the same dimension \( r \). For each \( n \) one chooses \( r \) prime numbers \( q_1, \ldots, q_r \equiv 1 \mod 3^n \). Then one proceeds to use a subgroup of \( \text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \). This subgroup contains the intersection with \( \text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \), and the quotient is isomorphic to \( G = (\mathbb{Z}/3^n\mathbb{Z})^r \). The associated Hecke algebra \( \hat{T}_1 \) is a free module over \( \mathbb{Z}_3[G] \), with \( G \)-coinvariants \( T \), and is the quotient of a representation ring \( R_1 = \mathbb{Z}_3[[T_1, \ldots, T_r]]/J_1 \), which again can be generated by \( r \) elements. The ideal \( J_1 \) is small due to the free action of the group \( G \). Now one takes a limit \( n \to \infty \), and in the limit \( R_1 \) and \( \hat{T}_1 \) become rings of power series and equal. Furthermore, one obtains \( R \) from \( R_1 \) and \( \hat{T} \) from \( \hat{T}_1 \) in both cases by putting in the additional \( r \) relations \( \sigma_i = 1 \), where \( \sigma_1, \ldots, \sigma_r \) are generators of \( G \). Finally, \( R = \hat{T} \), and this is a complete intersection.

To reduce to the minimal case, one estimates how both sides of the inequality

\[
\#p/p^2 \geq \#\mathbb{Z}_3/\eta \cdot \mathbb{Z}_3
\]

change as one proceeds from level \( M \) to a higher level \( N \) \((M|N)\). For the left-hand side \( \#H^1_f(Q, W_n) \) certain local conditions are weakened, and one obtains an upper bound. For the right-hand side there is the phenomenon of "fusion", that is, of congruences between oldforms and newforms. Here a lower bound has been constructed by Ribet and Ihara. Luckily the two bounds agree, and thus everything is shown.
Mapping Heredity: Using Probabilistic Models and Algorithms to Map Genes and Genomes

Eric S. Lander

The human genome is a vast biochemical jungle in which scientists have begun hunting for the genetic basis of inherited diseases. Even a one-letter error in the $3 \times 10^9$ base pairs (bp) of deoxyribonucleic acid (DNA) inherited from either parent may be sufficient to cause a disease. Thus, to detect inherited diseases, one must be able to detect mistakes present at just over one part in $10^{10}$. The task is sometimes likened to finding a needle in a haystack, but this analogy actually understates the problem: the typical 2-gram needle in a 6,000-kilogram haystack represents a 3,000-fold larger target. In certain respects, the gene hunter’s task is harder still, because it may be difficult to recognize the target even if one stumbles upon it. Although molecular biologists refer to the human genome as if it were well defined in mathematicians’ terms, it is recognized that, except for identical twins, no two humans have identical DNA sequences. Two genomes chosen from the human population are about 99.8 percent identical, affirming our common heritage as a species. But the 0.2 percent variation translates into some six million sequence differences. Common sites of sequence variations are called DNA polymorphisms. Most polymorphisms are thought to be nonfunctional variations, arising by mutation, having no deleterious consequence, and increasing (and decreasing) in frequency by stochastic drift. The presence of considerable DNA polymorphism in the population has sobering consequences for disease hunting. Even if it were straightforward to determine the entire DNA sequence of individuals, one could not find the gene for cystic fibrosis (CF) simply by comparing the sequences of a CF patient and an unaffected person: there would be too many polymorphisms.

How does a geneticist find the genes responsible for cystic fibrosis, diabetes, or heart disease?
When recombination occurs, the chromosomes carry a new combination of alleles.

Figure 1
Schematic drawing of genetic recombination in an $F_1$ heterozygote with distinct alleles at two loci (marked as A and B) on a chromosome. When no recombination occurs between A and B in meiosis, chromosomes carrying the original pair of alleles result. When recombination occurs, the resulting chromosomes carry a new combination of alleles.

Genetic Mapping

The Concept of Genetic Maps

Genetic mapping is based on the recognition of genetic markers. It is possible to find where a gene is without knowing what it is. Specifically, it is possible to identify the location of an unknown disease-causing gene by correlating the inheritance pattern of the disease in families with the inheritance pattern of known genetic markers. It is useful to return to Mendel’s Laws of Inheritance:

- **First Law.** For any gene, each parent transmits one allele chosen at random to its offspring.
- **Second Law.** For any two genes, the alleles transmitted by a parent are independent (that is, there is no correlation in the alleles transmitted).

Although Mendel’s First Law has held up well over the past 130 years, the Second Law turned out to be false in general. Two genes on different chromosomes show no correlation in their inheritance pattern, but genes on the same chromosome typically show correlation.

Consider the simple backcross in Figure 1, showing the inheritance of two genes A and B on the same chromosome. The $F_1$ individual carries one chromosome with alleles $a_1$ and $b_1$ at the two genes and another chromosome with alleles $a_2$ and $b_2$. Often, one or the other chromosome is transmitted completely intact to the offspring. If this always happened, the inheritance pattern at the two genes would be completely dependent: $a_1$ would always be co-inherited with $b_1$. But the situation is more interesting. Crossing over can occur at random points along the chromosomes, involving an even swap of DNA material. If a crossover occurs between genes A and B, it results in recombination between the genes, producing a chromosome carrying a new combination of alleles: $a_1b_2$ or $a_2b_1$. In fact, multiple crossovers can occur along a chromosome; recombination between two loci will result whenever an odd number of crossovers occur.

Genetic mapping is based on the recognition that the recombination frequency $\theta$ between two genes (or loci) provides a measure of the distance between them. If two genes are close together, $\theta$ will be small. If the recombination frequency is clearly less than 0.50, the genes are said to be linked.

The genetic distance $d_{A,B}$ between two genes A and B is defined as the expected number of crossovers between the genes. If one assumes that crossovers are distributed independently with respect to one another (this assumption is not quite right but is adequate for many purposes), genetic distances can easily be converted into recombination frequency, for the number of crossovers between genes A and B will then be Poisson distributed with mean $d = d_{A,B}$; and so the probability of an odd number of crossovers can be shown to be

$$\theta = \left(1 - e^{-2d}\right)/2.$$  

For small distances, the formula is $\theta \approx d$, which reflects the fact that the possibility of more than one crossover can be neglected. For large distances $d$, the recombination frequency $\theta$ approaches 0.50, that is, independent assortment.

Genetic mapping is an essential first step in characterizing a new mutation. Consider first the
situation of (1) a laboratory organism in which experimental matings can be set up at will and (2) traits that are monogenic and fully penetrant (that is, the phenotype is completely determined by the genotype at a single gene). For example, a *Drosophila* geneticist might find a dominantly acting mutation at a locus X, causing flies to have an extra set of wings (in fact, such mutations exist). He would set up crosses with strains carrying different genetic markers (that is, variants in other genes of known location) in order to find the regions showing correlated inheritance. Figure 2a shows the result of a backcross of this type. The gene A is clearly not linked to locus B but is tightly linked to locus C. The proportion of recombinant chromosomes provides a straightforward statistical estimator of the recombination frequency. In this case, the recombination frequency between A and B is about 20/200 = 10 percent. The gene A can be positioned more precisely by using a three-point cross shown in Figure 2b, in which two nearby genetic markers are segregating. Here, it is clear that A maps about midway between genes C and D (see figure caption).

For experimental organisms and simple traits, genetic mapping provides a straightforward way to locate the trait-causing gene to a small inter-

---

**Figure 2a**

Examples of three-point crosses. (A) Locus A is unlinked to locus B but is linked to locus C at a recombination fraction of 10 percent.

<table>
<thead>
<tr>
<th>Offspring Genotypes</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) $b\ ca$</td>
<td>45</td>
</tr>
<tr>
<td>(2) $++\ ca$</td>
<td>45</td>
</tr>
<tr>
<td>(3) $+\ ca$</td>
<td>45</td>
</tr>
<tr>
<td>(4) $b\ ++\ ca$</td>
<td>45</td>
</tr>
<tr>
<td>(5) $b\ c+\ ca$</td>
<td>5</td>
</tr>
<tr>
<td>(6) $+\ c+\ ca$</td>
<td>5</td>
</tr>
<tr>
<td>(7) $b\ +a\ ca$</td>
<td>5</td>
</tr>
<tr>
<td>(8) $+\ +a\ ca$</td>
<td>5</td>
</tr>
</tbody>
</table>

No linkage between B and A: Recombinant offspring $((3) + (4) + (5) + (8)) = 100/200 = 50\%$

Linkage between C and A: Recombinant offspring $((5) + (6) + (7) + (8)) = 20/200 = 10\%$

---

**Figure 2b**

(B) Locus A is located between loci C and D, at about 10 percent recombination fraction from each. The first two types of progeny involve chromosomes with no recombination; the next four involve a single recombination, and the last two involve double recombination (between C-A and A-D). The double recombination class is always least frequent, a property that allows one to determine the order of three linked loci from a cross in which they are all segregating.

<table>
<thead>
<tr>
<th>Offspring Genotypes</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>$cad$</td>
<td>81</td>
</tr>
<tr>
<td>$++\ ca\ d$</td>
<td>81</td>
</tr>
<tr>
<td>$+\ ca\ d$</td>
<td>9</td>
</tr>
<tr>
<td>$+\ +\ d\ ca\ d$</td>
<td>9</td>
</tr>
<tr>
<td>$c++\ ca\ d$</td>
<td>9</td>
</tr>
<tr>
<td>$+\ a\ d\ ca\ d$</td>
<td>9</td>
</tr>
<tr>
<td>$c+\ d\ ca\ d$</td>
<td>1</td>
</tr>
<tr>
<td>$+\ a+\ ca\ d$</td>
<td>1</td>
</tr>
</tbody>
</table>

(B) Locus A is located between loci C and D, at about 10 percent recombination fraction from each. The first two types of progeny involve chromosomes with no recombination; the next four involve a single recombination, and the last two involve double recombination (between C-A and A-D). The double recombination class is always least frequent, a property that allows one to determine the order of three linked loci from a cross in which they are all segregating.
val. *Drosophila* geneticists rarely need to appeal to statistical or mathematical concepts. For geneticists studying human families or complex traits, however, the situation is quite different.

**Challenges of Genetic Mapping: Human Families and Complex Traits**

Medical geneticists studying diseases face two major problems: (1) for human diseases, one cannot arrange matings at will but must rather retrospectively interpret existing families; and (2) for both human diseases and animal models of these diseases, the trait may not be simply related to the genotype at a single gene. Owing to these complications, genetic mapping of disease genes often requires sophisticated mathematical analysis.

The first problem is the inability to arrange matings. To offset this limitation, human geneticists need to have a huge collection of frequent, naturally occurring genetic markers so that the inheritance pattern of each chromosomal region can be followed just as if one had deliberately set up a cross incorporating specific genetic markers. In 1980 David Botstein set off a revolution by recognizing that the naturally occurring DNA polymorphisms in the human population filled the need [4]. By 1994, over 4,000 DNA polymorphisms had been identified and mapped relative to one another.

Even with a dense genetic map of DNA polymorphisms, human genetic mapping confronts several special problems of incomplete information: (1) For individuals homozygous \(a_1/a_1\) at a gene, one cannot distinguish between the two homologous chromosomes at this location. (2) For individuals heterozygous \(a_1/a_2\) at a gene, one cannot tell which allele is on the paternal chromosome and which is on the maternal chromosome unless one can study the individual's parents. (3) Information for deceased individuals (or for those who choose not to participate in a genetic study) is completely missing from the pedigree.

Another problem is that many traits and diseases do not follow simple Mendelian rules of inheritance. This problem has several aspects:

- **Incomplete penetrance.** For some "disease genes", the probability that an individual inheriting the disease gene will have the disease phenotype may be less than 1. This probability is called the penetrance of the disease genotype. Penetrance may depend on other unknown genes, age, environmental exposure, or random chance. For example, a gene called BRCA1 on chromosome 17 predisposes to early onset of breast cancer in some women, but the penetrance is estimated to be about 60 percent by age 50 and 85 percent by age 80.

- **Phenocopy.** Some diseases can be due to non-genetic causes. For example, colon cancer can be caused by mutations in the APC gene on human chromosome 5, but most cases of colon cancer are thought to be nongenetic in origin (and are often attributed to diet).

- **Genetic heterogeneity.** Some diseases may be caused by mutations in any one of several different genes.

- **Polygenic inheritance.** Some diseases may involve the interaction of mutations at several different genes simultaneously.

**Maximum Likelihood Estimation**

To handle the problem of incomplete information, geneticists have adopted the statistical approach of *maximum likelihood estimation* (MLE).

The geneticist would ideally like to have complete genotypic data \(X\)—for example, the genotype for every family member, including the precise parental chromosome from which each allele was inherited. Given complete information, it is usually easy to estimate the required parameters: for example, the recombination frequency can be estimated by counting recombinant chromosomes, and the penetrance can be estimated by finding the proportion of individuals with a disease-predisposing genotype who manifest the disease. Unfortunately, one typically has only incomplete data \(Y\), from which it is difficult to estimate \(\theta\) directly.

The maximum likelihood estimate \(\hat{\theta}\) is the value that makes the observed data \(Y\) most likely to have occurred, that is, the value that maximizes the likelihood function \(L(\theta) = \text{prob}(Y|\theta)\). Using Bayes' Theorem, one can calculate \(L(\theta)\).

To determine whether \(\hat{\theta}\) is significantly different from a null value \(\theta_0\) (for example, to see whether an estimated recombination frequency is significantly less than 50 percent), one examines the likelihood ratio \(Z = L(\hat{\theta})/L(\theta_0)\). If \(Z\) exceeds some appropriate threshold \(T\), a statistically significant effect has been found.

In principle, virtually any genetic problem can be treated by this approach. In practice, two important issues arise:

**Efficient Algorithms.** The number of terms in the Bayes sum scales as roughly \(O(c^{nm})\), where \(m\) is the number of people in the family, \(n\) is the number of genetic markers studied, and \(c\) is a constant. Except in the case of the smallest problems, it is infeasible to enumerate all the terms in the sum. Thus, it is a challenge even to calculate the likelihood \(L(\theta)\) at a single point, let alone to find the value \(\theta\) that maximizes the function. Considerable mathematical attention has been devoted to finding efficient ways to calculate \(L(\theta)\).

Recently, mathematical geneticists have explored ways to approximate \(L(\theta)\) by sampling...
from the sum. Modern techniques such as Gibbs sampling and importance sampling [12, 14, 15, 13, 21] have been introduced in the past few years. These methods exploit the fact that each piece of missing data depends only on local information in the pedigree. Finding good ways to compute the likelihood function remains a problem from the standpoint of genetics and an excellent test bed for new statistical estimation techniques.

**Statistical Significance.** In many genetic situations, one may search for a disease gene by estimating \( \hat{\theta} \) at many locations along the genome. When doing multiple comparisons, the threshold for statistical significance must be higher than the threshold for a single comparison. Surprisingly, the answer to this threshold question turns out to depend on relatively recent results from the theory of large deviations of diffusion processes. We elaborate on this idea in the next section, using an example from recent work in our laboratory on susceptibility to colon cancer.

**Excursion: Susceptibility to Colon Cancer in Mice and the Large Deviation Theory of Diffusion Processes**

Colon cancer is one of the most prevalent malignancies in western societies, with an estimated 145,000 new cases and 60,000 deaths per year in the United States alone. Although environmental factors such as diet can markedly influence the incidence of the disease, genetic factors are known to play a key role. Some families show striking clusters of colon cancer. Among such colon cancer families, there is a distinctive subtype called familial adenomatous polyposis (FAP), which is characterized by the fact that affected individuals develop a large number of intestinal growths called polyps that can become tumors. Genetic mapping studies [2, 17] showed that FAP was genetically linked to a region on the long arm of human chromosome 5; subsequently, physical mapping studies led to the isolation of the responsible gene, named APC [10, 11, 19].

One way to study the role of APC in tumorigenesis is to turn to biochemistry. Another way is to turn back to genetics for further insight. One observation about FAP families is that individuals inheriting precisely the same APC mutation may be affected to very different degrees.

By the usual scientific serendipity, animal studies turned out to hold an important clue. In 1990 William Dove's laboratory at the University of Wisconsin was performing mutagenesis experiments and identified a mouse that spontaneously developed colon tumors [18]. The dominantly acting mutation responsible for the trait was named Min (multiple intestinal neoplasia).

After considerable genetic mapping and cloning, Dove and his colleagues showed that Min was in fact a mutation in the mouse version of the APC gene [20].

The Min mouse thus provided a model of human colon cancer and, in particular, a way to look for other genes that might suppress the development of colon tumors. When Dove and colleagues crossed this mouse to another mouse strain called AKR, they got a surprising result: progeny develop many fewer colon tumors.

A backcross was arranged in which the \( F_1 \) progeny were mated back to the more susceptible strain (Figure 3). For any modifier locus, 50 percent of the progeny should inherit one copy of the suppressing allele from the AKR strain (that is, have genotype AB) and 50 percent should be homozygous for the nonsuppressing allele (that is, have genotype BB). Each animal inheriting the Min mutation was scored for its phenotype by dissecting the intestine and counting the number of tumors and for its genotype by typing the mice for a dense map of DNA polymorphisms that had been constructed in our laboratory [6].

The data for animal \( i \) can be thought of as a phenotype \( \phi_i \) and a continuous function \( \phi_i(x) \) indicating the genotype, which is either AB or BB at each position along the chromosome (Figure 4).
At every position \( x \) along the chromosome, the animals can be divided into two sets according to their genotype:

\[
\begin{align*}
AB(x) &= \{\text{animal } i | g(x) = AA\} \\
BB(x) &= \{\text{animal } i | g(x) = BA\}.
\end{align*}
\]

If a major modifier gene occurs at location \( x \), then the animals in \( AB(x) \) should have many fewer tumors than the animals in \( BB(x) \). One could thus perform a \( t \)-test at every position along the chromosome to find a region where the \( t \)-statistic \( Z \) exceeds some critical threshold \( T \).

How high a threshold is needed to ensure statistical significance, if one scans the entire genome? We will focus on a single chromosome. If there is no modifying gene along the chromosome, the \( t \)-statistic \( Z(x) \) at any given point \( x \) should be normally distributed with mean 0. It is thus easy to determine the appropriate significance level for the single test at \( x \). But we need to know about the distribution of max \( Z(x) \), where the maximum is taken over the entire chromosome.

It is not hard to show that the statistics \( Z(x) \) in our genetic example follow an Ornstein-Uhlenbeck process with \( \beta = 2 \). Using recent mathematical results [7, 16], one can thus show that, for large \( t \),

\[
\Pr \{\text{max}_{x \leq G} Z(x) > t\} \approx 2Gt^2(1 - \Phi(t)),
\]

where \( \Phi(t) \) is the standard normal distribution function and \( G \) is the length of the chromosome measured in expected numbers of crossovers (a unit called the morgan). In short, the probability of exceeding threshold \( t \) somewhere along a genome of length \( LG \) is larger by a factor of \( 2Gt^2 \) than the probability of exceeding it at a single point.

Returning to the problem of colon cancer, we applied this analysis to the entire mouse genome (the genetic length \( G = 16 \) morgans). By genetic mapping, we found a striking region on mouse chromosome 4 for which \( Z_{\text{max}} = 4.5 \). The nominal significance level of the statistic is \( p = 3.5 \times 10^{-6} \). After correcting for searching over an entire genome (by multiplying by \( 2GZ_{\text{max}}^2 \)), the genome-wide significance level is \( p \approx 0.002 \). This suggests that there is indeed a modifying gene in this region of chromosome 4.

On the strength of this analysis, several additional crosses were arranged to confirm this result. With more than 300 animals analyzed, the results are now unambiguous: the corrected significance level is now \( < 10^{-10} \), and it appears that a single copy of the suppressing form of the gene can decrease tumor numbers at least twofold. Physical mapping is now underway to clone the gene in order to learn its role of reducing colon cancer in genetically predisposed mice. With luck, it may suggest ways to do the same in humans.

References


Donald E. McClure

This report describes the employment experience over a two- to three-year period of individuals who received a doctorate in the mathematical sciences from a U.S. institution between July 1, 1990, and June 30, 1991. Results of the 1993 AMS-IMS-MAA Employment Profile Survey are analyzed and presented. This special survey collected information about employment histories for a sample of the target population over the period from the receipt of their degrees to fall 1993.

In 1990-1991, a total of 1,125 doctorates were awarded by mathematics, statistics, applied mathematics, and operations research departments in the U.S. In November 1991, the First Report of the 1991 Annual AMS-MAA Survey [1] reported an alarming 12 percent of this population to be unemployed and seeking employment. This percentage was over twice the rate of unemployment reported the year before for 1989-1990 degree recipients and was the highest rate reported in the fall since 1975. In the follow-up report on the 1991 Annual Survey in spring 1992 [2], the unemployment rate for 1990-1991 doctoral recipients was 5 percent; the rate reported in the spring had never exceeded 3 percent since the follow-up analyses were first reported in 1977.

The 1990-1991 doctoral recipients confronted a shock wave in the employment market, caused by three major forces coming together at one time. As documented in the 1991-1992 Academic Hiring Survey of the AMS Task Force on Employment [5] and in Annual Surveys [2,3,4], the employment market was severely affected by an increased number of new Ph.D.s, by drastically reduced levels of recruitment attributed to economic conditions, and by increased numbers of highly qualified recent U.S. immigrants seeking employment in the market for mathematical scientists.

There has been widespread concern in the mathematics community about the longer-term effects of the difficult market on employment of recent Ph.D.s. In spring 1993, the AMS-IMS-MAA Data Committee designed the Employment Profile Survey to learn more about these effects. The 1990-1991 doctoral recipients were chosen as the focus of the study, since they were the first group that was especially hard-hit by the declining job market.

The three factors causing the difficult market in 1991 persisted through 1992 and 1993. Not only did the 1990-1991 doctoral recipients face a difficult market when seeking their first jobs, but the factors that caused an initial imbalance between supply and demand remained in force during the subsequent two-year period when many of the 1990-1991 cohort were seeking more permanent situations than their first jobs.

The 1,125 doctorates awarded in 1990-1991 represented an 18 percent increase from the number awarded in 1989-1990. At that time, it was the highest count of new degrees reported.

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There was at the same time a precipitous drop in levels of recruitment by academic employers during 1990-1991 and further declines in 1991 to 1993. As reported in the Second Reports of the 1991, 1992, and 1993 Annual Surveys [2,3,4], the number of doctoral faculty positions which departments sought to fill in 1990–1991 was 17 percent lower than the number in 1989–1990 for the doctorate-granting mathematics departments (Survey Groups I, II, and III), 34 percent lower for masters-granting mathematics departments (Group M), 18 percent lower for bachelors-granting mathematics departments (Group B), and 33 percent lower for doctorate-granting statistics departments (Group IV). Over the three-year period, 1990–1991 through 1992–1993, the number of doctoral-level faculty positions that departments sought to fill declined 22 percent in Groups I, II, and III combined; 45 percent in Group M; 30 percent in Group B; and 37 percent in Group IV. There were simply fewer jobs.

Quantitative information about the effects on the employment market of highly trained recent U.S. immigrants is rather sketchy and difficult to measure. The 1991–1992 Academic Hiring Survey [5] was able to gauge part of the effect on academic positions filled in doctorate-granting mathematics departments during 1990–1991. Thirteen percent of all positions filled for 1991–1992 and 15 percent of the positions held by citizens of Eastern Europe and the former Soviet Union. The National Science Foundation recently reported a large increase in 1992 for the number of highly trained scientists and engineers receiving permanent resident status in the U.S., including substantial numbers of new permanent residents in the mathematical and computer sciences [6]. Many of these individuals are seeking positions appropriate for their skills and education and are having a substantial effect on the overall supply of mathematical scientists.

It is in this context that particular concern has been felt for the employment prospects of the 1990–1991 and other recent doctoral recipients. The Data Committee focused their attention for the special survey on the subpopulation whose employment or known address in the 1991 Annual Survey was in the U.S. There are 921 doctoral recipients in this group. Based on the final results of the 1991 Annual Survey, the employment matrix of the 921 doctoral recipients on the U.S. employment market in fall 1991 is given in Table 1. The data in Table 1 represents a complete census of the 1990–1991 doctoral recipients on the U.S. employment market. It is based on information provided first by the doctorate-granting departments and confirmed by a follow-up survey of the individuals themselves.

**Highlights**

- U.S. institutions awarded 1,125 doctorates in the mathematical sciences between July 1, 1990, and June 30, 1991. In fall 1991, 921 of these degree recipients held employment or had a known address in the U.S.
- By fall 1993, an estimated 856 of the 1990–1991 doctoral recipients remained in the U.S., and an estimated 65 had moved to a position or address outside the U.S. Among those in the U.S. whose employment status was known, an estimated 11 percent had not secured a position for fall 1993 as of spring/summer 1993.
- In the first fall after receiving their doctorates, an estimated 79 percent of the 816 individuals employed in the U.S. were in academic positions. In fall 1993, an estimated 76 percent of those with known employment in the U.S. were in academic positions.
- Among the 921 doctoral recipients in the U.S. in fall 1991, an estimated 401 were not in the same position in fall 1993 that they held in the first fall after receipt of their doctorates. An estimated 150 individuals moved out of U.S. academic positions, and an estimated 24 individuals moved from outside academia into U.S. academic positions.
- In the first fall after receipt of their doctorates, an estimated 54 percent of the group who held U.S. academic positions were in tenure-track positions. In fall 1993, an estimated 76 percent of the U.S. academic positions held by the 1990–1991 doctoral recipients were tenure-track positions. The number of positions held by this group and known to be tenure-track increased from an estimated 304 in the first fall after receipt of their doctorate to 357 in fall 1993.

**Employment Profile Survey**

The main questions addressed in the 1993 Employment Profile Survey relate to the employment histories of the target population of 921 individuals. Very good baseline information was available from the 1991 Annual Survey. Since the majority of new doctoral recipients traditionally enter the academic job market, special attention was directed to that sector of the market. Based on 1991 data, it was estimated that around 300 individuals held non-tenure-eligible positions in fall 1991; this subgroup was presumed to be actively seeking longer-term, career positions at some point in the early years after receipt of their degrees. The survey was designed to assure that meaningful estimates of employment patterns could be determined for the population as a whole and for the subpopulation who held temporary positions in 1991.

A random sample of 365 individuals, 40 percent of the population, was selected from the tar-
Classifications
The 1993 Employment Profile Survey is under the direction of the AMS-IMS-MAA Data Committee, whose members are Paul W. Davis, Lorraine Denby, John D. Fulton (chair), James Hurley, Don O. Loftsgaarden, James W. Maxwell (ex officio), Donald B. Rubin, Donald C. Rung, Ann K. Stehney, and Ann E. Watkins. Comments or suggestions regarding this Survey may be directed to the committee.

For these reports, departments are divided into groups according to the highest degree offered in the mathematical sciences:

Groups I and II include the leading departments of mathematics in the U.S. according to the 1982 Assessment of Research-Doctorate Programs conducted by the Conference Board of Associated Research Councils, in which departments were rated according to the quality of their graduate faculty.¹

Group I is composed of 39 departments with scores in the 3.0–5.0 range.

Group II is composed of 43 departments with scores in the 2.0–2.9 range.

Group III contains the remaining U.S. departments reporting a doctoral program.

Group IV contains U.S. departments (or programs) of statistics, biostatistics, and biometrics reporting a doctoral program.

Group V contains U.S. departments (or programs) in applied mathematics/applied science, operations research, and management science which report a doctoral program.

Group Va is applied mathematics/applied science.

Group Vb is operations research and management science.

Group M contains U.S. departments granting a master’s degree as the highest graduate degree.

Group B contains U.S. departments granting a baccalaureate degree only.

¹ These findings were published in An Assessment of Research-Doctorate Programs in the United States: Mathematical and Physical Sciences, edited by Lyle V. Jones, Gardner Lindzey, and Porter E. Coggeshall, National Academy Press, Washington, D.C., 1982. The information on mathematics, statistics, and computer science was presented in digest form in the April 1983 issue of the Notices, pages 257–267, and an analysis of the above classifications was given in the June 1983 Notices pages 392–393. For a listing of departments in Groups I and II see the April 1988 Notices, pages 532–533.

The sample and the sample design were chosen to control the sampling variability of the estimates of key proportions and subpopulation characteristics of interest. In particular, the sample was stratified in order to reduce variability of estimates and to assure proportionate representation in the sample of individual characteristics of interest: sex, citizenship status, Group of the degree-granting department, and category of employment in fall 1991.

Data were collected from the 365 individuals in the sample starting in spring 1993. Most of the data collection effort was completed by August 1993. However, the process of doing thorough follow-up and of validating responses extended in a few cases until April 1994. There was special attention to having as complete a response as possible from individuals in the sample whose fall 1991 employment was in the academic sector.

There is sampling variability in the following tables that describe various patterns of employment. For the sample size used, the standard deviation of an estimate of a proportion for the population as a whole is 2 percent. For example, when the proportion of the population employed in a Group B department in fall 1993 is estimated (Table 4A), that estimate is the value of a random variable with standard deviation .02; the true proportion for the population is 95 percent certain to be within .04, two standard deviations, of the estimate. When we focus on the subpopulation of 264 individuals who held a non-tenure-eligible position in the first fall after receiving their doctorate (Table 5A and Table 7), the standard deviation of the estimate of a proportion is 3.5 percent.

The response rates for the sample of 365 as a whole and for various subsamples of interests are shown in Table 2. Out of 263 sampled individuals whose type of employment in fall 1991 was in academia or a research institute, 258 or 98 percent either responded to the survey directly or information about their employment status was confirmed by other cognizant individuals.

The estimated tallies in the tables that follow are derived by scaling and adding proportions estimated within population strata. The final values are rounded floating-point values. As a result of rounding, it may appear that row and column subtotals of rounded values are not exactly right. This is merely an effect of intermediate rounding.

Employment History
Employment status is estimated for the target population at two points in time: the first fall after each individual received his or her doctorate, referred to as “Fall I,” and fall 1993.

Tables 3A and 3B report estimated employment status in Fall I (the first fall after receipt of doctorate). The patterns reflected here are slightly different from those shown in Table 1 for fall 1991. Indeed, for a number of individuals in the population, Fall I was actually fall 1990; 261 members of the population, 28 percent, received their degrees in July, August, or September of 1990.

The vigilant reader may observe apparent inconsistencies between Tables 3A and 3B and similarly for Tables 4A and 4B. For example, Table 3A estimates that 122 individuals from the whole population were employed in Business
Table 1: Fall 1991 Employment Status of 1990-1991 Doctoral Recipients in the Mathematical Sciences by Type of Granting Department
(Includes only those whose position or known address in fall 1991 was in the U.S.)

<table>
<thead>
<tr>
<th>TYPE OF EMPLOYER</th>
<th>TYPE OF DOCTORAL DEGREE-GRANTING DEPARTMENT</th>
<th>ROW TOTAL</th>
<th>ROW SUBTOTALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group I Math</td>
<td>Group II Math</td>
<td>Group III Math</td>
</tr>
<tr>
<td>Group I</td>
<td>99</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Group II</td>
<td>24</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>Group III</td>
<td>35</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>Group IV</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Group V</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Masters</td>
<td>29</td>
<td>28</td>
<td>24</td>
</tr>
<tr>
<td>Bachelors</td>
<td>44</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>Two-Year Colleges</td>
<td>8</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Other Academic Depts.</td>
<td>21</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Research Institutes</td>
<td>15</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Government</td>
<td>8</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Business and Industry</td>
<td>22</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Foreign, Academic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign, Nonacademic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Seeking Employment</td>
<td>6</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Still Seeking Employment</td>
<td>12</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td>12</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Unknown (non-U.S.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column Total</td>
<td>336</td>
<td>157</td>
<td>137</td>
</tr>
</tbody>
</table>

| Column Male | 277 | 121 | 110 | 105 | 113 | 726 |
| Subtotals Female | 59 | 36 | 27 | 41 | 32 | 195 |

*Non-U.S. citizens who returned to their country of citizenship and whose status is reported as "unknown" or "still seeking employment".


and Industry, while Table 3B estimates that 123 individuals from a subset of the population were employed in Business and Industry. Such discrepancies occur because the table entries are estimates based on a random sample and because slightly different strata were used for constructing the two tables; strata based on sex were used in forming Table 3A and strata based on citizenship status were used for Table 3B. Counts and percentages cited immediately below refer to Table 3A, unless otherwise noted. Percentages cited are among those whose employment status is known.

Of the 816 doctoral recipients employed in the U.S. in Fall I, a total of 644 (79 percent) held academic employment. The 644 academic positions include a total of 274 in doctorate-granting departments, 36 percent of total U.S. employment. As has been documented in previous Annual Survey reports, there are still signs of serious "underemployment" hidden beneath these raw counts. Underemployment is reflected in part-time positions and in numbers of individuals holding employment in the same department that awarded their degree. In the 1991 Annual Survey, for example, 45 individuals reported holding a position in the department that awarded their degree.

Among those whose employment status in Fall I is known, 63 individuals (7.1 percent) were unemployed. By contrast, in the final analysis of the fall 1990 employment status of 1989-90 doctoral recipients, only 2 percent were unemployed.

Table 3A shows differential employment patterns in Fall I depending on the type of degree earned and on sex. In particular, 88 percent of those people whose employer in Fall I was a Group I department earned their degrees from a Group I department, and 89 percent of the Group IV hires in Fall I were awarded their doctorates by a Group IV department. Group IV and Group V degree recipients were much more likely to have held employment in Business and Industry; 57 percent of the individuals who held employment in Business and Industry were from Group IV or V departments, while only 31 percent of the degrees awarded were from these two Groups. No unemployment at all is estimated among Group IV degree recipients, while 8.9 percent of recipients of mathematics degrees are estimated to have been unemployed in Fall I.

There are interesting differences in type of employment for men and women reported in Table 3A. Though there is no apparent difference in proportions holding jobs in doctorate-granting departments (29 percent of the women and
Table 2: Subpopulation Sizes, Target Sample Sizes, and Survey Response Rates for 1990-1991 Doctoral Recipients in the Mathematical Sciences Whose Employer or Known Address in Fall 1991 Was in the U.S.

<table>
<thead>
<tr>
<th>Description</th>
<th>Population Size</th>
<th>Target Sample Size</th>
<th>Number of Respondents</th>
<th>Response Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full Population</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990-91 Ph.D.s with Fall 1991 Employment in the U.S.</td>
<td>921</td>
<td>365</td>
<td>301</td>
<td>82%</td>
</tr>
<tr>
<td><strong>Subpopulation by Type of Fall 1991 Employer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctorate-Granting Department</td>
<td>296</td>
<td>117</td>
<td>115</td>
<td>98%</td>
</tr>
<tr>
<td>Academic Department, Nondoctorate-Granting</td>
<td>336</td>
<td>132</td>
<td>131</td>
<td>99%</td>
</tr>
<tr>
<td>Research Institute</td>
<td>33</td>
<td>14</td>
<td>12</td>
<td>86%</td>
</tr>
<tr>
<td>U.S. Nonacademic</td>
<td>171</td>
<td>68</td>
<td>26</td>
<td>38%</td>
</tr>
<tr>
<td>Unemployed or Unknown Status</td>
<td>85</td>
<td>34</td>
<td>17</td>
<td>50%</td>
</tr>
<tr>
<td><strong>Subpopulation by Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>726</td>
<td>286</td>
<td>233</td>
<td>81%</td>
</tr>
<tr>
<td>Female</td>
<td>195</td>
<td>79</td>
<td>68</td>
<td>86%</td>
</tr>
<tr>
<td><strong>Subpopulation by Citizenship Status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. Citizen</td>
<td>462</td>
<td>187</td>
<td>161</td>
<td>86%</td>
</tr>
<tr>
<td>Non-U.S. Citizen</td>
<td>432</td>
<td>168</td>
<td>132</td>
<td>79%</td>
</tr>
<tr>
<td>Unknown Status</td>
<td>27</td>
<td>10</td>
<td>8</td>
<td>80%</td>
</tr>
</tbody>
</table>

Source: 1993 AMS-IMS-MAA Employment Profile Survey (April 1994)

31 percent of the men), there are much greater differences in proportions holding jobs in bachelors-granting departments: an estimated 12 percent of the men and 26 percent of the women held Group B employment in Fall I. Nonacademic jobs were held by 20 percent of the men and 16 percent of the women. Table 3B shows the Fall I employment as it depends on citizenship status. Citizenship status is known for 894 members of the target population. Non-U.S. citizens who remained in the U.S. are more likely than U.S. citizens to have had a position in a doctorate-granting department. Among non-U.S. citizens, 40 percent held a position in a Group I-V department, and 23 percent of U.S. citizens held a position in a Group I-V department. In contrast, U.S. citizens held jobs in bachelors-granting departments in higher proportion than non-U.S. citizens. Among U.S. citizens, 21 percent held a position in a Group B department, while 8 percent of non-U.S. citizens held a position in a Group B department.

Tables 4A and 4B report estimated employment plans for fall 1993. Three points should be noted concerning the interpretation of results shown in these tables.

First, most of the survey data were collected before fall 1993, when a significant number of respondents were still on the open job market and may not yet have determined their employment for fall 1993. The responses indicate the plans as best they were known when each respondent provided the requested information. Thus, the reported "unemployment" is almost certainly higher than the actual unemployment later turned out to be in fall 1993.

Second, the employment status "Unknown Status" has multiple interpretations. It may indicate that the doctoral recipient truly did not know his or her plans for fall 1993. It may mean that the information was provided to the Data Committee by an individual other than the respondent per se, for example, by a department staff member, and that the individual providing the information did not know the doctoral recipient's plans even though the recipient did.

Third, because of the different response rates for academic vs. nonacademic strata in the sam-
Table 3A: Estimated Employment Status in First Fall after Receipt of Doctorate of 1990-1991 Doctoral Recipients in the Mathematical Sciences by Type of Granting Department (Includes only those whose position or known address in fall 1991 was in the U.S.)

(5 March 1995)

<table>
<thead>
<tr>
<th>Type of Employer First Fall after Doctorate</th>
<th>Type of Doctoral Degree-Granting Department</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group I Math</td>
<td>Group II Math</td>
</tr>
<tr>
<td>Group I</td>
<td>82</td>
<td>7</td>
</tr>
<tr>
<td>Group II</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td>Group III</td>
<td>31</td>
<td>13</td>
</tr>
<tr>
<td>Group IV</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Group V</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Masters</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>Bachelors</td>
<td>38</td>
<td>29</td>
</tr>
<tr>
<td>Two-Year Colleges</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Other Academic Depts.</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Research Institutes</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Government</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>Business and Industry</td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>Foreign, Academic</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Foreign, Nonacademic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Seeking Employment</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Still Seeking Employment</td>
<td>35</td>
<td>16</td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>Unknown (non-U.S.)*</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Column Total</td>
<td>336</td>
<td>157</td>
</tr>
</tbody>
</table>

*Non-U.S. citizens who returned to their country of citizenship and whose status is reported as "unknown" or "still seeking employment".


Table 3B: Estimated Employment Status in First Fall after Receipt of Doctorate of 1990-1991 Doctoral Recipients in the Mathematical Sciences by Citizenship Status (Includes only those whose position or known address in fall 1991 was in the U.S.)

(4 March 1995)

<table>
<thead>
<tr>
<th>Type of Employer First Fall after Doctorate</th>
<th>Type of Citizenship U.S. Citizens</th>
<th>Total Doctoral Recipients Whose Citizenship is Known</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group I</td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>Group II</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>Group III</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>Group IV</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>Group V</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Masters</td>
<td>51</td>
<td>11</td>
</tr>
<tr>
<td>Bachelors</td>
<td>96</td>
<td>21</td>
</tr>
<tr>
<td>Two-Year Colleges</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Other Academic Depts.</td>
<td>39</td>
<td>9</td>
</tr>
<tr>
<td>Research Institutes</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Government</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td>Business and Industry</td>
<td>55</td>
<td>12</td>
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<tr>
<td>Foreign, Academic</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Foreign, Nonacademic</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Not Seeking Employment</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Still Seeking Employment</td>
<td>32</td>
<td>7</td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Unknown (non-U.S.)*</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Column Total</td>
<td>462</td>
<td>100%**</td>
</tr>
</tbody>
</table>

* Percentage of those whose employment status is known.
** Column percents are rounded to the nearest whole percent.

Table 4A: Estimated Fall 1993 Employment Plans
of 1990–1991 Doctoral Recipients in the Mathematical Sciences by Type of Granting Department
(Includes only those whose position or known address in fall 1991 was in the U.S.)

(5 March 1995)

<table>
<thead>
<tr>
<th>Type of Employer Fall 1993</th>
<th>Type of Doctoral Degree-Granting Department</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type of Granting Department</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group I Math</td>
<td>Group II Math</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Masters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bachelors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-Year Colleges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Academic Depts.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Institutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business and Industry</td>
<td></td>
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</tr>
<tr>
<td>Foreign, Academic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign, Nonacademic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Seeking Employment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Still Seeking Employment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown (non-U.S.)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtotals</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Non-U.S. citizens who returned to their country of citizenship and whose status is reported as "unknown" or "still seeking employment".


Table 4B: Estimated Employment Status in Fall 1993
of 1990–1991 Doctoral Recipients in the Mathematical Sciences by Citizenship Status
(Includes only those whose position or known address in fall 1991 was in the U.S.)

(4 March 1995)

<table>
<thead>
<tr>
<th>Type of Employer Fall 1993</th>
<th>Type of Citizenship</th>
<th>Total Doctoral Recipients Whose Citizenship is Known</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U.S. Citizens</td>
<td>Non-U.S. Citizens</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Percent*</td>
</tr>
<tr>
<td>Group I</td>
<td>32</td>
<td>7</td>
</tr>
<tr>
<td>Group II</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Group III</td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>Group IV</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>Group V</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Masters</td>
<td>43</td>
<td>10</td>
</tr>
<tr>
<td>Bachelors</td>
<td>103</td>
<td>24</td>
</tr>
<tr>
<td>Two-Year Colleges</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td>Other Academic Depts.</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>Research Institutes</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Government</td>
<td>27</td>
<td>6</td>
</tr>
<tr>
<td>Business and Industry</td>
<td>56</td>
<td>13</td>
</tr>
<tr>
<td>Foreign, Academic</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Foreign, Nonacademic</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Not Seeking Employment</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Still Seeking Employment</td>
<td>48</td>
<td>11</td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Unknown (non-U.S.)*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Column Total</td>
<td>462</td>
<td>100%**</td>
</tr>
</tbody>
</table>

* Percentage of those whose employment status is known.

** Column percents are rounded to the nearest whole percent.

Table 5: Estimated Flow Between Types of Employment from First Fall after Doctorate to Fall 1993 for 1990-1991 Doctoral Recipients in the Mathematical Sciences Whose Employment or Known Address in Fall 1991 Was in the U.S. (This table reports type of employment in first fall after receipt of doctorate vs. type of employment planned for fall 1993 for only those individuals in the population who had any change in employment in the intervening period.)

<table>
<thead>
<tr>
<th>Type of Employment, First Fall after Doctorate</th>
<th>Type of Employment, Fall 1993</th>
<th>Row Total</th>
<th>Net Outflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic, Doctorate-Granting Department, or Research Institute</td>
<td>Academic, Non-Doctorate-Granting</td>
<td>65</td>
<td>30</td>
</tr>
<tr>
<td>Govt., Business and Industry</td>
<td>Employed Outside U.S.</td>
<td>8</td>
<td>28</td>
</tr>
<tr>
<td>Employed Outside U.S.</td>
<td></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Not Employed, U.S. Address</td>
<td>Unknown Status, U.S. Address</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown Status, Foreign Address</td>
<td>Column Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Net Inflow</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Table 4A shows differential employment patterns in fall 1993 depending on the type of degree earned and on sex. In particular, 83 percent of those people whose employer in fall 1993 was a doctorate-granting mathematics department, Groups I-III, earned their degrees from a Group I department. The proportion among those with plans to be employed in Business and Industry in the U.S. who held a mathematics doctorate (Groups I-III) increased to 48 percent. The unemployment rate estimated among Group IV degree recipients was still extremely low at 2 percent, while 11 percent of recipients of mathematics degrees are estimated to have been unemployed at this stage of their planning for fall 1993.

The differences in employment patterns seen in Fall I for men and women are still shown in the plans for fall 1993. The difference between proportions planning to hold a position in a doctorate-granting department is not significant (23 percent of the men and 27 percent of the women). There were much greater differ-

ple, some “selection biases” may affect the results in Tables 4A and 4B. We believe these effects are small, since the overall response rate is high. For example, because it was much more difficult to do thorough follow-up with individuals holding nonacademic employment, it may be that the estimate of numbers holding nonacademic employment in fall 1993 is negatively biased and counts of those in the “Unknown Status, U.S.” category are correspondingly inflated.

Counts and percentages reported immediately below refer to Table 4A unless otherwise noted. Percentages cited are among those whose employment status is known.

Of the 686 doctoral recipients employed in the U.S. in fall 1993, a total of 524 (76 percent) expected to hold academic employment. The 524 academic positions include a total of 193 in doctorate-granting departments, 37 percent of total U.S. employment.

Among those whose employment plans for fall 1993 were known, 86 individuals (10.8 percent) were unemployed.
Table 6A: Estimated Tenure Status in First Fall after Receipt of Doctorate of 1990-1991 Doctoral Recipients in the Mathematical Sciences (Includes only those whose position or known address in fall 1991 was in the U.S.)

<table>
<thead>
<tr>
<th>Type of Employer in First Fall after Receipt of Doctorate</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group I+II</th>
<th>Group IV</th>
<th>Group M</th>
<th>Group B</th>
<th>2-Year College</th>
<th>Other Acad.</th>
<th>Foreign Acad.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number in Tenure-Track Positions</td>
<td>5</td>
<td>10</td>
<td>46</td>
<td>62</td>
<td>21</td>
<td>5</td>
<td>72</td>
<td>105</td>
<td>17</td>
<td>23</td>
<td>304</td>
</tr>
<tr>
<td>Number in Non-Tenure-Eligible Positions</td>
<td>90</td>
<td>36</td>
<td>10</td>
<td>136</td>
<td>18</td>
<td>12</td>
<td>15</td>
<td>18</td>
<td>13</td>
<td>46</td>
<td>264</td>
</tr>
<tr>
<td>Unknown Tenure Status</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>23</td>
<td>3</td>
<td>0</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td>10</td>
<td>51</td>
</tr>
<tr>
<td>Total Number of Positions</td>
<td>100</td>
<td>54</td>
<td>67</td>
<td>221</td>
<td>41</td>
<td>17</td>
<td>95</td>
<td>131</td>
<td>30</td>
<td>79</td>
<td>619</td>
</tr>
<tr>
<td>Percent Tenure-Track</td>
<td>5%</td>
<td>22%</td>
<td>82%</td>
<td>31%</td>
<td>53%</td>
<td>30%</td>
<td>82%</td>
<td>85%</td>
<td>57%</td>
<td>33%</td>
<td>54%</td>
</tr>
</tbody>
</table>

* Percentage of those whose tenure status is known.


Table 6B: Estimated Tenure Status in Fall 1993 of 1990–1991 Doctoral Recipients in the Mathematical Sciences (Includes only those whose position or known address in fall 1991 was in the U.S.)

<table>
<thead>
<tr>
<th>Type of Employer in Fall 1993</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group I+II</th>
<th>Group IV</th>
<th>Group M</th>
<th>Group B</th>
<th>2-Year College</th>
<th>Other Acad.</th>
<th>Foreign Acad.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number in Tenure-Track Positions</td>
<td>8</td>
<td>13</td>
<td>57</td>
<td>77</td>
<td>18</td>
<td>8</td>
<td>89</td>
<td>118</td>
<td>22</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td>Number in Non-Tenure-Eligible Positions</td>
<td>49</td>
<td>0</td>
<td>5</td>
<td>54</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>13</td>
<td>10</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>Unknown Tenure Status</td>
<td>5</td>
<td>3</td>
<td>8</td>
<td>15</td>
<td>12</td>
<td>0</td>
<td>10</td>
<td>3</td>
<td>5</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Total Number of Positions</td>
<td>62</td>
<td>15</td>
<td>69</td>
<td>147</td>
<td>35</td>
<td>13</td>
<td>101</td>
<td>133</td>
<td>37</td>
<td>49</td>
<td>531</td>
</tr>
<tr>
<td>Percent Tenure-Track</td>
<td>14%</td>
<td>100%</td>
<td>92%</td>
<td>59%</td>
<td>78%</td>
<td>60%</td>
<td>97%</td>
<td>90%</td>
<td>68%</td>
<td>60%</td>
<td>33%</td>
</tr>
</tbody>
</table>

* Percentage of those whose tenure status is known.


ences in proportions holding jobs in bachelors-granting departments: an estimated 14 percent of the men and 34 percent of the women planned to hold Group B employment in fall 1993. Nonacademic jobs were expected to be held by 24 percent of the men and only 8 percent of the women.

Table 4B shows the fall 1993 employment as it depends on citizenship status. Among non-U.S. citizens, 28 percent expected to hold a position in a Group I-V department, and 22 percent of U.S. citizens expected to hold a position in a Group I-V department. Similar to the patterns seen in Fall I, U.S. citizens held jobs in bachelors-granting departments in higher proportion than non-U.S. citizens. Among U.S. citizens, 24 percent held a position in a Group B department, while 7 percent of non-U.S. citizens held a position in a Group B department.

Table 5 reports the types of changes made by those individuals who had any change in their employment between Fall I and fall 1993. An es-
Table 7: Estimated Fall 1993 Employment Plans
of 1990-1991 Doctoral Recipients in the Mathematical Sciences Whose First Position Was in Academia, by Tenure Status in First Fall after Doctorate
(Includes only those whose position or known address in fall 1991 was in the U.S.)

<table>
<thead>
<tr>
<th>Type of Employer Fall 1993</th>
<th>Tenure Status in First Fall after Doctorate</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tenurable</td>
<td>Nontenable</td>
</tr>
<tr>
<td>Group I</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Group II</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Group III</td>
<td>46</td>
<td>15</td>
</tr>
<tr>
<td>Group IV</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>Group V</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Masters</td>
<td>69</td>
<td>23</td>
</tr>
<tr>
<td>Bachelors</td>
<td>102</td>
<td>34</td>
</tr>
<tr>
<td>Two-Year Colleges</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>Other Academic Depts.</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Research Institutes</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Government</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Business and Industry</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Foreign, Academic</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Foreign, Nonacademic</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Not Seeking Employment</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Still Seeking Employment</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Unknown (Foreign)**</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Column Total</td>
<td>304</td>
<td>100%**</td>
</tr>
</tbody>
</table>

* Percentage of those whose employment status is known.
** Column percents are rounded to the nearest whole percent.
*** Non-U.S. citizens who returned to their country and whose status is reported as "unknown" or "still seeking employment".


estimated 401 individuals in the target population had changed their employment status at some time in this period. The trend away from academic employment and the flow from doctorate-granting to non-doctorate-granting departments can be readily seen.

Tenure Status and Academic Employment

In the 1991 Annual Survey, approximately 50 percent of the individuals holding academic employment had positions that were term-contract, non-tenure-eligible positions. Almost half of the non-tenure-eligible positions had contract durations of one or two years. Because of the uncertain future of these positions, the Employment Profile Survey also examined changes in tenure status and the evolution of employment status as a function of eligibility for tenure.

Tables 6A reports tenure status by type of academic employer in Fall I. Table 6B reports the same cross-tabulation in fall 1993.

In Fall I, an estimated 54 percent of the academic positions were tenure-eligible among those positions for which tenure status was known. There were striking variations in the percentage of tenure-eligible positions across different types of departments. While only 5 percent of the positions held in Group I departments were tenure eligible, 85 percent of the positions in Group B departments were tenure eligible. In the doctorate-granting departments overall (Groups I-V), 35 percent of the positions were tenure eligible. In the non-doctorate-granting departments (Groups M and B), 84 percent of the positions in Fall I were tenure eligible.

In fall 1993, there were fewer total academic positions, but a higher proportion were tenure eligible. In fall 1993, an estimated 76 percent of the academic positions were tenure eligible among those positions for which tenure status was known. Variations are still seen in the percentage of tenure-eligible positions across different types of departments. By 1993, 14 percent of the positions held by the 1990-91 doctoral recipients in Group I departments were tenure eligible; the increase in the percentage is attributable more to the decrease in the number
Table 8: Estimated Fall 1993 Tenure Status
of 1990-1991 Doctoral Recipients in the Mathematical Sciences by Tenure Status
in the First Fall After Doctorate
(Includes only those whose position or known address in fall 1991 was in the U.S.)
The subpopulation reported includes individuals whose first position and whose position planned for Fall 1993 were both academic.

<table>
<thead>
<tr>
<th>(8 March 1995)</th>
<th>Tenure Status in First Fall after Doctorate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tenurable</td>
</tr>
<tr>
<td>Tenurable</td>
<td>281</td>
</tr>
<tr>
<td>Nontenable</td>
<td>0</td>
</tr>
<tr>
<td>Unknown</td>
<td>8</td>
</tr>
<tr>
<td>Column Total</td>
<td>289</td>
</tr>
</tbody>
</table>


of non-tenure-eligible positions than to an increase in the estimated number of tenure-eligible positions. In fall 1993, 90 percent of the positions in Group B departments were tenure eligible. In the doctorate-granting departments overall (Groups I-V), 62 percent of the positions were tenure eligible. In the non-doctorate-granting departments (Groups M and B), 93 percent of the positions in fall 1993 were tenure eligible.

Between Fall I and fall 1993, the total number of tenure-eligible positions increased by 53 (17 percent).

Table 7 shows the dependence of employment plans for fall 1993 on tenure status in Fall I. It is apparent that holding a tenure-eligible position affects the stability of employment. Among the subpopulation that held tenure-eligible positions in Fall I, only 4 percent reported that they were unemployed and seeking employment for fall 1993. All of the others from this subpopulation whose employment status was known remained in academic positions. Among those who held non-tenure-eligible positions in Fall I, 17 percent were unemployed and seeking employment for fall 1993.

The likelihood of holding a fall 1993 position in a doctorate-granting department, and especially in a Group I department, is much higher among the subpopulation that held non-tenure-eligible positions in Fall I. In fall 1993, an estimated 24 percent of the non-tenure-eligible subpopulation planned to hold a position in a Group I department, compared to 1 percent of the tenure-eligible subpopulation. In contrast, members of the subpopulation that held tenure-eligible positions in Fall I are much more likely to have held a position in a Group B or M department in fall 1993 (57 percent of the tenure-eligible subpopulation vs. 22 percent of the non-tenure-eligible subpopulation).

Table 8 reports estimated transitions in tenure status for the 509 individuals who are estimated to have held academic employment both in Fall I and in fall 1993. Among this group of 1990-91 doctoral recipients, 60 percent held tenure-eligible positions in Fall I, and 76 percent expected to hold tenure-eligible positions in fall 1993. The change in percentage reflects both an increase in the number of tenure-eligible positions and a decrease in the number of non-tenure-eligible positions held by this group.

Bibliography

What is the Future for the Physical and Mathematical Sciences?

Congressman George E. Brown, Jr.

The following is the text of a speech presented by Congressman George E. Brown, Jr. (D-California) at the annual meeting of the American Association for the Advancement of Science on February 17, 1995, in Atlanta, Georgia.

I am honored to once again be invited to participate in a symposium on the future of science by the American Association for the Advancement of Science (AAAS). I do not know if you have asked me here out of habit, given my frequent pronouncements on the subject at AAAS meetings, or out of pity, given my somewhat diminished status following the recent elections. I will take a more optimistic view and assume that you have asked me here because you think I have something useful to say, a point of view that we will leave to the commentators to judge.

As I reviewed the many speeches and articles that I have offered over the past several years on the health of science, I am struck by how often I have pleaded with the scientific community to pay attention to the changes taking place in the world and to the need to become more closely linked with social goals and needs. Given the results in November, I should have been giving these same speeches to the Democratic Party.

Unlike the Democratic Party, the scientific community has been responding to these changing times with studies, symposia, white papers, and the series of dialogues sponsored by the National Research Council’s Commission on Physical Sciences, Mathematics, and Applications, “The Changing Environment for the Physical and Mathematical Sciences”. This last series of meetings, led by Rad Byerly, Norm Metzger, Al Teich, and Dick Zare, has led up to this session.

What I would like to do this morning is to briefly address some of the same science policy issues I have addressed before but to put them in the current political context.

Put in temporal context, my comments today trace back to the keynote address that I made to the American Association for the Advancement of Science three years ago. This was followed by a June 1992 report from the then Science, Space, and Technology Committee on the health of research. Lest the science and technology community fail to take note of these actions, I proceeded to provide a Chinese water torture of articles and speeches on the subject of the need for the community to reassess its place in society and begin to redefine itself and its relationship to society.

Now, some three years later, the social and political context to which you were adapting has changed. After Senator Mikulski, Dr. Jack Gibbons, and I urged, each in our different ways, that the science and technology community link your activities to a new set of national needs, the leadership of the new Republican-led Congress signaled their desire to see funding priorities shift back to favor basic research. Early indications are that they want to return to the Reagan-era tilt toward basic research and away from applied and developmental research, except in the defense area, with outright hostility toward government-industry technology development programs for civilian purposes.
I am sure that among some in the science community there is a feeling of relief. I know well that many in the basic research fields were uncomfortable with calls to evaluate their research in light of national goals, goals that are not clearly defined. I also know that many felt that I was pushing this issue too hard and too often and was abandoning basic research—a view that is incorrect, I might add. Before you quietly rejoice over drinks this evening about the apparent turn of good fortune brought by the elections, let me make a few observations.

First, this apparent shift away from a broad definition of research that reaches "downstream" to technology development actually poses a greater threat to the basic research community than the current situation. The reason I say this is because if early trends continue, basic research will become isolated, and this will be more true in the physical and mathematical sciences, with fewer dollars and fewer publicly funded applied research programs to help address calls for increased accountability from a results-oriented political system. In the end, basic research will come isolated, and this will be more true in the physical sciences.

Second, anyone in basic research who feels that they can stand up to an American public that is engaging in current levels of political channel surfing has my best wishes. Nearly one half of the House of Representatives has served one term or less and this sudden, large turnout of elected representatives but will have to do it largely on its own, at least if the reductions in federal funding for applied research and development occur on the scale that many fear. Of course, each scientific discipline will face slightly different conditions, depending upon its sources of economic support in the public and private sector.

Third, even if a utopian return to the cloistered halls of basic research resulted from this political change, the basic research community would find that the cloister is smaller than the one they left. The magnitude of cuts that are looming boggles the mind. I recently expressed my disappointment at President Clinton's research and development (R&D) budget, which proposes essentially flat funding for fiscal year 1996. And his budget cuts do not reduce the annual federal deficit but only maintain it at current levels, adding another trillion dollars to the national debt over the next five years and paying for a $56 billion tax cut over the same period. The Republicans intend not only to balance the budget but also to offset a tax cut that has been conservatively estimated to cost $200 billion over the next five years. This will require about a trillion dollars more in cuts than the president is proposing. What this will mean to federal R&D funding is anyone's guess. My own prediction is a 25 percent cut in total R&D funding over the next five years, with some areas suffering even more.

In the end, it is folly to think that any publicly funded endeavor can escape public scrutiny in the current political climate. Putting on my partisan hat, it is even more naive, given present politics, to think that research, basic or applied, will not be linked to the conservative Republican social and political agenda. For example, environmental research discovers environmental problems that might lead to regulation. Global warming would be a good example. Biological research may lead to the discovery of additional endangered species or even endangered ecosystems, leading to the "taking" of private property by the government to protect these species and ecosystems. Enough examples of these linkages exist to convince me that our R&D system will be increasingly linked to real-world debates and issues. The only problem is that someone else is defining your goals, and you do not yet have your own, more appropriate set of goals against which your work can be honestly evaluated.

This leaves you in the worst situation: under fiscal attack without benefit of goals and performance standards that you have defined, being judged by inappropriate measures designed by an ill-informed society. And, unlike public television, you don't even have Big Bird to help you defend yourselves before Congress! So it seems elemental to me that the need to link your work to true national needs which you have had a part in defining is more important than ever.

Now at this point I could elaborate on the need for the science community to define a new mission or to set new goals given the changes in the world. I could and have cited the pressing need for this change due to the end of the Cold War. I could and have cited the massive changes that have begun to take place in our lives due to the
utilization of science and technology, changes which have begun to affect our definition of self. I could describe the dawning of the era of mobile international capital and a stationary work force, a situation that will result in the emergence of new high technology centers in the developing world and an internationalization of science that makes national boundaries meaningless. Instead, let me try to motivate you with a more personal interest: self-preservation.

I cannot really begin to describe the magnitude of federal funding cuts that will affect research and development activities, especially at research universities. But I fear that they will be deep and broad. These politically driven changes reflect the other broad changes—end of the Cold War, etc.—that I have described in the past and indicate that we have crossed over a threshold, undergone a phase change, if you will. What this means to me is that the equation that has described the cyclical nature of political and social trends may have changed. Simply waiting for the cycle of support for science to come around again will not work because the cycle is broken. We now have to push harder than ever to make our own way through this period of readjustment and may have to make basic adjustments of our own, if indeed the basic social equation has been rewritten by global events.

Remember that a strong federal government is a fairly recent phenomenon. With the Great Depression, the federal government expanded and created new areas of activity or took some over from the states. Then with World War II, the government expanded more, as any government does during wartime. But with the Cold War, we entered a period of continuing centralization of power and programs that continued, largely unabated, until the Soviet Union dissolved.

Likewise, our extensive higher-education system is also a fairly recent event. During World War II, science and technology played a large role and was well supported. After the war, the G.I. bill of rights brought large numbers of people into universities. The outlays of the military-industrial complex during the Cold War continued the expansion in higher-education. Now, the justification for such a large higher-education system can no longer be found in our national military security concerns. Just as we are rethinking our justification for a large central government, the higher-education community, as well as the science and technology community, must rethink its situation.

And given that those of us in government and higher education are facing what seems to be a threshold event, we should step back and discard our commonly held perceptions of ourselves. Large government and a large higher-education system are both relatively recent occurrences. What we are facing may be so different that even our lexicon no longer applies. What we are trying to do in politics is to think “outside of the box” of our recent experience and expectations, and I urge you to do the same.

For example, higher education has gotten to be a large endeavor. How large? How about larger than the automobile, aircraft, textile, construction machinery, mining machinery, toy and sporting goods, household video and audio, and refrigeration and heating equipment industries combined in terms of direct employment! In 1989 higher education in this country employed nearly 2.5 million people, 1.5 million of whom were professional staff. Now what use can we make of this new perspective?

We have been arguing that our college and university system is needed to take us into the high technology realm expected in the twenty-first century. Maybe we should argue that cutting federal support for R&D and higher-education funding has a direct impact on 1995 employment. It also will increase tuition costs to the middle class and have other direct fiscal impact. This approach is not a permanent fix to what ails us, but it may buy time and soften the blow of some of the cuts to come. If it works for the auto industry, with a mere 218,000 workers, it ought to work for higher education and the research community that resides there. Their jobs are worth saving too.

Likewise when you step back and look at where the budgetary pressures are coming from, you observe that they come largely from our inability to solve nagging social problems. Escalating medical costs, many of which are due to
preventable diseases, crime and incarceration costs, alcoholism and other addiction costs, and a host of other social problems are putting pressure on the budget and thus on federal research funding.

Perhaps the way to save research funding for the physical and mathematical sciences is to invest in social science research that can help us solve some of these expensive social problems. Until this situation changes we will all pay, some of us through increased hospital bills or more expensive goods, and some of us, such as the R&D community, will pay as federal research funding is cut to reduce the deficit and pay for these social ills.

Now many of you may think that these are screwy ideas, and perhaps they are. But they are just illustrative of the kind of thinking that is needed if, as I suspect, we are facing major changes in the way we Americans view all social institutions, including higher-education institutions. The reality is that federal dollars that used to be spent on high-energy physics research facilities will now be going to high-security correctional facilities. If this is going to change, we are going to have to think "outside of the box" and do it soon.

We are also going to have to think honestly. We can no longer deny the excess capacity, or more correctly, unfocused capacity in our higher-education system. Our graduate degree-granting institutions can no longer support the Ph.D.s they are graduating. A clear indication of this is the fact that 40 percent of college faculty members today are part-time employees, up from 22 percent in the early 1970s. This army of gypsy professors illustrates both the financial pressure on higher-education institutions and the excess of Ph.D.s for whom their higher-education training directs them solely toward employment in—higher-education.

We must address this situation somehow. I do not have the answers, but commend to you the paper, "Scientific Elites and Scientific Illiterates", presented by David Goodstein in February 1993 at the Sigma Xi forum, "Ethics, Values, and the Promise of Science". This paper and others that have started to appear in recent months illustrate some thinking that needs examining in the midst of our current crisis.

For example, we need to reassess the role of the Ph.D. in society. In the current political and fiscal climate, do we want to replicate university researchers and college professors at a rate above the replacement rate? Does research and high technology development demand Ph.D.s, or can technically adept masters- and undergraduate- degreed students fill some of the roles that the vast army of underpaid and underemployed postdocs currently perform?

Stepping back again, I think that Congress and the nation can and do expect more from the research community than we see currently. At the very least we expect you to exercise a modicum of common sense. And common sense dictates that we make good on our promises of societal benefit where those benefits are no longer the more obvious ones of national military security. Common sense dictates that we envision a new definition of security as I mentioned before, based on a healthy, growing, and sustainable economy; an improved global environment; and—most important—a just and equitable society, first in our own country and then in an increasingly interdependent global community.

Our challenge for the twenty-first century must be no less than building a new human culture—more democratic; providing for more autonomous, self-directed growth for individuals and social institutions; less bureaucratic and more sensitive to complex signals of all kinds, including market signals, that can guide us to new levels of understanding ourselves and the universe which nurtures us.

Guiding us in this work should be basic principles of justice and harmony. Lest you think that I could get through a speech without some philosophical inspiration, I would turn to some of the thinking of Mohandas Gandhi, a hero of mine since the 1930s. Gandhi urged us to avoid the seven social sins which he described as politics without principle, wealth without work, commerce without morality, pleasure without conscience, education without character, science without humanity, and worship without sacrifice. To fail at this will put scientists, and all of us as individuals and as a society, adrift without guidance in a time of major change.

More concretely, if the scientific community cannot reconnect with basic social values, you will find yourselves in a role as central to policy making as a Democrat in Washington, a status I wouldn’t wish on anyone.
Eugene Wigner died in Princeton, NJ, on January 1, 1995, at the age of 92. He had been one of the last survivors of the generation that witnessed the creation of quantum mechanics and participated in the exciting initial years of its development. He spent most of six active decades on the faculty of Princeton University. Although he was best known for his physical and mathematical analyses of symmetry in quantum mechanics, he also made important contributions to solid-state physics, physical chemistry, nuclear engineering, and epistemology. In his later years, he found himself in the unusual position of being highly esteemed by physicists, mathematicians, chemists, engineers, and philosophers.

Eugene Wigner was born Jenő Pál Wigner in Budapest, Hungary, on November 17, 1902. Since he was a somewhat sickly child, his parents arranged for his early education to occur at home. However, later on he spent four years at the famous Lutheran gymnasium (high school) of Budapest, where he had the good fortune to have as friend and classmate (one class behind him) Jancsi (=Johann=John) von Neumann. Wigner was attracted by mathematics and physics, but, following his father's wish that he study something that could be useful in the leather tannery where his father was a foreman, Wigner got a degree in chemical engineering from the Technische Hochschule in Berlin. His thesis (1925), written under the supervision of Michael Polanyi, was on the theory of chemical reactions. Wigner's acumen so impressed Polanyi that he recommended him for his first position as a physicist, assistant to the physicist Richard Becker.

During the next decade and a half Wigner continued his study of the theory of chemical reactions but used the then new quantum mechanics. He did related work with Victor Weisskopf on the theory of line breadth in atomic spectra as well as a study of nuclear reaction rates with Gregory Breit. However, the main focus of his effort was in the application of group theory to the study of the symmetry properties of stationary states of atoms, molecules, atomic nuclei, and crystals.

It was also during this period that Wigner made a transition from Germany to the United States. From 1930 to 1933 Wigner and von Neumann had a common arrangement: they spent one term each year at their jobs in Berlin and one at Princeton University. In the spring of 1933 the National Socialists came to power in Germany, and the Berlin positions of von Neumann and Wigner vanished. Von Neumann then joined the faculty of the new Institute for Advanced Study. Wigner spent three years full-time in Princeton and then went to Wisconsin for two years. In the fall of 1938 he was back in Princeton in an endowed professorship, just in time to hear the news of the discovery of nuclear fission, a phenomenon whose consequences dominated the next decade of his life.

Wigner and his friend Leo Szilard foresaw as clearly as anyone the disastrous consequences of the Third Reich's acquiring nuclear weapons before the Allies. They persuaded Albert Einstein to write a letter alerting President Roosevelt. The result was the Manhattan Project, a large-scale effort to separate $U^{235}$ from $U^{238}$ in uranium ore and to create nuclear reactors to pro-
duce plutonium as well as to design bombs which used these products as explosives. Wigner was heavily involved in design studies for the nuclear reactors. Most of the work took place in the mathematics department of the University of Chicago, code-named the Metallurgical Laboratory. It was here that Wigner acquired his reputation as a formidable nuts-and-bolts engineer. When his design work for the plutonium production reactors was done, Wigner turned to the design of power reactors. This continued after the war; he spent 1946-47 as director of research at Oak Ridge on leave from Princeton. Wigner and his coworker Alvin Weinberg collected their knowledge and experience in the definitive treatise, *The Physical Theory of Neutron Chain Reactors* (1958).

He returned to academic life in 1947 but, over the next three decades, often served as a consultant to the federal government in nuclear matters. Both his scientific achievements and his service were richly recognized with prizes and awards, of which only a few will be mentioned: Medal for Merit, 1946; Fermi Award, 1958; Max Planck Medal, 1961; Nobel Prize for Physics, 1963; National Medal of Science, 1969.

After his retirement in 1971, he remained active until the late 1980s.

In the remainder of this obituary I have singled out for discussion a few points from Wigner's work on the application of group theory to the study of symmetry in quantum mechanics. More details and more complete coverage are to be found in Volume I of Wigner's *Collected Works* in the magistral annotations of Brian Judd, Part II "Applied Group Theory 1926–1935", and George W. Mackey, Part III "Mathematical Papers".

Wigner began his study of symmetry in quantum mechanics with the problem of classifying the behavior of eigenfunctions of the Schrödinger Hamiltonians for atoms under permutations of the electrons. Inspired by a paper of Heisenberg on helium (two electrons), he first treated the case of three electrons, without recourse to the representation theory of the permutation group. However, he found the case of \( n \geq 4 \) electrons too complicated to do by hand. On the advice of von Neumann, he studied the pre-World War I papers of Frobenius, Schur, and Burnside on the representation theory of finite groups, as well as the later papers of Weyl and of Schur on continuous groups. The latter enabled him to enlarge his study to the consideration of the action on eigenfunctions, of rotations \( R \) of the coordinates of \( n \) electrons \( \vec{x}_1, \ldots, \vec{x}_n \):

\[
\vec{x}_1, \ldots, \vec{x}_n \to R\vec{x}_1, \ldots, R\vec{x}_n.
\]

He recognized that if the Hamiltonian commutes with the action on wave functions of permutations of coordinates or with the action on wave functions of rotations of coordinates, then the linear subspace spanned by the eigenfunctions of a fixed eigenvalue is left invariant by these actions and, in the subspace, yields a unitary representation of the permutation and the rotation group. Such a representation is a direct sum of irreducibles, so the dimension of the linear space spanned by the eigenfunctions must be a sum with possible multiplicities of the dimensions of the irreducible representations of the groups. This is the elementary group theoretical explanation for the ubiquitous appearance in atomic physics of degenerate multiplets of multiplicity \( 2j + 1 \) where \( j \) is a positive integer or half-odd integer. Later on, in the context of nuclear physics, this argument led to a theory of super-multiplets in which the group \( SU(2) \) is replaced by the group \( SU(4) \).

Up to this point, Wigner had treated the unphysical case of spinless electrons. However, in the very same issue of the *Zeitschrift für Physik* in which he had published these considerations, there appeared Pauli's paper on nonrelativistic electrons with spin \( 1/2 \). Within a few months von Neumann and Wigner published the first of three papers generalizing everything that Wigner had done to the case of spin \( 1/2 \) Pauli electrons. These papers were not easy to read, and it seems plausible that they, together with Hermann...
Weyl's classic book *Gruppentheorie und Quantenmechanik* (1928) were the origin of the use by physicists of the phrase "die Gruppenpest" to describe this approach to spectroscopy. (The German word is often translated "group pest", but the alternative "group plague" is probably better, if you take into account some of the passionate animadversions on group theory by physicists in those days.) In any case, it is instructive to compare Weyl's book with Wigner's *Gruppentheorie und Ihre Anwendung auf die Quantenmechanik der Atomenspektren* (1931).

Both books have introductory chapters on linear transformations, groups, and quantum mechanics. Here Weyl puts more emphasis on vector spaces; Wigner on calculations with matrices. Wigner confines his attention to the permutation group and rotation group or its covering group $SU(2)$. However, he goes into much more detail on the representation theory of these groups. For example, he derives the Wigner Eckart formula for the matrix elements of tensor operators. This permits him to derive the intensity relations for spectral lines that follow from rotation invariance. He also gives a quantitative and general analysis of the splitting of spectral lines in the presence of external symmetry-breaking interactions.

Weyl, on the other hand, discusses the Lorentz group, its covering group $SL(2, C)$, and the relation of their finite-dimensional representations to quantum field theory. Physicists interested in spectroscopy naturally preferred Wigner's book to Weyl's, but, of late, there has also been mathematical interest in the kind of detailed formulae for the Clebsch-Gordon coefficients that Wigner's book contains.

The work of Wigner best known among mathematicians is undoubtedly his construction of a class of irreducible unitary representations of the inhomogeneous Lorentz group. This group is not compact, and all its irreducible unitary representations except the trivial one are infinite dimensional. The representation theory of such groups was still unknown territory when Wigner published his fundamental paper in 1938. Of course, later, as a result of the work of Gelfand, Naimark, Bargmann, and others on such groups as $SL(2, C)$ and $SL(2, R)$, this theory became highly developed. Wigner limited his considerations to those irreducible representations in which the spectrum of the representation of the translation subgroup lies in or on the future cone:

$$(k^0)^2 - (k^1)^2 - (k^2)^2 - (k^3)^2 \geq 0.$$ 

The irreducibles turned out to be characterized by the squared mass ($= \text{the left-hand side of the inequality}$) and the representation of the so-called little group, the group of transformations leaving a vector of mass $^2 = m^2$ fixed. When $m^2 > 0$, the little group is isomorphic to $SO(3)$ or $SU(2)$ and so is determined by a positive integer or half-odd integer, the spin. For $m^2 = 0$, the little group is isomorphic to the euclidean group of a two-dimensional plane or to the two-sheeted covering of such a group; the physically interesting irreducible representations are determined by a helicity which is an integer or half-odd integer. Wigner came to the problem of the determination of the unitary ray representations of the inhomogeneous Lorentz group by adopting a space-time point of view in a discussion of symmetry in quantum mechanics. By an analogue of the argument he had presented in his book for the case of symmetry in space at a fixed time, he showed that a quantum mechanical theory invariant under inhomogeneous Lorentz transformations has an associated unitary ray representation of the inhomogeneous Lorentz group. It is a remarkable fact that the law of evolution of states in the most general quantum mechanical theory can be characterized by a measure class and multiplicity function on the masses, spins and helicities.

In his later years Wigner devoted most of his scientific effort to sharpening what he saw as the paradoxes in the standard interpretations of the quantum theory of measurement. He became convinced that an essential extension of physical theory to include consciousness was necessary.
Eating *Humble Pi*

*Conrad Plaut*

**Humble Pi:**
The Role Mathematics Should Play in American Education  
*Michael K. Smith, Ph.D.*  
218 pages  
Prometheus Books  
$26.95 Hardcover

"We live in a world dominated by mathematicians." With these words, Dr. Mike Smith, an education and psychology professor at the University of Tennessee, begins his quixotic crusade, *Humble Pi*. Mathematicians, believing in the "supremacy" of their field, "make people feel... dumb in everything," "may feel entitled to control whatever they can," and "cannot escape from themselves." Brandishing a long rubber lance of psychology, Smith sets out to free the beleaguered American high school student from the difficult and impractical mathematics being imposed by this numerologist horde. (All of this comes as a big surprise to the typical mathematician, who has little or no control over the high school curriculum and only feels dominant when grading calculus exams.)

Yet even a casual reading of Smith's book reveals a serious misunderstanding of the history and purpose of mathematics, as well as numerous errors in basic math and logic. The first such error appears in the introduction, in the midst of a discussion, ironically, of logical ability. "Many mathematicians and mathematics educators claim," writes Smith, "that the study of mathematics... makes (students) more logical and concise and better critical thinkers. Thus, to do badly in mathematics makes one illogical, confused, stupid." Indeed Smith shows throughout the book a remarkable inability to distinguish between the truth of a statement and that of its converse.

Of course Smith's credibility in writing about reform of mathematics education depends on his having at least some mathematical ability. In the first chapter, he invites comparison of himself with Gauss, who awed his elementary school teacher and fellow students by instantly adding the numbers from one to 100. "I bet," Smith recalls telling some schoolmates, "I can add up the numbers from 1 to 100 in my head faster than all four of you can do it together with pencil and paper." After revealing the "trick" formula $n(n + 1)/2$, Smith, who produces self-help materials for the SAT, considers the following SAT problem: How much greater is the sum of the numbers from 101 to 200 than the sum of the numbers from 101 to 200? Then Smith writes the answer in a way that is completely incorrect.

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numbers from 1 to 100? The solution, he carefully explains, is to plug the numbers 200 and 100 into the formula $n(n + 1)/2$ and take the difference, to obtain 15,050. The point he is trying to make is that this problem, like many others on the SAT, only involves remembering mathematical tricks and formulas. Yet his point remains unmade because (as the reader may already have observed) his solution is, in fact, wrong. The correct answer can be found by simply observing that each number in the first group is exactly 100 more than the corresponding number in the second group. In adding up the first group we add 100 extra 100's for a total of 10,000 more. So let the buyers of Smith's "more than a dozen" instructional materials for the SAT and other tests beware! His method of blindly plugging numbers into formulas, while popular among freshman calculus students, is not the way of success. It is also not the way of mathematics.

Smith quotes Galileo, Descartes, Bacon, Locke, Tolstoy, and contemporary mathematicians and scientists on the power and general usefulness of mathematical thinking. He then tries to argue that they are all wrong. But toppling the ideas of great thinkers requires great scholarship, and there is precious little of that in Humble Pi. Instead of directly attacking those he quotes, Smith assaults a much weaker foe—John Allen Paulos, author of the best-seller Innumeracy—and declares a general victory. To strengthen his point, he observes that people with Ph.D.s in mathematics sometimes make mistakes. He presents, as scientific evidence, an experiment that William James did on himself. (Smith, an occasional teacher of statistics, should at least know that a sample of one is not statistically significant.) Yet when the dust has settled (and there is plenty of dust in this battle), Bacon's delightful commentary on "the mathematics" emerges clean—having remained, with the rest of Smith's true foes, watching from the sidelines: "For if the wit be too dull, they sharpen it; if too wandering, they fix it; if too inherent in the sense, they abstract it."

Smith, astonishingly, contends that the nineteenth century saw "the decline of mathematics." He completely misunderstands the revolutionary developments of the 1800s: the gradual realization that mathematical concepts do not need some kind of concrete "existence" in order to be useful. Even though we cannot physically have $-5$ apples, $-5$ is still an immensely practical concept. (Perhaps Smith, who still ponders the reality of negative numbers, has never bounced a check.) No less is true of deeper mathematical ideas like non-Euclidean geometries, which, despite the philosophical agony they caused in the last century, are profoundly useful. Smith fails to grasp that mathematics necessarily evolves from simple to complex, as the phenomena it describes become more and more complicated. Thus he repeatedly ridicules math problems which, by themselves, are too simple to represent modern real-world problems. Yet we cannot ask students to undertake complex "real" problems without first doing simpler, basic mathematics. To do so would be like asking students to study literature without first learning to read.

"Could you be admitted to college today?" Smith asks his reader. The question is rhetorical; the presumed answer is something like, "Gosh, I'm not really sure." He describes multiplication by a fraction as "complicated" and presumes the reader will agree. Humble Pi is a book written by someone who knows virtually nothing about mathematics, is intended for an audience which knows virtually nothing about mathematics, and makes recommendations that will ensure the next generation of Americans knows virtually nothing about mathematics. It should be a book that is taken seriously by no one. The fact that Humble Pi has been taken seriously by the popular media (Smith even appeared on CNN) and in some education circles does not bode well for mathematics education in this country.

What is the ultimate advice of Humble Pi to America? We should give our high school students the "freedom" to use their teenage wisdom and maturity to decide whether to take mathematics (but still force them to go to school). We should teach less mathematics. We shouldn't worry that our math test scores have slipped into last place, and by all means avoid setting national mathematics standards. We should let Japan develop the new technology and concentrate on our own "strengths": marketing, advertising, video games, and "quality" television. Now there are the makings of a great nation!
Policy and Academic Mathematics

Frank Hoppensteadt

In planning, assessing and running a modern department of mathematics, we must take the high ground in arguing for support and resources based on principles, vision, and quality. And yet performance, productivity, and responsibility are important, too. We can help shape the future of our profession or stand by helplessly while others do.

Following are some observations I’ve made at a number of major universities in the U.S. and Europe and during meetings of deans and of chairpersons.

1. The number of students testing into remedial precalculus courses, e.g., ninth and tenth grade mathematics, is exploding. Failure rates in these courses are high.

2. At almost every meeting with alumni a university president is confronted by someone stating that a relative has a math course and cannot understand the instructor.

3. Anecdotal information indicates that student interest in classes (by attendance percentage) is down (one life science prof quipped, “30 percent don’t come and don’t care, 20 percent don’t come but care, 20 percent come but don’t care, 30 percent come and care”). In addition, rudeness—not attending class, abusing faculty verbally or physically, talking, leaving early, reading newspapers, etc.—appears to be increasing.

4. When these issues are raised, the response can be in several parts.
   a. It is someone else’s problem, probably the K-12 system or the university admissions office or Reagan/Bush policies on reducing aid to families.
   b. We need more money to continue building research competence.
   c. Mathematics education is a lower priority than research here.

Rarely does someone say, “Our teaching has problems. I have a stake in the quality of the teaching we do in this department, and I will take on this problem and help to solve it.”

5. There is a significant amount of “math bashing” done by the mathematics community itself, and it comes from those at all levels of achievement. For example, mathematicians on the National Science Board often seem not to take a step above their own interests to speak for the larger mathematics community. (I am sure this misses many important contributions by NSB members, and the community and I would like to be told of these successes.) Math bashing is voting against our own interest, encouraging attacks by those inside and outside the university who can use our resources and by anyone with a motive to disparage our work.

6. External economic pressures that are beyond our control act on us. For example, public universities spend more than they receive in state appropriations, so the difference must be made up through tuition, other external sources or through eliminating programs and faculty. One point of view states that this difference is due to productivity and efficiency in the economy over-
all improving that much faster than productivity and efficiency in the university.

Most math faculty take a principled view that includes their life's work as repayment to those who went before, passing on to others what they have learned and created. At the same time, faculty appear to be angry and concerned about their own jobs. Many faculty my age would like to be twenty years younger. Many faculty report feeling powerless and not in control in spite of having, with tenure, one of the most secure jobs in our economy and having almost complete control of their work load.

The ageing issue is relevant to us. That members of a mathematics department must carry equitable work loads seems fair (and obvious), but this is not easy to define or to implement. As faculty mature, the nature of their work load must change. When they started out, they likely had space and time protected to help them develop their careers (e.g., lower teaching loads, lower committee assignments, added infrastructure support, etc.). Who wouldn't want to return to that period of limberance?

Unfortunately, this perquisite often runs against learning how to be a professional mathematician supported by a higher-education institution. There are many jobs that need doing in a large and smoothly operating department, and these jobs can only be done well by mature, professional faculty. For example, the curriculum is highly important in a department, and it is the major thing in a university over which faculty have complete control. But young people are trained to view it as being tedious work to avoid. This negative imprint does not go away, even though curriculum committees control what we pass on through teaching and how we do it! Many faculty wind up abandoning active research at some point but do not willingly take up heavier teaching and administrative duties to share the work load. This is partly due to negative impressions of this work during the period when they were shaped professionally; sometimes it is due to disregard for academic responsibility.

The paradox here—in the limit, either productivity and efficiency or above inflation tuition must increase without bound—can be dealt with to some extent by retirement. Unfortunately, there are colleagues of ours who retire in place and compound the burden on their departments. At present universities are reluctant to challenge these people for competence; fair, effective, and tested procedures for removal and response to subsequent litigation are not yet in place. New methods for dismissal will appear as productivity pressures mount, and we must participate in their development and interpretation. Mature faculty must take on more duties, including teaching and administration. We are professional mathematicians. Our academic jobs are all closely connected with teaching, and we must take professional attitudes toward all facets of our work. The nip is that if we don't make critical decisions, then others will, with the result being unhappy, impotent faculty.

We should carefully review what we want to accomplish as a department to meet external and internal demands and then decide what work load policies are appropriate. Policymaking may seem antipodal to the spontaneity associated with creativity, but in fact we all do have our own work load policies—hidden or articulated. There is a tendency to move forward with qualitative arguments for increased resources, ignoring the concerns of others about the department's performance, productivity, and responsibilities. When departments come forward with intellectual arguments, oblivious to how they are paid and for what, then administrative skepticism goes up. Proposals that actually decrease productivity destroy the credibility of the request.

To do this planning and make these decisions, it is essential to have accurate and timely information. Possible sources are the university trustees, president, vice-presidents, deans, colleagues in other departments and universities, academic governance and informed professional societies. Getting the information from these sources requires organization, dedication, and hard work.

These issues will demand more time and attention over the next five years as we are forced more and more to confront basic existential questions.

Universities are pressured by citizens, business, government, alumni, and students to do various, often conflicting, things. All pressure points cannot be relieved at the same time. In addition, there is a rise in irrationalism (shades of the anti-Enlightenment). This exasperating situation drives many excellent people away from administrative and leadership roles in departments toward pleasant memories of their formative years, and this at a time when they are most desperately needed.

The issue of language skills provides an interesting example. Students who fail remedial courses will often attempt later courses, fail, and then tell parents they cannot understand the instructor—which is true, but the language not understood is mathematics not accented English. This often results in complaints about language skills of instructors, and unless we respond to complaints promptly we start down a slippery slope. For the most part these complaints are not well founded. However, they exert very strong negative feedback on many goals we are trying to accomplish. For example, foreign students are not the only ones being knocked down by the language skills com-
being accountable: a chair's view

john ewing

mathematicians hear a good deal about performance, productivity, and responsibility these days. university administrators relate stories about angry alumni and legislators. they bemoan faculty who retire in place. they ask for work load policies that meet external and internal demands. and they warn us that if we don’t take action now, then someone else will take action for us. in short, they are under pressure and they demand accountability.

accountability is in fashion, and i am always a bit skeptical of fashions. nonetheless, i agree—we ought to be accountable. chairs (and faculty) are under pressure too. we also listen to students and parents and legislators, and we are generally in favor of responsibility and accountability. but these are practices, not principles. they describe the way in which we deal with personnel and money; they should not be the foundation of a university. universities are built on ideals and principles.

university administrations seem to grudgingly allow us to make our case on principles. mathematics needs smaller classes because it is learned actively, not passively. departments should avoid hiring large numbers of part-time faculty because it is healthy for all faculty to be involved in the entire curriculum. faculty should be supported in their scholarship because teaching devoid of scholarship lacks soul and excitement. these are arguments based on principle, vision, and quality; they make no mention of performance or productivity.

is that irresponsible? is it irresponsible to argue causes on intellectual grounds? i hope not, at least in a university.

i worry about "accountability", not because it is bad to be accountable but because we have come to view accountability in a narrow and shallow way. taking our cue from the social sciences, we insist on measuring success of faculty, students, and programs by statistics, often gathered in questionable surveys using faulty inference. should we worry whether a new program will fail half our majors? of course we should. but we don’t need a computer to warn us about that. should we measure the effect of a program by incremental changes in retention over a five-year period? or by the fluctuations in total grant support? or by the number of pages the faculty publishes? each of those statistics contributes something to our understanding of the department, but that understanding is imprecise and limited.

do we design programs based on such measures? i find well-intentioned professional educators insisting that the answer is yes. for grants, for changes in the curriculum, for students themselves, the goal is first to stipulate the statistics you want to achieve and then to declare success when the measurements are correct. this is a pernicious trivialization of education.

i am not proposing that faculty confront administrators with intellectual arguments, oblivious to how they are paid or what purpose they would serve. but why should making intellectual arguments preclude pragmatism? can’t we make the intellectual arguments and keep a sense of proportion about what is possible and practical? surely that’s what a university is about.

don’t throw away those statistics; surely don’t dispense with pragmatism. but we can make intellectual arguments as well about what is good for our students, for our university, and for our subject. more and more, we are led to believe those intellectual arguments are vague and subjective, not true measures of value. we lose much more than just our beliefs when we succumb to such arguments.

counting is easy; it’s thinking that is hard

calls for accountability are made to all departments. why is there a special call to mathematics? indeed, there is a standard litany of “observations” about mathematics departments: too many remedial students, too many complaints from alumni, too little interest in courses. administrators sometimes view the reaction of mathematicians to these problems as petulant and self-centered, shifting the blame elsewhere if possible, and refusing to shoulder responsibility.

they are wrong. i suspect they would come to a different conclusion if they came to a few sectional meetings of the MAA or to the panels at national meetings or to the MER workshops. mathematicians have shouldered more responsibility than any other discipline in the university. they are leading science reform across the country and around the world, and the sciences are leading educational reform in general. they care not only about what is possible and practical? surely that’s what a university is about.

i am not proposing that faculty confront administrators with intellectual arguments, oblivious to how they are paid or what purpose they would serve. but why should making intellectual arguments preclude pragmatism? can’t we make the intellectual arguments and keep a sense of proportion about what is possible and practical? surely that’s what a university is about.

don’t throw away those statistics; surely don’t dispense with pragmatism. but we can make intellectual arguments as well about what is good for our students, for our university, and for our subject. more and more, we are led to believe those intellectual arguments are vague and subjective, not true measures of value. we lose much more than just our beliefs when we succumb to such arguments.

john ewing is chairman of the department of mathematics at indiana university in bloomington, il. his e-mail address is ewing@indiana.edu.
to complain about the instruction in mathematics? At our university, mathematics gives 46 percent As and Bs in lower-division courses; English gives 80 percent; education gives 88 percent. Why do you suppose the students are unhappy? Are the students less interested and less motivated? I spoke with the father of a student last week: He was angry because the instructor asked students to stop by for a 10-minute individual tutorial every three weeks; it wasn’t a scheduled part of the class. I wonder where the student’s disinterest comes from?

I know about the pressure from citizens, government, alumni, and students. Once again, chairs feel that pressure as well. But all too often, the response to such pressure is simple acquiescence. The problem of language skills is indeed a good example. Even instructors with colloquial, fluent English fall victim to student complaints. Each year, the university tightens the language test that all foreign graduate student instructors must pass; some of our American students would have a difficult time passing. Why make it so tough? Because we are “embarrassed” by the complaints. We want to appear to be caring, responsible, and accountable.

Should we be accountable? Of course we should. But being accountable doesn’t mean agreeing with every cockamamie assertion made by members of the legislature or the Board of Trustees. Are there irresponsible faculty? Sure there are. But should we treat the entire faculty with disdain because some play tennis with more skill than they teach or do research? Those of us who don’t play tennis so well and who care about our students and the mathematical enterprise need support, not disdain.

The pressure from alumni and legislators isn’t new: search the pages of the Monthly, for example, and you will find similar complaints for the past one hundred years. It’s only the way in which universities (and deans) react to such pressure that varies.

I meet many mathematicians in my several roles, and I travel extensively to meetings of both the MAA and the AMS across the country. Most mathematicians are neither petulant nor self-serving. They do a remarkable job, teaching large numbers of students under increasingly hostile conditions. Most such faculty in most major departments do that while maintaining active scholarship, and many help to run a complicated business enterprise (teaching tens of thousands of students) or direct dissertations or work on curriculum reform. They need to be encouraged, rewarded, and defended against unfair criticism.

Do we want better performance and more productivity? As a matter of practicality, supporting and encouraging the large majority of faculty who excel in their jobs will have far more benefit to the university than wringing our hands about the minority who don’t.
1995 Bergman Trust Prize Awarded

Harold P. Boas and Emil J. Straube have been named joint awardees of the Stefan Bergman Trust for 1995. The trust, established in 1988, recognizes mathematical accomplishments in the areas of research in which Stefan Bergman worked.

The previous beneficiaries of the trust are: David W. Catlin (1989), Steven Bell and Ewa Ligocka (1991), Charles Fefferman (1992), Yum Tong Siu (1993), and John Erik Fornæss (1994). On the selection committee for the 1995 award were Frederick Gehring, J. J. Kohn (chair), and Yum Tong Siu.

Award Citation

Boas and Straube have had a very fruitful collaboration and have proved a series of important results in the theory of several complex variables. In particular, they have made spectacular progress in the study of global regularity of the Bergman projection and of the \( \bar{\partial} \)-Neumann problem. They have established global regularity, in the sense of preservation of Sobolev spaces, on a large class of weakly pseudoconvex domains. This is a remarkable achievement, since it gives natural conditions for global regularity in cases where local regularity does not hold; it also gives rise to a series of important problems concerning global regularity in situations when the Sobolev spaces are not preserved.

Biographical Sketches

Harold P. Boas was born on June 26, 1954, in Evanston, Illinois. He received his A.B. and S.M. degrees in applied mathematics from Harvard University in 1976 and his Ph.D. in mathematics from the Massachusetts Institute of Technology in 1980 under the direction of Norberto Kerzman. He was a J. F. Ritt Assistant Professor at Columbia University (1980–1984) before moving to Texas A&M University, where he advanced to the rank of associate professor in 1987 and full professor in 1992. He has held visiting positions at the University of North Carolina at Chapel Hill.

Emil J. Straube was born August 27, 1952, in Flums, Switzerland. He received his diploma in mathematics from the Swiss Federal Institute of Technology (ETH) in 1977 and his Ph.D. in mathematics, also from ETH, in 1983 under the direction of Konrad Osterwalder. He was a visiting research scholar at the University of North Carolina (1983–1984), a visiting assistant professor at Indiana University (1984–1986), and a visiting assistant professor at the University of Pittsburgh (1986–1987). He became an assistant professor at Texas A&M University in 1987 and was promoted to the rank of associate professor in 1991.

About the Prize

The Bergman Prize honors the memory of Stefan Bergman, best known for his research in several complex variables as well as the Bergman projection and the Bergman kernel function, which bear his name. A native of Poland, he taught at Stanford University for many years and died in
1977 at the age of 82. He was an AMS member for 35 years. When his wife died, the terms of her will stipulated that funds should go toward a special prize in her husband’s honor.

The AMS was asked by Wells Fargo Bank of California, the managers of the Bergman Trust, to assemble a committee to select recipients of the prize. In addition, the Society assisted Wells Fargo in interpreting the terms of the will to assure sufficient breadth in the mathematical areas in which the prize may be given. Awards are made every year in the following areas: (1) the theory of the kernel function and its applications in real and complex analysis; and (2) function-theoretic methods in the theory of partial differential equations of elliptic type with attention to Bergman’s operator method.

—AMS News Release

Astala Awarded Salem Prize

The 1994 Salem Prize has been awarded to K. Astala of the University of Jyvaskyla for his work on quasiconformal mapping and distortion. The prize, established in 1968, is given each year to a young mathematician who is judged to have done outstanding work in the area in which Raphaël Salem worked, primarily Fourier series and related topics. The selection committee for the 1994 prize consisted of J. Bourgain, V. Havin, Y. Katznelson, and E. M. Stein.

—J. Bourgain, Institute for Advanced Study

Fulbright Awards Announced

The J. William Fulbright Foreign Scholarship Board and the United States Information Agency made more than 800 awards to visiting academics, professionals, and independent scholars to lecture or conduct research in the United States during 1994–95.

The list below contains the name of each mathematics grantee and his or her permanent institutional affiliation, followed by the institution he or she will be visiting.

Yaniv Almog, Technion-Israel Institute of Technology, Massachusetts Institute of Technology; Gian M. Besana, University of L'Aquila (Italy), University of Notre Dame; Timothy T. Dunne, University of Cape Town (South Africa), Indiana University; Ahmed F. Ghaleb, Cairo University (Egypt), Princeton University; Tatjana Velkova Ivanova, Bulgarian Academy of Sciences, Massachusetts Institute of Technology; Georgi E. Karadzhov, Bulgarian Academy of Sciences, University of California, Los Angeles; Jan Kra­tochvil, Charles University (Czech Republic), University of Oregon; Jilai Mikram, Mohammed V University (Morocco), Pacific Lutheran University; Kenneth O. Nord­strom, University of Helsinki (Finland), University of Maryland, Baltimore County; Rimas Norvaisa, Institute of Mathematics and Informatics (Lithuania), Massachusetts Institute of Technology; Katalin Pappne Kovacs, Eotvos Loránd University (Hungary), University of Illinois at Urbana-Champaign; Lars T. Ryden, Lund University (Sweden), University of California, Berkeley; Fatin Sezgin, Ataturk University (Turkey), Syracuse University; Renato Spigler, University of Lecce (Italy), Duke University; Dimitrina Nino­va Stavrova, University of Sofia (Bulgaria), Auburn University; Jozsef Temesi, Budapest University of Economic Sciences (Hungary), University of New Hampshire; Graeme Wake, Massey University (New Zealand), Claremont Graduate School; Gheorghita G. Zbaganu, Romanian Academy of Sciences, Rockefeller University; and Pavol Zlatos, Comenius University (Slovak Republic), University of Illinois at Urbana-Champaign.

—Chronicle of Higher Education

Guggenheim Fellowships Awarded

The John Simon Guggenheim Memorial Foundation has announced the names of 152 Guggenheim Fellows for 1995. The awards, totaling $4.3 million, are granted on the basis of unusually distinguished achievement in the past and exceptional promise for future accomplishment. The list of new 1995 Fellows includes artists, writers, scientists, and humanities scholars.

Seven mathematical scientists were among the 1995 awardees. Their names, affiliations, and areas of research are indicated below.

Yakov Eliashberg, Stanford University, studies in symplectic and contact topology; Yuri Gurevich, University of Michigan, foundational issues in computer science; Tien-Yien Li, Michigan State University, studies in polynomial systems; Henri Moscovici, Ohio State University, Chern-Weil theory for pseudomanifolds; Ingrid Olkin, Stanford University, studies of multivariate distributions; Sorin Teodor Popa, University of California, Los Angeles, classification of subfactors; and Michael S. Waterman, University of Southern California, computational methods for DNA and protein sequences.

—from Guggenheim Foundation News Release

Deaths

Frances E. Baker, Professor Emeritus of Vassar College, Poughkeepsie, NY, died on April 4, 1995. Born on December 19, 1902, she was a member of the Society for 42 years.

Albert L. Blakers, Professor Emeritus of the University of Western Australia, died on March 6, 1995. Born on January 2, 1917, he was a member of the Society for 47 years.

Robert H. Breusch, Professor Emeritus of Amherst College, Amherst, MA, died on March 29, 1995. Born in April 1907, he was a member of the Society for 51 years.

William V. Caldwell, retired from the Department of Mathematics at the University of Michigan-Flint, died on Feb-
Two Excellent Textbooks!

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This book provides a leisurely and fairly comprehensive introduction to Gröbner bases and their applications. With over 120 worked examples and 200 exercises, this book is suitable as a supplement to a course in commutative algebra or as a textbook for a course in computer algebra or computational commutative algebra. Students of computer science and engineering who have some acquaintance with modern algebra will also find this book appropriate.

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Erratum

The date of death for Raphael M. Robinson (May 1995, p. 575) was incorrectly listed as December 11, 1994. The correct date is January 27, 1995. The Notices regrets this error.
MAA Contributed Papers in Orlando

The Mathematical Association of America and the American Mathematical Society will hold their annual joint meetings from Wednesday, January 10, 1996, through Saturday, January 13, 1996, in Orlando, Florida. The complete meetings program will appear in the October 1995 issues of Focus and the AMS Notices. This preliminary announcement is designed to alert participants about the MAA's contributed papers sessions and their deadlines.

Please note that the days scheduled for these sessions remain tentative. The organizers listed below solicit contributed papers pertinent to their sessions; proposals should be directed to the organizer whose name is followed by an asterisk (*). For additional instructions, see the Submissions Procedures instructions on page ??.

Sessions generally must limit presentations to ten minutes, but selected participants may extend their contributions up to twenty minutes. Each session room contains an overhead projector and screen; blackboards will not be available. You may request one additional overhead projector, a 35mm slide projector, or a 1/2-inch or 3/4-inch VHS VCR with one color monitor. Persons needing additional equipment should contact as soon as possible but prior to October 23, 1995: Donovan H. Van Osdol, Department of Mathematics, University of New Hampshire, Durham, NH 03824, e-mail: dvanosdo@math.maa.org.

My Favorite ODE Solver and Why, Friday morning and Saturday afternoon.

Courtney Coleman (*)
Harvey Mudd College
301 East Twelfth Street
Claremont, CA 91711-5990
phone: 909-621-8023
e-mail: coleman@hmc.edu
fax: 909-621-8366
Robert Borrelli, Harvey Mudd College
This session will accept suitable papers from people who have used ODE solvers in introductory courses in ordinary differential equations. The focus will be on solvers that are available to college teachers and students either for free or for a reasonable fee. The speakers will say why they like the solver, what it can do for the introductory ODE course, and something about the minimal hardware requirements, and will give examples of experiments in ODEs that use the solver to advantage.

Assessment of Student Learning for Improving the Undergraduate Major in Mathematics, Friday morning and Saturday afternoon.

William Marion (*)
Valparaiso University
Department of Mathematics and Computer Science
Valparaiso, IN 46383
phone: 219-464-5422
e-mail: bmarion@exodus.valpo.edu
fax: 219-464-5065
Barbara T. Faires, Westminster College
In January 1995 the MAA's Committee on the Undergraduate Program in Mathematics (CUPM) adopted a document prepared by its Subcommittee on Assessment en-
undergraduate mathematics departments. We invite papers on such programs—ones that are still in the planning stage or have just begun or are ongoing.

**Standards for Introductory College Mathematics Courses before Calculus**, Wednesday morning and Thursday afternoon.

Gregory D. Foley (*)
Sam Houston State University
Division of Mathematics and Information Sciences
Huntsville, TX 77341-2206
phone: 409-294-3708
e-mail: mth_gdf@shsu.edu
fax: 409-294-1882

Jon Wilkin, Northern Virginia Community College
In the autumn of 1995 the American Mathematical Association of Two-Year Colleges will publish *Crossroads in Mathematics: Standards for Introductory College Mathematics before Calculus*. This document is aimed at breathing new life into a too-often neglected part of the undergraduate mathematics program—freshman or pre-freshman courses that either provide a foundation for further mathematical study or serve as terminal courses for students in liberal arts, humanities, social science, teacher preparation, or two-year technical programs. We invite papers that offer innovative content and approaches for courses at this level.

**Planning Reformed Calculus Programs: Experiences and Advice**, Thursday morning and Friday morning.

Martin E. Flashman (*)
Humboldt State University
Department of Mathematics
Arcata, CA 95521
phone: 707-826-4950
e-mail: Flashman@axe.humboldt.edu
fax: 707-826-3140

Changing calculus programs involves more than adopting textbooks or technology. The CUPM subcommittee on Calculus Reform and the First Two Years (CRAFTY) is sponsoring this session so departments planning changes can share experiences and advice. We invite papers reporting on the process or results of planning calculus reform. Possible topics include connections with client disciplines and administration; articulating goals; pedagogy, technology, and topic selection; resource considerations; preparations for change; and continuing program assessment.

**Innovations in Teaching Linear Algebra**, Wednesday afternoon, Thursday evening, and Friday afternoon.

Donald LaTorre (*)
Clemson University
Department of Mathematical Sciences
Clemson, SC 29634-1907
phone: 803-656-3437
e-mail: latorrdr@clemson.edu
fax: 803-656-5230

Steven J. Leon (ATLAST), University of Massachusetts at Dartmouth; David C. Lay (LACSG), University of Maryland

The teaching of undergraduate linear algebra is undergoing substantial change. This session invites papers on personal experiences with innovations in teaching linear algebra, including: 1) the creative use of computer algebra systems, supercalculators, or computer software; 2) experiences with the NSF-funded ATLAST summer workshops; 3) experiences with the core curriculum recommended by the Linear Algebra Curriculum Study Group (LACSG); 4) "gems" of exposition in linear algebra; and 5) other innovative teaching initiatives in undergraduate linear algebra.

**Active Learning Strategies for Statistics and Probability**, Wednesday morning and Thursday afternoon.

Allan J. Rossman (*)
Dickinson College
Department of Mathematics
P.O. Box 1773
Carlisle, PA 17013-2896
phone: 717-245-1690
e-mail: rossman@dickinson.edu
fax: 717-245-1690

Mary R. Parker, Austin (Texas) Community College
We invite presentations on the active engagement of students in the process of learning about statistics and probability. These learning strategies may include projects, hands-on activities, experiments, writing, computer exercises, and open-ended questions about real data. Issues might include the incorporation of these into the course, effects on students' achievements and attitudes, and their use in courses other than the introductory course, such as mathematics for liberal arts, precalculus, and mathematical statistics.

**The Scholarship of Humanistic Mathematics**, Thursday morning and Saturday afternoon.

Alvin White (*)
Harvey Mudd College
301 East Twelfth Street
Claremont, CA 91711-5990
phone: 909-621-8867
e-mail: awhite@hmc.edu
fax: 909-621-8366

Joan Countryman, The Lincoln School; Harald Ness, University of Wisconsin Center

The idea that teaching, learning, and creating mathematics issue from the same psyche as literature, aesthetics, and music has attracted, since 1986, a worldwide network of people who share that idea. The existence of the Humanistic Math Network has encouraged individuals and groups to try new approaches to teaching, doing, and publishing. We invite papers that describe these new approaches, including projects, poetry, and stories.

**Chaotic Dynamics and Fractal Geometry**, Wednesday morning and Thursday afternoon.

Denny Gulick (*)
University of Maryland
Department of Mathematics
College Park, MD 20742
phone: 301-650-1443
e-mail: dng@math.umd.edu
During the past few years, chaotic dynamics and fractal geometry have gained prominence in mathematics and in applications. The goal of this special session is to promote these fascinating subjects. We invite papers on topics related to either chaotic dynamics or fractal geometry. The papers need to have an expository flavor.

Constructivism across the Curriculum, Wednesday morning and Thursday afternoon.

David M. Mathews (*)
Longwood College
201 High Street
Farmville, VA 23909
phone: 804-395-2184
e-mail: dmathews@math.purdue.edu
fax: 804-395-2635
Keith E. Schwingendorf, Purdue University North Central

We invite papers describing undergraduate courses in mathematics or statistics that reflect the use of constructivist learning theory. Papers may address courses for elementary education majors, liberal arts, or other special groups of students, or courses for mathematics majors. Content areas might include algebra and trigonometry through calculus to linear algebra, analysis, abstract algebra, and beyond. The goal of this session is to disseminate innovative, successfully class-tested pedagogical techniques and classroom strategies that reflect the constructivist theoretical view of how mathematics is learned.

Creating an Active Learning Environment: Preparing Pre-service Teachers, Thursday morning and Saturday morning.

Hubert J. Ludwig (*)
Ball State University
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fax: 317-285-1721
Kay Meeks Roebuck, Ball State University

Pre-service teachers must be prepared to create classroom environments in which students are active participants in the process of learning mathematics. Active learning techniques include the utilization of appropriate technology, discovery learning, and using concrete models. We invite papers related to the preparation of pre-service teachers for the utilization of active learning techniques in their teaching, particularly those describing courses and/or projects designed to prepare pre-service teachers to use computers as a teaching tool.

Interactive Mathematics Texts in the Classroom—A MathKit Perspective, Saturday afternoon.

James E. White (*)
Institute for Academic Technology
University of North Carolina, Chapel Hill
2525 Meridian Pkwy., Suite 400
Durham, NC 27713
phone: 919-405-1926
e-mail: jimw@iat.mhs.unc.edu

Starting in 1992, the MAA sponsored the Interactive Mathematics Text Project, a project jointly funded by IBM and NSF. During the years of the project, an authoring environment called MathKit was developed in collaboration with scores of mathematics and science teachers. MathKit includes computer algebra and graphics in an intuitive scripting language called MathScript. To date, teachers (and their students) have created over 300 interactive mathematics and science "WorkBooks" in MathKit. In this session, we invite teachers to report on various aspects of student use of MathKit WorkBooks, both in classrooms and at home.

Teaching Mathematics by Blind Instructors or to Blind Students, Wednesday afternoon.

Norberto Salinas (*)
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Department of Mathematics
Lawrence, KN 66045-2142
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fax: 913-864-5255

The theme of this session is the use of alternative techniques by blind instructors to teach mathematics to sighted students and the use of adaptive equipment and high technology in the learning process. Presentations will include demonstrations of these techniques.

Innovations in Teaching Precalculus Algebra Courses, Friday morning.

Mohammad H. Ahmadi (*)
University of Wisconsin
Department of Mathematics and Computer Science
Whitewater, WI 53190
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e-mail: ahmadm@uwvax.uww.edu
fax: 414-472-5238

This session focuses on courses ranging from basic to college algebra. Presentations are invited on personal experiences in teaching such courses using innovative instructional techniques such as (but not limited to) cooperative learning, computer software, and use of laboratories. The paper should describe the methods of teaching, student assessment techniques, and effectiveness of the approach on variables such as student performance.

Interdisciplinary Programs with Undergraduate Mathematics, Friday afternoon.

Jerry Johnson (*)
University of Nevada, Reno
Mathematics Department (084)
Reno, NV 89557
phone: 702-784-4433
e-mail: jjohnson@math.unr.edu
fax: 702-784-1080
Louis Gross, University of Tennessee

There has been an increasing call for undergraduate courses to have more applications and more contact with other disciplines, and the NSF has regularly funded interdisciplinary projects with mathematics as their centerpiece. Papers are sought that describe undergraduate interdisciplinary courses, activities, or programs which involve a significant mathematics component and are well along
in their development. Special consideration will be given to programs that are innovative and can be readily disseminated. Incorporation of technology is also desirable.

*Research in Undergraduate Mathematics Education,*
Wednesday afternoon and Thursday morning.

Annie Selden (§)
Tennessee Technological University
Department of Mathematics
Cookeville, TN 38505
phone: 615-372-3441
e-mail: js9484@tntech.edu
fax: 615-372-6172
after August 15:
Center for Research in Mathematics and Science Education
San Diego State University
6475 Alvarado Road, Suite 206
San Diego, CA 92120
John Selden, Mathematics Education Resources Company
This session is sponsored by the AMS-MAA Committee on Research in Undergraduate Mathematics Education (CRUME). We solicit research papers which address questions concerning the teaching and learning of undergraduate mathematics. Both theoretical and empirical investigations utilizing qualitative or quantitative methodologies are welcome. Whenever possible, these should be set within established theoretical frameworks and further existing work. We are especially interested in reports on completed studies.

**Submission Procedures for Contributed Paper Proposals**

After you have selected a session to which you wish to contribute a paper, forward the following directly to the organizer (indicated above with an (*));

- the name(s) and address(es) of the author(s), and
- a one-page summary of your paper.

The summary should enable the organizer(s) to evaluate the appropriateness of your paper for the selected session. Consequently, you should include as much detailed information as possible within the one-page limitation.

Your summary must reach the designated organizer by **Friday, August 25, 1995.** The organizer will acknowledge receipt of all paper summaries. If the organizer accepts your paper, you will receive a standardized abstract form. Use this form to prepare a brief abstract. Please return the completed form as instructed by the organizer by Friday, September 8, 1995. Abstracts received after the deadline will not be published in the January 1996 *Abstracts of Papers Presented to the American Mathematical Society.* The *Abstracts* will be available in the meetings registration area during the conference in Orlando.

**DO NOT FORWARD COMPLETED SUMMARIES TO THE MAA OR TO THE AMS. THEY ARE TO BE SENT TO THE SESSION ORGANIZER.**

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**News from The Fields Institute**

In 1996–97, The Fields Institute for Research in Mathematical Sciences will sponsor an emphasis year in Algebraic Model Theory. The organizing committee for the program consists of B. Hart (McMaster University), A. Lachlan (Simon Fraser University), A. Macintyre (Oxford University), M. Makkai (McGill University), R. McKenzie (Vanderbilt University), and M. Valeriote (McMaster University). All activities will take place from August 1996 to June 1997. The program will comprise a mixture of workshops, graduate courses, lecture series, and seminars.

Three workshops are currently planned. One on Geometric Model Theory will be held January 13–17, 1997, and another on Model Theory of Functions will be held March 17–21, 1997. The third, to be held May 26–June 9, 1997, will be a longer workshop with emphasis on permutation groups, stable groups, model theory of modules, model theory of analytic functions, decidability theory, and tame congruence theory.

In the fall term of 1996, three graduate courses are scheduled: Geometric Model Theory, Model Theory of Analytic Functions, and Tame Congruence Theory.

In addition to these activities, there will be a weekly colloquium, regular research and graduate seminars, and a lecture series concerning the interactions of model theory with other disciplines.

Aside from the organizers, some of the participants will be: G. Cherlin (Rutgers University), L. van den Dries (University of Illinois), R. Freese (University of Hawaii), E. Hrushovski (Hebrew University of Jerusalem and Massachusetts Institute of Technology), D. Marker (University of Illinois at Chicago), A. Pillay (University of Notre Dame), and R. Willard (University of Waterloo).

Support is available to cover some of the transportation and accommodation costs of short- and long-term visitors. Participation of graduate students and postdoctoral fellows will be an integral part of the year’s activities. Postdoctoral positions for 1996–97 will be offered as well as support for graduate students. The Fields Institute will advertise these positions in the fall of 1995.

For more information, send e-mail to model@fields.utoronto.ca or contact: Algebraic Model Theory Program, The Fields Institute, 185 Columbia Street West, Waterloo, Ontario, Canada, N2L 5Z5; fax 519-725-0704.

—The Fields Institute
Call for Nominations for Balaguer Prize

Each year the Institut d'Estudis Catalans presents the Ferran Sunyer i Balaguer Prize. This international award recognizes an outstanding mathematical monograph presenting the latest developments in an active area of mathematics research. Ferran Sunyer i Balaguer (1912-1967) was a self-taught Catalan mathematician who, in spite of a serious physical disability, was very active in research in classical analysis and achieved international recognition.

The competition for the prize is open to all mathematicians. Monographs submitted for the prize must be original, written in English, and at least 150 pages long. It must be in an area in which the applicant has made important contributions. The winner will be chosen by a scientific committee consisting of: Gerhard Frey (Universität Essen), Joan Girbau (Universitat Autònoma de Barcelona), Paul Malliavin (Université de Paris VI), Joseph Oesterlé (Université de Paris VI), and Alan Weinstein (University of California, Berkeley).

The prize of 1,800,000 pesetas is provided by the Ferran Sunyer i Balaguer Foundation. The winning monograph will be published in Birkhäuser-Verlag's series Progress in Mathematics, subject to the usual regulations concerning copyright and author's rights.

Monographs, preferably typeset in TeX, should be sent before December 15, 1995, to: Institut d'Estudis Catalans, Carme, 47, 08001 Barcelona, Spain; e-mail crm@crm.es. The name of the prizewinner will be announced in Barcelona in April 1996.

—From Institut d'Estudis Catalans Announcement

New BMS Publications

The Board on Mathematical Sciences (BMS) of the National Research Council (NRC) has just released two timely publications: the report Mathematical Challenges from Theoretical/Computational Chemistry, and the book Calculating the Secrets of Life: Applications of the Mathematical Sciences in Molecular Biology. These are the latest in a series of BMS publications that describe connections between research in the mathematical sciences and such areas as materials science, physical oceanography, nonlinear optics, digital image analysis, acoustics and electromagnetics, robotic control, and dynamic biomedical imaging.

Computational methods are rapidly becoming major tools of theoretical, pharmaceutical, biological, and materials chemists. Accordingly, the mathematical models and numerical analysis that underlie these methods have an increasingly important and direct role to play in many areas of chemistry. Mathematical Challenges from Theoretical/Computational Chemistry is the 142-page report growing out of a joint project of the BMS and the Board on Chemical Sciences and Technology in which a cross-disciplinary NRC study committee explored the research interface between the mathematical sciences and computational chemistry. Aimed at nonspecialists, it documents prominent examples of past successful cross-fertilizations between the fields and explores mathematical research opportunities in a broad range of chemical research frontiers. A number of sidebars and an extensive glossary make the report accessible to a variety of readers. The report also discusses cultural differences between the two fields and makes recommendations for overcoming those differences and generally promoting this interdisciplinary work. As the report states: "In scanning the research needs of theoretical/computational chemistry, the committee found opportunities for synergistic research with almost the entire mathematical sciences community, where that term is used in its broadest sense to include core and applied mathematicians, statisticians, operations researchers, and theoretical computer scientists in academia, government laboratories, and industry. The common denominator shared by mathematical scientists who have contributed or could contribute to progress in chemistry is not a particular background; rather, it is a willingness to truly collaborate."

The BMS convened the NRC Committee on the Mathematical Sciences in Genome and Protein Structure Research to determine whether increased interaction was needed between the mathematical sciences and molecular biology. The committee unanimously agreed that it was needed and that the major barrier to such interaction was communication: mathematical scientists interested in molecular biology found that learning about this new and rapidly growing field was a difficult obstacle. The committee...
The Emergence of the American Mathematical Research Community, 1876 — 1900: J. J. Sylvester, Felix Klein, and E. H. Moore
Karen Hunger Parshall and David E. Rowe

By placing the development of American mathematics within the context of broader external factors affecting historical events, the authors show how the character of American research was decisively affected by the surrounding scientific, educational, and social contexts of the period. Aimed at a general mathematical audience and at historians of science, this book contains an abundance of unpublished and archival material, numerous rare photographs, and an extensive bibliography.

Lectures in the History of Mathematics
Henk J. M. Bos, Volume 7

This volume contains eleven lectures covering a variety of topics. The lectures include "Recognition and Wonder: Huygens, Tractional Motion, and Some Thoughts on the History of Mathematics," "The Lemniscate of Bernoulli," and "Queen and Servant: The Role of Mathematics in the Development of the Sciences." The lectures, presented between 1970 and 1987, were delivered in a variety of venues and appeared only in less accessible publications. Mathematics teachers as well as historians will appreciate this insightful, wide-ranging book.

Mathematics Awareness Week 1995

The Joint Policy Board for Mathematics—the American Mathematical Society, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics—would like to thank the sponsors of Mathematics Awareness Week 1995: the U.S. Army Research Office, Oxford University Press (with offices in New York and London), and Springer-Verlag (Textbooks in Mathematical Sciences—TIMS—a new undergraduate text series).

Please send news clippings from your Mathematics Awareness Week activities to: 1529 Eighteenth St., NW, Washington, DC 20036.

—MAW Committee
Combinatorial Optimization

This book grew out of the fourth Special Year at DIMACS that was devoted to the subject of combinatorial optimization. The workshop organizers and participants wrote surveys about the hottest results and ideas in their fields. Rather than a set of conference proceedings, this book is a carefully refereed collection of articles written by outstanding researchers.

Inside:

• An in-depth look at many topics not presently treated in textbooks.

Interconnection Networks and Mapping and Scheduling Parallel Computations

This book contains the refereed proceedings of a DIMACS workshop held in February 1994. The workshop attracted researchers from universities and laboratories, as well as practitioners involved in design, implementation, and application of massively parallel systems.

Inside:

• Interconnection networks of parallel architectures of today and of the near future, including network topologies, network properties, message routing, network embeddings, network emulation, mappings, and efficient scheduling.

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Editors: Yu. Ilyashenko, Moscow State University, Israel Yakovenko, The Weizman Institute of Science, Israel

This book examines qualitative properties of vector fields in the plane, in the spirit of Hilbert's Sixteenth Problem.

**Principle Topics Explored**
- Bifurcations of limit cycles of planar vector fields
- Desingularization of singular points for individual vector fields and for analytic families of such fields

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Editor-in-chief: O. A. Ladyzhenskaya, St. Petersburg Department of A. N. Steklov Mathematical Institute

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  - "Collections of Multiple Sums"


Editor: N. N. Uraltseva, Steklov Institute of Mathematics, St. Petersburg

This collection focuses on nonlinear problems in partial differential equations. Most of the papers are based on lectures presented at the seminar on partial differential equations and mathematical physics at St. Petersburg University.

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- The existence and properties of solutions of various classes of nonlinear evolution equations
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- Bifurcations of solutions
- Equations of mathematical physics

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# Visiting Mathematicians

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Reference

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

Upcoming Deadlines

August 11, 1995 (Project Development only), and December 29, 1995 (Project Development only): Grants for Collaboration with Colleagues in Central Europe and Eurasia.
Office for Central Europe and Eurasia, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-3680; fax 202-334-2614; e-mail ocee@nas.edu.

August 1, 1995: Applications for AWM Travel Grants for Women.
Travel Grant Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, MD 20742-2461; telephone 301-405-7892; e-mail awm@math.umd.edu.

Council for the International Exchange of Scholars, 3007 Tilden Street, NW, Suite 5M, Box GNEWS, Washington, DC 20008-3009; telephone 202-686-7877; e-mail (applications requests only) cies1@ciesnet.cies.org.

National Research Council, Associateship Programs (TJ2094/D3), 2101 Constitution Avenue, NW, Washington, DC 20418; fax 202-334-2759

Where to Find It

A brief index to information which appeared in previous issues of the Notices.

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Air Force Office of Scientific Research, program officers in math
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AMS e-mail addresses
October 1994, p. 935

AMS Ethical Guidelines
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Army Research Office, program officers in math
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Board on Mathematical Sciences, National Research Council
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Department of Energy, program officers in math
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Mathematical Sciences Education Board (1994-1995)
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National Science Board of NSF, members
May 1995, p. 589

NSF, mathematical scientists on the Advisory Committee for the Mathematical and Physical Sciences Directorate
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NSF, program officers in the Division of Mathematical Sciences and Education and Human Resources Directorate

National Security Agency, program officers in math
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Office of Naval Research, program officers in math
November/December 1994, p. 1174

Officers and Committee Members of the AMS
September 1994, p. 856

Proposed Amendments to the AMS Bylaws
June 1995, p. 692
July 1995

4-14 Advanced Course in Elliptic Cohomology, Centre de Recerca Matemàtica, Campus of the Universitat Autònoma de Barcelona.

Program: This is the first of a series of courses, at a level suitable for advanced graduate students or recent Ph.Ds, which the CRM plans to offer every year, either at the beginning or the end of the summer.

Speakers: H. R. Miller (MIT) "Local and global aspects of elliptic spectra"; and C. B. Thomas (Univ. of Cambridge) "Elliptic cohomology and moonshine".

Information: www http://crm.es; ftp: crm.es; e-mail: crm@crm.es; Centre de Recerca Matemàtica, Institut d'Estudis Catalans, Apartat 50, E-08193 Bellaterra, Spain, tel: (34-3) 581.10.81; fax: (34-3) 581.22.02.

5-10 1995 World Conference on Natural Resource Modelling, University of Natal, South Africa.

Program: The purpose of the conference is to provide a forum for the presentation of recent progress in the mathematical modelling of natural resource systems; of their inherent physical, chemical, and biological processes, and of the economic and operational basis for their management.

Invited Speakers: M. Demement (Univ. of California, Davis) and C. Breen (Institute of Natural Resources at Univ. of Natal, Pietermaritzburg, South Africa).


14-15 The Fifth Annual Conference on Technology Focusing on Graphics and Symbolic Calculators, Hotel Sofitel Houston, TX.

Conference Highlights: Introduction of brand-new calculator models; presentations by outstanding educators who are widely recognized for their expertise in the use of technology for teaching mathematics; workshops and demonstrations of handheld graphics calculator products.

Pre-Conference: A pre-conference on Thursday, July 13 will feature: computer algebra systems workshops, calculus reform sessions, and algebra reform sessions.

Information: Conference on Technology, San Jacinto College, 8060 Spencer Highway, Pasadena, TX. 77501-2007; tel: 713-476-1804; fax: 713-478-2757; e-mail: sasedger@stjc.cc.tx.us.

30-August 3 Mathematica in Calculus Workshop, Bowdoin College, Brunswick, Maine.

Program: The workshop will explore issues raised by incorporation of Mathematica into reformed calculus instruction and feature detailed, hands-on experience with four major Mathematica-based NSF-supported calculus projects: the Bowdoin College Mathematica laboratory development project for Duke Univ.'s Project CALC, the calculus & Mathematica program from the Univ. of Illinois and Ohio State Univ., the Knox College Mathematica laboratory development project, and the Calculus with Mathematica program from the Univ. of Iowa.

Workshop Presenters: W. Barker (Bowdoin College), W. Davis (Ohio State Univ.), D. Schneider (Knox College), and R. Stroian (Univ. of Iowa).

Funding: Funding from the NSF will provide a limited amount of local support for participants who do not have their own grants.

Information: Further information may be obtained by contacting as soon as possible W. Barker, Dept. of Mathematics, Bowdoin College, Brunswick, Maine 04011; tel: 207-725-3571; fax 207-725-3750. E-mail is the preferred means of communication: e-mail: barker@bowdoin.edu.

August 1995

7-10 Summer School on Algebraic Geometry, Bilkent University, Ankara, Turkey.

Funding: Funding is available to accommodate all graduate students attending the school.

Deadline: Deadline is June 15, 1995, but late applicants will be considered if funds are still available.


16-18 Workshop on Optimal Design for Materials and Structures, University of Utah, Salt Lake City, UT.

Sponsor: National Institute of Standards and Technology: Center for Theoretical and Computational Materials Science.

Information: NIST Workshop, A. Cherkaev/B. Palais, Mathematical Dept., The Univ. of Utah, Salt Lake City, UT 84112; tel: 801-581-6822; fax: 801-581-4148; e-mail: optimal@math.utah.edu.

September 1995

4-8 Differential Equations, Group Theory, Calculus of Variations, Hradec n. Moravici, Czech Republic.

Lecturers: J. Kijowski (Polish Academy of Sciences), D. Krupka (Silesian Univ., Czech Republic), J. F. Pommaret (Ecole Nationale des Ponts et Chaussees, France).

Course fee: US$400 includes organizational expenses, course material, refreshments, and the book by J. F. Pommaret on the topics of the course. The organizers wish to offer special prices for participants from East Europe (dependent on sponsoring). To apply, please contact the Local Organizer.


Information: Open Education & Sciences, P. O. Box 84, 746 20 Opava 1, Czech Republic; or D. Krupka, Silesian Univ., Opava, Czech Republic; tel: 42-653-454 214; fax: 42-653-215 029; e-mail: Dienstler.Krupka@fpf.slu.cz.

22-30 Advanced Course on Complex Dynamics, Centre de Recerca Matemàtica (Barcelona).

Invited Speakers: J. C. Yoccoz, (Université Paris-Sud, "Small divisors"), and R. Pérez Marco (Université Paris-Sud), "Rational Iteration".


Information: www http://crm.es; ftp: crm.es; e-mail: crm@crm.es; Centre de Recerca Matemàtica, Institut d'Estudis Catalans, Apartat 50, E-08193 Bellaterra, Spain; tel: (34-3)581.10.81; fax: (34-3)581.22.02.

29-30 Twenty-Third Annual Mathematics and Statistics Conference, Miami University, Oxford, OH.

Program: Mathematical modeling in the undergraduate curriculum.

Principal Speakers: J. Casti (Santa Fe Institute), D. Maki (Indiana Univ.), and P. Straffin
Mathematics Calendar

(Notices of the AMS)
Mathematics Calendar

presentation during student sessions. An extended abstract (up to 3 pages) of the paper should be submitted to the mailing address by January 29, 1996. If possible, a TeX version of the abstract should be sent by e-mail. Those interested in organizing a mini-symposia are invited to submit proposals including a name for the session and names of 3-4 speakers. Deadline and notification of acceptance as for contributed papers.

Information: ECMI 96, Mathematical Institute, Building 303, Technical Univ. of Denmark, DK-2800 Lyngby, Denmark; tel: +45 45 25 30 30; fax: +45 45 88 13 99; e-mail: ecmi96@mat.dtu.dk; WWW: http://www.mat.dtu.dk/ECMI96.

August 1996

*12-30 School on Algebraic Groups & Arithmetic Groups, International Centre for Theoretical Physics.
Directors: M. S. Raghunathan (T. I. F. R., Bombay, India), and G. Harder (Universität Bonn, Germany).
Information: S. Laurenti, e-mail: laurenti@ictp.trieste.it.

September 1996

Directors: R. Duran (Universidad de Buenos Aires, Argentina), A. Quarteroni (Politecnico di Milano, Italy), and A. Valli (Università di Trento, Italy).
Information: S. Laurenti, e-mail: laurenti@ictp.trieste.it.

Volume 2 of What's Happening in the Mathematical Sciences features the same lively writing as Volume 1, and has all new topics. Here you can read about a new class of solitons, the contributions wavelets are making to solving scientific problems, how mathematics is improving medical imaging, and Andrew Wiles's acclaimed work on Fermat's Last Theorem. What's Happening can be recommended to all mathematics majors, graduate students, and mathematics clubs—not to mention mathematicians who enjoy reading about recent developments in fields other than their own. What's Happening highlights the excitement and wonder of mathematics.

Volume 2, July 1994, 51 pp. (softcover), List $8;
Volume 1, 1993, List $7. Order code HAPPENING/1NA

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New Publications Offered by the AMS

American Mathematical Society Translations—Series 2

The Interplay between Differential Geometry and Differential Equations
V. V. Lychagin, Editor
Volume 167

This work applies symplectic methods and discusses quantization problems to emphasize the advantage of an algebraic geometry approach to nonlinear differential equations. One common feature in most of the presentations in this book is the systematic use of the geometry of jet spaces.

Contents

Institutional member and bookstore prices are also available.

CBMS Issues in Mathematics Education

Changing the Culture: Mathematics Education in the Research Community
Naomi D. Fisher, Harvey B. Keynes, and Philip D. Wagreich, Editors
Volume 5

This volume is an outgrowth of a series of programs organized by the Mathematicians and Education Reform (MER) Network between 1990 and 1993. These programs explored the ways in which the mathematical sciences community has responded to educational challenges. Mathematicians who had made a serious commitment to educational reform served as role models, inspiring others to contribute their efforts to this important work. The discussions raised many questions and highlighted many insights about the nature of educational reform and how the mathematics research community can contribute to it. The papers in this volume present perspectives on the future of these efforts, varied examples of how individual mathematicians have become involved in educational reform, and case studies of how the community is responding to the need for reform. Viewing the mathematics culture through the prism of his or her own experience and encounters, each author contributes a valuable piece for the reader to consider in trying to envision what the large picture will be as mathematics education continues to evolve.

Institutional member and bookstore prices are also available.

June 1995, 294 pages (hardcover), ISBN 0-8218-0428-6, LC 91640741, ISSN 0065-9290
1991 Mathematics Subject Classification: 17B37, 35Axx, 58Axx
Individual member $59, List $98
To order, please specify TRANS2/167N

Call 1-800-321-4AMS (4267) or fax Customer Services at 401-331-3842 for more information.

NOTICES OF THE AMS VOLUME 42, NUMBER 7
New Publications Offered by the AMS

CBMS Regional Conference Series in Mathematics

Classification of Subfactors and Their Endomorphisms
Sorin Popa
Number 86

This monograph provides a more unified and self-contained presentation of the results presented in Popa's earlier papers on this topic. The classification is in terms of the standard invariant $N,M$ of the subfactor $N \subset M$. "Classifications of Subfactors and Their Endomorphisms" is based on lectures presented by Popa at the NSF-CBMS Regional Conference held in Eugene, Oregon, in August, 1993.

Contents
Preliminaries; Approximate innerness for subfactors; Central freeness for subfactors; More on central freeness: the type III cases; The main classification result; Applications; Appendix; References.

July 1995, 110 pages (softcover),
ISBN 0-8218-0321-2, LC 95-17877, ISSN 0160-7642
1991 Mathematics Subject Classification: 46L35, 81ED5
All individuals $17, List $29
To order, please specify CBMS/86N

Colloquium Publications

Fully Nonlinear Elliptic Equations
Luis A. Caffarelli and Xavier Cabré
Volume 43

This book demonstrates the development of the regularity theory of solutions of fully nonlinear elliptic equations. Caffarelli and Cabré offer a detailed presentation of all techniques needed to extend the classic Schauder and Calderon-Zygmund regularity theory for linear elliptic equations to a fully nonlinear context.

The authors present key ideas and prove all results needed for the theory of viscosity solutions of nonlinear equations, and regularity theory for convex fully nonlinear equations and for fully nonlinear equations with variable coefficients.

This book is suitable as a text for graduate courses in nonlinear elliptic partial differential equations.

Contents
Introduction; Preliminaries; Viscosity solutions of elliptic equations; Alexandroff estimate and maximum principle; Harnack inequality; Uniqueness of solutions; Concave equations; $W^{2,p}$ regularity; Hörder regularity; The Dirichlet problem for concave equations; Bibliography; Index.

July 1995, 104 pages (hardcover),
ISBN 0-8218-0437-5, LC 95-15024, ISSN 0065-9258
1991 Mathematics Subject Classification: 35J60; 35B45, 35B65
Individual member $23, List $39
To order, please specify COLL/43N

Contemporary Mathematics

$SL(2)$ Representations of Finitely Presented Groups
G. W. Brumfiel and H. M. Hilden
Volume 187

This book is essentially self-contained and requires only a basic abstract algebra course as background. The book includes and extends much of the classical theory of $SL(2)$ representations of groups.

Readers will find $SL(2)$ Representations of Finitely Presented Groups relevant to geometric theory of three dimensional manifolds, representations of infinite groups, and invariant theory.

Features...
• A new finitely computable invariant $H(\pi)$ associated to groups and used to study the $SL(2)$ representations of $\pi$.
• Invariant theory and knot theory related through $SL(2)$ representations of knot groups.

(continued)
New Publications Offered by the AMS

Contents

The definition and some basic properties of the algebra $H[\pi]$; A decomposition of the algebra $H[\pi]$ when $\frac{1}{2} \in k$; Structure of the algebra $H[\pi]$ for two-generator groups; Absolutely irreducible $SL(2)$ representations of two-generator groups; Further identities in the algebra $H[\pi]$ when $\frac{1}{2} \in k$; Structure of $H^+[\pi]$ for free groups $\pi_n$; Quaternion algebra localizations of $H[\pi]$ and absolutely irreducible $SL(2)$ representations; Algebra-geometric interpretation of $SL(2)$ representations of groups; The universal matrix representation of the algebra $H[\pi]$; Some knot invariants derived from the algebra $H[\pi]$; Appendix A; Appendix B; References.

1991 Mathematics Subject Classification: 20C15, 20C07

Individual member $29, List $49
To order, please specify CONN/187N

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Homotopy Theory and Its Applications
Alejandro Adem, R. James Milgram, and Douglas C. Ravenel, Editors

Volume 188

This book is the result of a conference held to examine developments in homotopy theory in honor of Samuel Gitler in July 1993 (Cocoyoc, Mexico). It includes several research papers and three expository papers on various topics in homotopy theory.

The research papers discuss the following:
- application of homotopy theory to group theory
- fiber bundle theory
- homotopy theory

The expository papers consider these topics:
- the Atiyah-Jones conjecture (by C. Boyer)
- classifying spaces of finite groups (by J. Martino)
- instanton moduli spaces (by J. Milgram)

Homotopy Theory and Its Applications offers a distinctive account of how homotopy theoretic methods can be applied to a variety of interesting problems.

Contents

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DIMACS: Series in Discrete Mathematics and Theoretical Computer Science

Parallel Processing of Discrete Optimization Problems
Panos M. Pardalos, Mauricio G. C. Resende, and K. G. Ramakrishnan, Editors

Volume 22

This book contains papers presented at the Workshop on Parallel Processing of Discrete Optimization Problems held at DIMACS in April 1994. The contents cover a wide spectrum of the most recent algorithms and applications in parallel processing of discrete optimization and related problems. Topics include parallel branch and bound algorithms, scalability, load balancing, parallelism and irregular data structures and scheduling task graphs on parallel machines. Applications include parallel algorithms for solving satisfiability problems, location problems, linear programming, quadratic and linear assignment problems. This book would be suitable as a textbook in advanced courses on parallel algorithms and combinatorial optimization.

Contents
C. Busch and M. Mavronicolas, Proving correctness for balancing networks; A. Clementi, J. Rolim, and L. Kucera, A note on parallel randomized algorithms for searching problems; R. Corrêa and A. Ferreira, Modeling parallel branch-and-bound for asynchronous implementations; O. Damberg and A. Migdalas, A data parallel space dilation algorithm for the concentrator location problem; A. Gerasoulis, J. Jiao, and T. Yang, A multistage approach for scheduling task graphs on parallel machines; J. Gu, Parallel algorithms for satisfiability (SAT) problem; G. Karypis, A. Gupta, and V. Kumar, Experiences with a parallel formulation of an interior point algorithm; P. S. Laursen, Experiences with a synchronous parallel branch and bound algorithm; N. R. Mahapatra and S. Dutt, New anticipatory load balancing strategies for parallel A"^{} algorithms; B. Mikolajczak, A parallel algorithm for computing all homomorphisms of deterministic finite automata; T. M. Niccum, J. Srivastava, B. Himatsingka, and J. Li, Query optimization and processing in parallel databases; S. Pande and K. Psarris, Scheduling acyclic task graphs on distributed memory parallel architectures; A. Reinefeld, Scalability of massively parallel depth-first search; C. Roucairol, On irregular data structures and asynchronous parallel branch and bound algorithms; C. Schitt and J. Clausen, Parallel algorithms for the assignment problem—An experimental evaluation of three distributed algorithms; J. MacGregor Smith and K. Xu, Serial & parallel algorithms for QSP problems.

July 1995, 229 pages (softcover), ISBN 0-8218-0305-0, LC 95-15011, ISSN 0271-4132
1991 Mathematics Subject Classification: 55-06; 55-02, 55R35, 55R25, 55N22, 58D27, 20D08
Individual member $29, List $49
To order, please specify CONN/188N

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NOTICES OF THE AMS

VOLUME 42, NUMBER 7

798
Mathematical Surveys and Monographs

Conjugacy Classes in Semisimple Algebraic Groups
James E. Humphreys
Volume 43

After the fundamental work of Borel and Chevalley in the 1950s and 1960s on the structure and classification of semisimple algebraic groups over an arbitrary algebraically closed field, further results were obtained on conjugacy classes and centralizers. Conjugacy Classes in Semisimple Algebraic Groups draws together results achieved by Lusztig, Richardson, Spaltenstein, Springer, Steinberg, and others. This book provides a unified exposition of work done over the past thirty years.

Contents
Review of semisimple groups; Basic facts about classes and centralizers; Centralizers of semisimple elements; The adjoint quotient; Regular elements; Parabolic subgroups and unipotent classes; The unipotent variety and the flag variety; Nilpotent orbits and unipotent classes; Finite groups of Lie type; Springer's Weyl group representations; Complements; References; Index.

July 1995, 196 pages (hardcover), ISBN 0-8218-0333-6, LC 95-15956, ISSN 0076-5376
1991 Mathematics Subject Classification: 20G15, 17B20, 22E10
Individual member $35, List $59
To order, please specify SURV/43N

Memoirs of the AMS

Some Special Properties of the Adjunction Theory for 3-Folds in \( \mathbb{P}^5 \)
Mauro C. Beltrametti, Michael Schneider, and Andrew J. Sommese
Volume 116, Number 554

This work studies the adjunction theory of smooth 3-folds in \( \mathbb{P}^5 \). Because of the many special restrictions on such 3-folds, the structure of the adjunction theoretic reductions are especially simple, e.g. the 3-fold equals its first reduction, the second reduction is smooth except possibly for a few explicit low degrees, and the formulae relating the projective invariants of the given 3-fold with the invariants of its second reduction are very explicit. Tables summarizing the classification of such 3-folds up to degree 12 are included. Many of the general results are shown to hold for smooth projective n-folds embedded in \( \mathbb{P}^n \) with \( n \leq 2n - 1 \).

Contents
Introduction; Background material; The second reduction for n-folds in \( \mathbb{P}^{2n-1} \); General formulae for threefolds in \( \mathbb{P}^2 \); Nefness and birness of \( K_X + 2K \); Ampleness of \( K_X + 2K \); Nefness and birness of \( K_X + 3K \); Invariants for threefolds in \( \mathbb{P}^3 \) up to degree 12; References.

July 1995, 63 pages (softcover), ISBN 0-8218-0234-8, LC 95-15957, ISSN 0065-9266
1991 Mathematics Subject Classification: 14J30, 14M07; 14C30
Individual member $18, List $30
To order, please specify MEMO/116/554N

Stable Networks and Product Graphs
Tomás Feder
Volume 116, Number 555

A network is a collection of gates, each with many inputs and many outputs, where links join individual outputs to individual inputs of gates; the unlinked inputs and outputs of gates are viewed as inputs and outputs of the network. A stable configuration assigns values to inputs, outputs, and links in a network, to ensure that the gate equations are satisfied. The problem of finding stable configurations in a network is computationally hard. In this work, Feder restricts attention to gates that satisfy a nonexpansiveness condition requiring small perturbations at the inputs of a gate to have only a small effect at the outputs of the gate. The stability question on the class of networks satisfying this local nonexpansiveness condition contains stable matching as a main example, and defines the boundary between tractable and intractable versions of network stability.

Contents
Abstract; Acknowledgements; Introduction; Preliminaries; Stability in nonexpansive networks; Optimization and enumeration; Stable matching; Metric networks and product graphs; Bibliography; Index.

July 1995, 223 pages (softcover), ISBN 0-8218-0347-6, LC 95-15926, ISSN 0065-9266
1991 Mathematics Subject Classification: 05C12, 90C05, 90C10, 90C25
Individual member $53, List $89
To order, please specify MEMO/116/555N

Finite Rational Matrix Groups
G. Nebe and W. Plesken
Volume 116, Number 556

The study of finite rational matrix groups reduces to the investigation of the maximal finite irreducible matrix groups and their natural lattices, which often turn out to have rather beautiful geometric and arithmetic properties. This book presents a full classification...
in dimensions up to 23 and with restrictions in dimensions and \( p + 1 \) and \( p - 1 \) for all prime numbers \( p \). Nonmaximal finite groups might act on several types of lattices and therefore embed into more than one maximal finite group. This gives rise to a simplicial complex interrelating the maximal finite groups and measuring the complexity of the dimension. Group theory, integral representation theory, arithmetic theory of quadratic forms and algorithmic methods are used.

Contents

Finite rational matrix groups: Introduction; Notation, basic definitions, and constructions; Methods; Odd dimensions; Groups of type \( L_2(p) \) of degree \( p + 1 \); Dimensions 2p; Dimension 12; Dimension 18; Appendix: The Gram matrices fixed by the primitive r.i.m.f. groups of degree \( n = 12, 14, 15, 18, 20, 21 \) and 22; List of notations; References; Finite rational matrix groups of degree 16: Introduction; Methods: Invariant quadratic forms and subgroups; The simplicial complexes \( M^{b}_{Q} \) and \( M^{r}_{Q} \); Results in dimension 16; Determination of the primitive r.i.m.f. groups of degree 16; The simplicial complexes \( M^{b}_{Q} \) and \( M^{r}_{Q} \); Appendix: The Gram matrices fixed by the primitive r.i.m.f. groups of degree 16; References.

July 1995, 144 pages (softcover), ISBN 0-8218-0343-3, LC 95-15923, ISSN 0065-9266

Individual member $22, List $37

To order, please specify MEMO/116/556N

Weyl Groups and Birationally Transformations among Minimal Models
Kenji Matsuki
Volume 116, Number 557

This work provides a unified way of looking at the apparently sporadic Weyl groups connected with the classical algebraic geometry of surfaces from the viewpoint of the recently established Minimal Model Program for 3-folds (Mori's Program). Matsuki explores the correspondence between the algebraic objects (the Weyl chambers, roots, reflections) and geometric objects (the ample cones of minimal models, extremal rays, flops) for the Weyl groups appearing with rational double points, Kodaira-type degenerations of elliptic curves and K3 surfaces. A complete table for all the extremal rays of Fano 3-folds also appears here for the first time, along with some interesting examples of flops for 4-folds.

Contents

Introduction; Weyl groups appearing in the symmetry among minimal models; Weyl groups for Fano 3-folds; Summary and speculation about the connection with algebraic groups; References.


Individual member $22, List $36

To order, please specify MEMO/116/557N
Following are some of our more popular books and videotapes as well as some with similar topics to those appearing in the New Publications section of this issue.

Harmonic Analysis Techniques for Second Order Elliptic Boundary Value Problems, by Carlos E. Kenig, 1994, 0-8218-0309-3, 146 pages (softcover). To order, please specify CBMS/83NP

The Classification of the Finite Simple Groups, by Daniel Gorenstein, Richard Lyons, and Ronald Solomon, 1994, 0-8218-0334-4, 165 pages (hardcover). To order, please specify SURV/40.1NP


Geometry and Quantum Field Theory, edited by Daniel S. Freed and Karen K. Uhlenbeck, 1995, 0-8218-0297-6, 441 pages (softcover). To order, please specify CONM/183NP

How to Teach Mathematics: a personal perspective, by Steven G. Krantz, 1993, 0-8218-0197-X, 76 pages (softcover). To order, please specify HTMNP

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A. Kononenko, Twisted cocycles and rigidity problems

Ken Ono, Parity of the partition function

Yoshikazu Katayama, Colin E. Sutherland, and Masamichi Takesaki, The intrinsic invariant of an approximately finite dimensional factor and the cocycle conjugacy of discrete amenable actions

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Meetings & Conferences
of the AMS

The following pages give 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 con-
tents 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 com-
mittee. For some meetings the list may be incomplete.

Meetings:

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August 6-8 Burlington, Vermont p. 814
Summer Meeting
October 7-8 Boston, Massachusetts p. 814
November 3-4 Kent, Ohio p. 815
November 11-12 Los Angeles, California p. 815
November 17-18 Greensboro, North Carolina p. 816
November 29-December 2 Guanajuato, Mexico p. 816

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Annual Meeting
March 22-23 Iowa City, Iowa p. 818
April 13-14 New York, New York p. 818
April 19-21 Baton Rouge, Louisiana p. 819
May 22-24 Antwerp, Belgium p. 819
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October 11-12 Chattanooga, Tennessee p. 820
November 1-3 Columbia, Missouri p. 820

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January 8-11 San Diego, California p. 820
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October 24-26 Milwaukee, Wisconsin p. 821

1998
January 7-10 Baltimore, Maryland Annual Meeting p. 821
March 27-28 Manhattan, Kansas p. 822

Conferences:

1995
June 25-July 27, AMS-IMS-SIAM Joint Summer Research
Conferences in the Mathematical Sciences, Seattle, Wash-
ington. See November/December 1994 issue for details.
July 9-29, AMS Summer Institute on Algebraic Geometry,
Santa Cruz, California. See November/December 1994.
July 17-August 11, AMS-SIAM Summer Seminar in Ap-
p lied Mathematics on Mathematics of Numerical Analysis:
Real Number Algorithms, Park City, Utah. See Novem-

Other Events Cosponsored by the Society

1995
August 20-24, Second International Workshop on Vortex
Flows and Related Numerical Methods, Montreal, Canada.

Important Information Regarding AMS Meetings

Potential organizers and speakers should refer to the Janu-
ary issue of the Notices for guidelines on participation
and abstract submission. Close attention should be paid
to specified deadlines in this issue. Unfortunately, late
abstracts cannot be accommodated.

Requests for general information concerning abstracts
may be sent to abs-misc@math.ams.org. Completed elec-
tronic abstracts should be submitted to abs-submit@math.ams.org; paper abstracts should be
sent to the Abstracts Coordinator, AMS Meetings and Conferences Department, P. O. Box 6887, Providence, RI 02940;
telephone: 401-455-4182. Any other inquiries about AMS
meetings may be sent to meet@math.ams.org.

Should your university be interested in hosting an AMS
meeting, see the January issue for details.
Jerusalem, Israel
Hebrew University (Givat Ram)
May 24–26, 1995

Meeting #901
First joint meeting of the AMS and the Israel Mathematical Union (IMU).
Associate secretary: Lance W. Small
Announcement issue of Notices: January 1995, p. 146
Program issue of Notices: July 1995, p. 823
Issue of Abstracts: Summer 1995, (Note: This is a later issue than previously published.)

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Burlington, Vermont
University of Vermont
August 6–8, 1995

Meeting #902
Burlington MathFest including the 97th Summer Meeting of the AMS, 73rd Summer Meeting of the Mathematical Association of America (MAA), and summer meetings of the Association for Women in Mathematics (AWM) and Pi Mu Epsilon (PME).
The Joint Meetings Committee which bears the financial responsibility for these meetings has made decisions to reduce costs by eliminating some traditional services at MathFests and making substitutions for some others. We hope that participants will support these changes as a way to make the MathFest financially viable.

Watch these pages in future issues for how these changes may affect you.
Associate secretary: Robert J. Daverman
Announcement issue of Notices: May 1995, p. 615
Program issue of Notices: August 1995
Issue of Abstracts: Summer 1995

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Updates to Program
National Association of Mathematicians: The title of the David Blackwell Lecture given by Donald F. St. Mary is Computational ocean acoustics.

Miscellaneous
Badge/Program Distribution: Those participants who register in advance and elect not to receive their badges and programs by mail before the MathFest will be given their badges and programs upon check-in at the University residence hall. All other participants who do not receive these items in the mail must come to the MathFest Registration Desk in Billings Hall to pick them up.

University Housing: Participants who desire university residence hall accommodations are advised to register for them in advance. If there are any rooms available on site for walk-ins, they will be sold as room only with no meal package. Breakfast and lunch will be available on a very limited cash basis in the dining halls; several eating establishments are within walking distance. Prices for on-site dormitory rooms (if available) are $22/single; $18/double (per person).

Social Events
AWM Reception: This event will take place Sunday evening, 9:30 p.m. to 11:00 p.m., not on Monday.

Boston, Massachusetts
Northeastern University
October 7–8, 1995

Meeting #903
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: August 1995
Program issue of Notices: October 1995
Issue of Abstracts: Fall 1995

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: July 3, 1995
For abstracts: July 24, 1995

Invited Addresses
Kevin D. Corlette, University of Chicago, Harmonic maps, harmonic forms, and locally symmetric spaces.
Daniel S. Freed, University of Texas at Austin, Geometry and quantum field theory.
Freydoon Shahidi, Purdue University, Automorphic L-functions and representation theory.
Andrei V. Zelevinsky, Northeastern University, Totally positive factorizations of unipotent matrices.
Special Sessions

Harmonic maps, locally symmetric spaces, and related issues, Kevin D. Corlette, and Jonathan A. Poritz, University of Maryland at College Park.

Graph theory, Karen L. Collins, Wesleyan University, and Ruth Haas, Smith College.

Geometry of 3-manifolds, William D. Dunbar, Simon’s Rock of Bard College, Robert Meyerhoff, Boston College, and Jeffrey Weeks, Canton, N.Y.

Ergodic theory, Stanley J. Eigen, Northeastern University, and Vidhu S. Prasad, University of Massachusetts, Lowell.

Representation theory and combinatorics, Sergey Fomin and Richard P. Stanley, Massachusetts Institute of Technology, and Andrei V. Zelevinsky.

Geometry, topology, and quantum field theory, Daniel S. Freed, and Ezra Getzler, Massachusetts Institute of Technology.

Discussions across boundaries in mathematics education, Maurice E. Gilmore, Northeastern University, Deborah Hughes Hallett, Harvard University, and Paul W. Davis, Worcester Polytechnic Institute.

Geometric and hyperbolic dynamics, Boris Hasselblatt, and Zhiguo H. Nitecki, Tufts University.

Syzygies and geometry, Anthony A. Iarrobino, Jr., Alex Martin, and Jerzy Weyman, Northeastern University.

Partial differential equations in geometry and mathematical physics, Christopher K. King, Robert C. McOwen, and Mikhail A. Shubin, Northeastern University.

Automorphic forms and representation theory, Lawrence E. Morris, Clark University, and Freydoon Shahidi.

Discrete geometry, Egon Schulte, Northeastern University, and Marjorie Senechal, Smith College.

Cohomology of groups and geometric topology, Alexandru I. Suciu, Northeastern University.

Differential geometry and Lie groups, Chuu-Lian Terng, Northeastern University.

For consideration of contributed papers in Special Sessions: July 25, 1995
For abstracts: August 15, 1995

Invited Addresses

Luchezar L. Avramov, Purdue University.
Alice Silverberg, Ohio State University.
Peter J. Sternberg, Indiana University.
Rodolfo H. Torres, University of Michigan, Ann Arbor.

Special Sessions

Functional analysis and operator theory, Richard M. Aron and Per Enflo, and Andrew M. Tonge, Kent State University.

Foundations and mathematical aspects of computer science, Johnnie W. Baker and Meera Sitharam, Kent State University.

Toric varieties, intersection theory, and enumerative geometry, Chunsheng Ban, Lars J. Ernstrom, Gary P. Kennedy, and Lee J. McEwan, Ohio State University, Mansfield.

Groups and geometries and related topics, Curtis D. Bennett, Bowling Green State University and Daniel E. Frohardt, Wayne State University.

Representation theory of finite groups and related topics, Stephen M. Gagola and Donald L. White, Kent State University.

Harmonic analysis and applications, Steve C. Hofmann, University of Missouri, Columbia, and Rodolfo H. Torres.

Homological aspects of commutative ring theory, Andrew R. Kustin and Matthew Miller, University of South Carolina, Columbia.

Mathematical and computational chemistry and biology, Victor A. Nicholson, Kent State University.

Algebraic topology, John F. Oprea, Cleveland State University, and Paul Schick, John Carroll University.

Numerical linear algebra and scientific computing, Lothar Reichel, Arden Ruttan, and Richard S. Varga, Kent State University.

Arithmetic algebraic geometry, Alice Silverberg and Yuri G. Zarhin, Russian Academy of Sciences.

Ginzburg-Landau systems, Peter J. Sternberg.

Kent, Ohio

Kent State University

November 3–4, 1995

Meeting #904

Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: September 1995
Program issue of Notices: November 1995
Issue of Abstracts: Fall 1995

Deadlines
For organizers: Expired

Los Angeles, California

University of Southern California

November 11–12, 1995

Meeting #905

Western Section
Associate secretary: Lance W. Small
Announcement issue of Notices: September 1995
Meetings & Conferences

Program issue of Notices: November 1995
Issue of Abstracts: Fall 1995

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: July 25, 1995
For abstracts: August 15, 1995

Invited Addresses
Martin T. Barlow, University of British Columbia.
Paul Goerss, University of Washington.
Ellen E. Kirkman, Wake Forest University.
Luen-fai Tam, University of California, Irvine.

Special Sessions
Stochastic analysis, Kenneth S. Alexander, University of Southern California, and Ruth Williams, University of California, San Diego.
Flat surface and billiard dynamics, Eugene Gutkin, Nicola Haydn, and Christopher M. Judge, University of Southern California.
Representations of classical orders and finite dimensional algebras, Lawrence S. Levy, University of Wisconsin, Madison, and Birge K. Zimmermann-Huisgen, University of California, Santa Barbara.
Harmonic maps, Andrejs E. Treibergs, University of Utah, and Luen-fai Tam.
Spectral dynamics and conformal geometry, Paul Yang and Xianghe Dai, University of Southern California.

Greensboro, North Carolina
University of North Carolina at Greensboro

November 17-18, 1995

Meeting #906
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: September 1995
Program issue of Notices: November 1995
Issue of Abstracts: Fall 1995

Invited Addresses
H. Thomas Banks, North Carolina State University.

Mladen Bestvina, University of California, Los Angeles, and University of Utah, R-trees in geometry, topology, and group theory.
Bodil Branner, Technical University, Denmark.
Curtis Greene, Haverford College.

Special Sessions
Complex dynamics, Bodil Branner.
Algebraic combinatorics of posets and tableaux, Lynne M. Butler, Haverford College, and Curtis Greene.
Geometric topology, Alexander Chigogidze, University of Saskatchewan, and Richard B. Sher, University of North Carolina at Greensboro.
Geometric group theory, Mark E. Feighn, Rutgers University, and Michael Handel, Lehman College (CUNY).
Theory of ordered sets, Bernd S.W. Schroder, Hampton University.
Control and optimization design arising in industrial processes, H. T. Tran, North Carolina State University.
Set-theoretic topology, Jerry E. Vaughan, University of North Carolina at Greensboro.
Number theory and related topics, Theresa P. Vaughan, University of North Carolina at Greensboro.
Complexity theory, Jie Wang, University of North Carolina at Greensboro.

Guanajuato, Mexico

November 29-December 2, 1995

Meeting #907
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: August 1995
Program issue of Notices: November 1995
Issue of Abstracts: None

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: July 25, 1995
For abstracts: July 25, 1995
Second joint meeting of the AMS and the Sociedad Matematica Mexicana.

Invited Addresses
H. Thomas Banks, North Carolina State University.

Abstract Submission
Abstracts for this meeting should be submitted on the AMS form to the organizing committee of the SMM at the following address: Comite Organizador, CIMAT, A.P. 402,
3600 Guanajuato, GTO, Mexico. E-mail submissions should be sent to: abs-submit@math.ams.org. Please adhere to the deadlines listed above.

Invited Addresses

David Gabai, California Institute of Technology.

Luis Gorostiza, CINVESTAV-IPN.

David W. McLaughlin, Courant Institute of Mathematical Sciences, New York University.

Victor Neumann, IMATE-UNAM.

José Antonio de la Peña, IMATE-UNAM.

Dennis Sullivan, Graduate School & University Center, City University of New York.

Special Sessions

Stochastic processes, Rodrigo Banuelos, Purdue University, and Luis Gorostiza, CINVESTAV.

Differential geometry, Charles Boyer, University of New Mexico, and Adolfo Sanchez Valenzuela, CIMAT.


Complex analysis and operator theory, Enrique Ramirez de Arellano, CINVESTAV, and Norberto Salinas, University of Kansas.

Hamiltonian systems with few degrees of freedom, Rafael de la Llave, University of Texas at Austin, and Arturo Olvera, IIMAS-UNAM.


Low dimensional topology, Mario Eudave and Max Neumann, IMATE-UNAM, and John E. Luecke, University of Texas at Austin.

Convexity and combinatorial geometry, Paul R. Goodey, University of Oklahoma, and Luis Montejano, IMATE-UNAM.

Representations of finite dimensional algebras and applications, Edward L. Green, Virginia Polytechnic Institute and State University, and Roberto Martínez Villa, IMATE-UNAM.

General topology and continuum theory, Alejandro Illanes, IMATE-UNAM, and Leonard R. Rubin, University of Oklahoma.

Applied nonlinear analysis, William Kath, ESAM-McCormick School of Engineering, Northwestern University, Antonia Minzoni, IIMAS-UNAM, and Jean Taylor, Rutgers University.

Associative rings, Sergio Lopez-Permouth, Ohio University, Athens, and Francisco Raggi, IMATE-UNAM.

Graph theory and combinatorics, Victor Neumann, IMATE-UNAM, and Michael D. Plummer, Vanderbilt University.

Complex algebraic geometry, singularities, and foliations, Sevin Recillas, Unidad Morelia del Instituto de Matemáticas, and Le Dung Trang, Paris.

Smooth dynamical systems, José Seade, IMATE-UNAM, and John Smilie, Cornell University.

Commutative algebra and algebraic coding theory, Horacio Tapia, UAM-Iztapalapa, Wolmer V. Vasconcelos, Rutgers University, and Rafael Villarreal, ESFM-IPN.

Orlando, Florida
January 10-13, 1996

Meeting #908

Joint Mathematics Meetings including the 102nd Annual Meeting of the AMS, 79th Annual Meeting of the Mathematical Association of America (MAA), and annual meetings of the Association for Symbolic Logic (ASL), the Association for Women in Mathematics (AWM), and the National Association of Mathematicians (NAM).

Associate secretary: Lance W. Small

Announcement issue of Notices: October 1995
Program issue of Notices: January 1996
Issue of Abstracts: Winter 1996

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: September 10, 1995
For abstracts: October 2, 1995

Invited Addresses

Irving Kaplansky, Mathematical Sciences Research Institute, Rings and things (Retiring Presidential Address).

Janos Pach, Hungarian Academy of Science.

Peter W. Shor, AT&T Bell Laboratories.

Special Sessions

History of mathematics, Thomas Archibald, Acadia University, and Victor J. Katz, University of the District of Columbia.

Mathematics and education reform, William H. Barker, Bowdoin College; Naomi Fisher, University of Illinois at Chicago; Kenneth C. Millett, University of California, Santa Barbara; Hugo Rossi, University of Utah; and Philip D. Wagreich, University of Illinois at Chicago. (AMS-MAA)

Quantum information and computation, Charles Bennett and Peter W. Shor, IBM, Yorktown Heights.

Recursive and feasible mathematics, Douglas Cenzer, University of Florida, Gainesville, and Jeffrey B. Remmel, University of California, San Diego.

Analytic methods in several complex variables, F. Michael Christ, UCLA.

Knot theory, Tim D. Cochran, Rice University.

Number theory and diophantine questions, Henri R. Darmon, McGill University, and Andrew J. Granville, University of Georgia.

Algebraic groups and invariant theory, Amassa C. Fauntleroy and Aloysius Helminck, North Carolina State University.

Differential geometry and mathematical relativity, Gregory J. Galloway, University of Miami, Coral Gables.

Geometry, topology, and analysis on noncompact manifolds, Peter E. Haskell, Virginia Polytechnic Institute & State University.

Multi-dimensional complex dynamics, John H. Hubbard, Cornell University, and Ralph W. Oberste-Vorth, University of South Florida.

Non-selfadjoint operator algebras and their applications, Timothy D. Hudson and Elias G. Katsoulis, East Carolina University.

Commutative algebra, Craig L. Huneke, Purdue University and University of Michigan, Ann Arbor, Gennady Lyubeznik, University of Minnesota, Minneapolis.

Representation theory and harmonic analysis of topological groups, Carolyn E. Johnston, Florida Atlantic University, and Gail D. L. Ratcliff, University of Missouri, St. Louis.

Mathematical physics, Michael P. Loss, Georgia Institute of Technology.

Algebra, algebra cohomology, and polynomial identities, Andy R. Magid, University of Oklahoma, and Lance W. Small, University of California, San Diego.

Research in undergraduate mathematics education, Annie Selden, Tennessee Technical University, and John Selden, MERC. (AMS-MAA)

Computational harmonic analysis and approximation theory, Richard A. Zalik, Auburn University.

New York, New York

Courant Institute of Mathematical Sciences, New York University

April 13-14, 1996

Eastern Section

Associate secretary: Lesley M. Sibner

Announcement issue of Notices: To be announced

Program issue of Notices: To be announced

Issue of Abstracts: Spring 1996

Deadlines

For organizers: July 13, 1995

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Invited Addresses

Claude R. Lebrun, SUNY at Stony Brook.

Ze'ev Rudnick, Princeton University.

Jose Scheinkman, University of Chicago, Department of Economics.

Michael F. Singer, North Carolina State University.
Special Sessions

Partial differential equations, Patricia E. Bauman, Purdue University, West Lafayette, Fang-Hua Lin, Courant Institute, and Peter Sternberg, Indiana University.


Global Riemannian geometry, Tobias H. Colding, Courant Institute, Claude R. LeBrun, and Santiago R. Simanca, Polytechnic University.

Number theory, William Duke, Rutgers University, and Ze'ev Rudnick.

Hyperbolic geometry and discrete groups, Jane P. Gilman, Rutgers University, Newark.

Gauge field theory, Janet C. Talvacchia, Swarthmore College.

Topological methods, Charles R. Traina, Lawrence Narisi, and Edward Beckenstein, St. John's University.

Stochastic models in mathematical finance, Thaleia Zariphopoulou, University of Wisconsin, Madison.

Baton Rouge, Louisiana

Louisiana State University

April 19–21, 1996

Southeastern Section

Associate secretary: Robert J. Daverman

Deadline for abstracts: To be announced

Invited Addresses

Ronald A. Fintushel, Michigan State University.
Fritz Gesztesy, University of Missouri, Columbia.
Edward L. Green, Virginia Polytechnic Institute and State University.
William A. Morris, AT&T Bell Laboratories.

Special Sessions

Real algebraic geometry and ordered algebraic structures, Charles N. Delzell and James J. Madden, Louisiana State University, and Scott Woodward, Southern University.

Nonlinear partial differential equations, J. Robert Dorroh and Gisele Ruiz Goldstein, Louisiana State University.

Control theory, Guillermo Ferreyra and Peter R. Wolenski, Louisiana State University.

Low-dimensional topology, Patrick M. Gilmer, Rick Litherland, and Neal W. Stoltzfus, Louisiana State University.

Fluid dynamics, Jerome A. Goldstein and Michael M. Tom, Louisiana State University.

Number theory and quadratic forms, Jurgen Hurrelbrink, Jorge F. Morales, Robert V. Perlis, and Paul B. van Wamelen, Louisiana State University.

Rings and modules, Ellen E. Kirkman, Wake Forest University, and Dan Zacharia, Syracuse University.

Stochastic analysis and its applications, Hui-Hsiung Kuo and Ambar N. Sengupta, Louisiana State University.

Transform theory and evolution equations, Frank Neubrander and Lutz Weis, Louisiana State University.

Antwerp, Belgium

May 22–24, 1996

First joint meeting of the AMS and the mathematical societies of the BENELUX countries (Belgium, the Netherlands, and Luxemburg).

Associate secretary: Robert J. Daverman

Deadline for 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

Lawrenceville, New Jersey

Rider University

October 5–6, 1996

Eastern Section

Associate secretary: Lesley M. Sibner

Deadline for abstracts: To be announced

Deadlines

For organizers: January 5, 1996

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced
Meetings & Conferences

Special Sessions

*Homotopy theory*, Martin Bendersky, Hunter College, and Donald M. Davis, Lehigh University.

*Mirror symmetry and toric varieties*, Ciprian S. Borcea, Rider University, and Sylvain E. Cappell, New York University, Courant Institute.

*Partial differential equations in geometry*, Thomas P. Branson, University of Iowa, Iowa City, and Robert C. McOwen, Northeastern University.

*Operads, Hopf algebras, and categories*, Arthur M. DuPre, Rutgers University, and James D. Stasheff, University of North Carolina, Chapel Hill.

*Elliptic surfaces*, William L. Hoyt, Rutgers University, and Charles F. Schwartz, Rider University.

*Geometric topology*, Norman Levitt, Rutgers University, and Georgia Triantafillou, Temple University.

*Automorphic forms*, J. S. Li, University of Maryland, and P. Sarnak, Princeton University.

*Radon transforms and tomography*, Andrew G. Markoe, Rider University, and Eric Todd Quinto, Tufts University.

*Invariants of smooth 4-manifolds*, John Morgan, Columbia University, and Frank S. Quinn, Virginia Polytechnic Institute and State University.

*Combinatorial and computational geometry*, William Steiger, Rutgers University, and Ileana Streinu, Smith College.

*Algebraic K-theory*, Charles A. Weibel, Rutgers University.

Columbia, Missouri

*University of Missouri, Columbia*

**November 1–3, 1996**

Central Section

Associate secretary: Andy R. Magid

Announcement issue of *Notices*: To be announced

Program issue of *Notices*: To be announced

Issue of *Abstracts*: Fall 1996

**Deadlines**

For organizers: February 1, 1996

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

**Invited Addresses**

Alejandro Adem, University of Wisconsin, Madison.

David Barrett, University of Michigan, Ann Arbor.

Patricia E. Bauman, Purdue University.

Yan Soibelman, Kansas State University.

**Special Sessions**

*Partial differential equations and mathematical physics*, Mark S. Ashbaugh, University of Missouri, Columbia.

*Harmonic analysis and probability*, Nakhlé H. Asmar and Stephen J. Montgomery-Smith, University of Missouri, Columbia.

*Differential geometry*, John K. Beem and Adam D. Helfer, University of Missouri, Columbia.

*Differential equations and dynamical systems*, Carmen C. Chicone and Yuri Latushkin, University of Missouri, Columbia.

*Commutative algebra*, Steven Dale Cutkosky and Hema Srinivasan, University of Missouri, Columbia.

*Gauge theory and its interaction with holomorphic and symplectic geometry*, Stamatis A. Dostoglou, University of California at Santa Barbara, Jan Segert and Shuguang Wang, University of Missouri, Columbia.

*Spectral theory and completely integrable systems*, Fritz Gesztesy, University of Missouri, Columbia.

Chattanooga, Tennessee

*University of Tennessee, Chattanooga*

**October 11–12, 1996**

Southeastern Section

Associate secretary: Robert J. Daverman

Announcement issue of *Notices*: To be announced

Program issue of *Notices*: To be announced

Issue of *Abstracts*: Fall 1996

**Deadlines**

For organizers: January 10, 1996

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

**Special Sessions**

*Commutative ring theory*, David F. Anderson and David E. Dobbs, University of Tennessee, Knoxville.

San Diego, California

**January 8–11, 1997**

Joint Mathematics Meetings including the 103rd Annual Meeting of the AMS, 80th Annual Meeting of the Mathematical Association of America (MAA), and annual meetings of the Association for Symbolic Logic (ASL), the Association for Women in Mathematics (AWM), and the National Association of Mathematicians (NAM).

Associate secretary: Lesley M. Sibner

Announcement issue of *Notices*: To be announced
Meetings & Conferences

Memphis, Tennessee
University of Memphis
March 21–22, 1997
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Winter 1997

Deadlines
For organizers: April 8, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Atlanta, Georgia
Georgia Institute of Technology
October 10–12, 1997
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1997

Deadlines
For organizers: August 2, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

College Park, Maryland
University of Maryland in College Park
April 12–13, 1997
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1997

Deadlines
For organizers: June 21, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Milwaukee, Wisconsin
University of Wisconsin, Milwaukee
October 24–26, 1997
Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1997

Deadlines
For organizers: January 4, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions
Computability theory, Steffen Lempp, University of Wisconsin, Madison, and Robert I. Soare, University of Chicago.

Detroit, Michigan
Wayne State University
May 2–4, 1997
Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced

Baltimore, Maryland
January 7–10, 1998
Joint Mathematics Meetings including the 104th Annual Meeting of the AMS, 81st Annual Meeting of the Math-
Complex Dynamical Systems:
The Mathematics Behind the Mandlebrot and Julia Sets
Robert L. Devaney, Editor

This book presents lectures delivered during the AMS Short Course held at the Joint Mathematics Meetings in Cincinnati in January 1994. The lectures cover a wide range of topics, including the classical work of Julia and Fatou on local dynamics of analytic maps as well as recent work on the dynamics of quadratic and cubic polynomials, the geometry of Julia sets, and the structure of various parameter spaces. Among the other topics are recent results on Yoccoz puzzles and tableaux, limiting dynamics near parabolic points, the spider algorithm, extensions of the theory to rational maps, Newton's method, and entire transcendental functions.

Meetings & Conferences

Manhattan, Kansas
Kansas State University
March 27-28, 1998
Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1998

Deadlines
For organizers: June 26, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Manhattan, Kansas
Kansas State University
March 27-28, 1998
Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1998

Deadlines
For organizers: June 26, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
Program of the Sessions
Jerusalem, Israel, May 24-26, 1995

Wednesday, May 24

8:00-9:00 Registration
9:00-9:30 Greetings

Invited Address
9:30-10:30 Efim Zelmanov, University of Chicago.
(1) Lie algebra methods in group theory.

Special Session on Approximation Theory
11:00-11:30 Yu. Brudnyi, Technion, Haifa.
(2) Approximation spaces.
11:40-12:10 E. Belinsky, Tel Aviv University.
(3) Asymptotic characteristics classes of functions with bounded mixed derivatives.
12:20-12:50 P. Shvartsman, Technion, Haifa.
(4) Generalizations of Whitney's extension theorem.

Special Session on Associative Algebra
11:00-11:20 David Saltman, University of Texas, Austin.
(5) More division algebras are cyclic.
11:25-11:45 Eric Brussel, University of Texas, Austin.
(6) Decomposability and proper embeddings of division algebras.
11:50-12:10 Nikolaus Vonessen, University of Southern California, Los Angeles.
(7) Rational central simple algebras.
(8) Embedding modules in graded modules.
12:40-13:00 Martin Lorenz, Temple University, Philadelphia.
(9) Class groups of multiplicative invariants.

Special Session on Automorphic Forms
10:00-10:40 Freydoon Shahidi, Purdue University, West Lafayette.
(10) L-functions and poles of intertwining operators.
11:00-11:40 William Duke, Rutgers University, New Brunswick.
(11) The dimension of the space of cusp forms of weight one.

Special Session on Field Arithmetic
11:00-11:50 Zee Chatzidakis, Université de Paris VII.
(20) Model theory of fields with automorphism.
11:40-12:15 Aharon Razon, Tel Aviv University.
(21) Primitive recursive decidability for rings of large algebraic integers.
12:25-13:00 Hélène Lejeune, Angers.
(22) Pairs of PAC fields.

Special Session on Functional Analysis
11:00-12:25 Ted Odell, University of Texas, Austin.
(23) A problem in spreading models.
11:30-11:55 Morry Zippin, Hebrew University, Jerusalem.
(24) Extension of operators from \( w^* \) closed subspaces of \( \ell_1 \) into \( C(K) \) spaces.
12:00-12:25 Maria Girardi, University of South Carolina, Columbia.
(25) Universal non completely continuous operators.
12:30-12:55 Leonid Hanin, Michigan Technological University, Houghton.
(26) Duality for generalized Lipschitz classes and applications.

The time limit for each talk in the Special Sessions is 40 minutes. The names of all joint authors of presented papers appear in the collected list of papers of each Special Session. The names that appear in this section are of those authors that will present the paper in person. The number that appears before the title indicates the position of the talk in the program of Special Sessions.

JULY 1995 NOTICES OF THE AMS 823
Program of the Sessions – Jerusalem, Israel, May 24-26

Special Session on Game Theory and Mathematical Economics
11:00-11:40 William F. Lucas, Claremont Graduate School.
(27) On the existence of cores for m-type assignment games.
11:40-12:20 Ehud Lehrer, Tel Aviv University.
(28) Merging of compatible probability measures.
12:20-13:00 Irinel Dra
gan, University of Texas, Arlington.
(29) New properties of the Banach frame.

Special Session on Geometry and Topology — Symplectic and Contact Topology
11:00-11:40 Yakov Eliashberg, Stanford University.
(30) Confoliations on 3-manifolds.
11:50-12:20 I. Ustilovsky, Tel Aviv University.
(31) Geodesics of Hofer’s metric on the group of Hamiltonian diffeomorphisms.
12:25-13:00 M. Bialy, Tel Aviv University.
(32) New applications of symplectic topology.

Special Session on Group Theory
11:00-11:20 Hyman Bass, Columbia University, New York.
(33) Tree lattices.
11:30-11:50 Andy Magid, University of Oklahoma, Norman.
(34) Deformations of representations.
12:00-12:20 Shmuel Rossetti, Tel Aviv University.
(35) Intersections of subgroups of free groups: The Hanna Neumann Problem.
12:30-12:59 Gustav Lehrer, University of Sydney.
(36) Deformation and representation theory of cellular algebras.

Special Session on Logic
11:00-11:30 M. Dzamonja, Hebrew University of Jerusalem.
(37) Some results on successors of singulars.
11:40-12:10 J. Cummings, Hebrew University of Jerusalem.
(38) Reflection.
12:20-13:00 Moti Gitik, Tel Aviv University.
(39) Some results on $\omega_1$ saturated ideals and revalued measurable cardinals.

Special Session on Mathematical Education
11:00-11:15 Tommy Dreyfus, Technological Institute, Holon.
(40) What is research in mathematics education? — Report from an ICMI study.
11:20-11:35 Ed Dubinsky, Purdue University, West Lafayette.
(41) Epistemological investigations of concepts in undergraduate mathematics.
11:40-11:55 Marvin I. Friedman, Boston University.
(42) What every mathematics student should know.
12:00-12:15 Daniel L. Goroff, Harvard University, Boston.
(43) Poincaré’s lessons on mathematics education.
12:20-12:35 Brian Greer, Queen’s University, Belfast.
(44) A life-span theory of mathematical cognition?
12:40-12:55 Anna Sierpinski, Concordia University, Montreal.
(45) The synthetic and the analytic in linear algebra.

Special Session on Optimization and Nonlinear Analysis
11:00-11:20 Arrigo Cellina, SISSA, Trieste.
(46) Some existence results for non-coercive functionals.
(47) A concentration phenomenon for N-dimensional isoperimetric variational problems.
11:50-12:10 Thomas I. Seidman, University of Maryland, Baltimore.
(48) Existence of optima in the absence of convexity.
12:15-12:35 Itai Shafrir, Technion, Haifa.
(49) Minimization of the Ginzburg-Landau functional with weight.
12:40-13:00 Alexander J. Zaslavski, Technion, Haifa.
(50) Existence and structure of extremals of variational problems.

Special Session on Game Theory and Mathematical Economics
11:00-11:30 Ross Pinsky, Technion, Haifa.
(51) The asymptotic behavior of the principal eigenvalue for small perturbations.
11:40-12:10 Aizik Volpert, Technion, Haifa.
(52) Applications of topological degree to traveling waves.
12:20-12:50 Shlomo Engelberg, Tel Aviv University.
(53) The stability of the viscous shock profiles for Burgers’ equation with 4th-order viscosity.

Special Session on Partial Differential Equations
11:00-11:35 Mark Freidlin, University of Maryland, College Park.
(54) Large scale approximation for reaction-diffusion equations.
11:40-12:15 Rafail Khasminskii, Wayne State University, Detroit.
(55) Stability index of discrete systems.
12:20-12:55 Boris Rozovskii, University of Southern California, Los Angeles.
(56) Wiener chaos expansion for stochastic PDE’s.

Special Session on Algebraic Number Theory
16:00-16:40 Michael Larsen, University of Pennsylvania, Philadelphia.
(58) Interpolating U(2, 1)-Eisenstein series.
16:40-17:20 Shai Haran, Technion, Haifa.
(59) The mystery of the prime at infinity.
17:20-18:00 Ron Livné, Hebrew University, Jerusalem.
(60) Asymptotics of cubic exponential sums.

Special Session on Approximation Theory
16:00-16:30 J. Szadabos, Hungarian Academy of Sciences, Budapest.
(61) Shepard operators on infinite intervals.
16:40-17:10 P. Vertesi, Hungarian Academy of Sciences, Budapest.
(62) Remarks on the Shepard operators.
17:20-17:50 E. Passow, Temple University, Philadelphia.
(63) Rational approximation to $|x|$.

Special Session on Associative Algebra
16:00-16:20 Ed Formanek, Pennsylvania State University, University Park.
(64) Braided representations of low degree.
16:25-16:45 Amitai Regev, Pennsylvania State University, University Park, and Weizmann Institute, Rehovot.
(65) Some recent results on codimensions ofPI-algebras.
16:50-17:10 Antonio Giambruno, University di Palermo.
(66) On a class of central polynomials for $n \times n$ matrices.
17:15-17:35 Allan Berele, DePaul University, Chicago.
(67) Embedding and nonembedding theorems for PI-algebras.
17:40-18:00 Michael Friger, Ben Gurion University, Beer Sheva. 
(68) Higman's theorem and almost regular automorphisms.

Special Session on Braids and Low-Dimensional Topology
16:00-16:25 D. D. Long, University of California, Santa Barbara. 
(69) The topology of complex plane curves.
16:30-16:55 Sofia Lambropoulou, University of Cambridge. 
(70) Markov traces and skein knot invariants for the solid torus.
17:00-17:25 Roger Alperin, San Jose State University. 
(71) Some representations of groups of automorphisms of a free group.
17:30-17:55 Jun Morita, University of Tsukuba. 
(72) The functor $D^{(n)}$, braid groups and $SL_2$ of rings.

Special Session on Complex Analysis
16:00-16:20 H. Masur, University of Illinois at Chicago. 
(73) The Poisson boundary of the mapping class group and of Teichmüller space.
16:30-16:50 B. Maskit, State University of New York at Stony Brook. 
(74) On classical Schottky groups.
17:00-17:20 M. Tretkoff, Stevens Institute of Technology, Princeton. 
(75) The classification of surfaces revisited.
17:30-17:50 E. Dynkin, Technion, Haifa. 
(76) An inequality for rational functions.

Special Session on Ergodic Theory
16:00-16:40 Manfred Denker, University of Göttingen. 
(77) Markov fibré systems.
16:50-17:20 James T. Campbell, Memphis State University. 
(78) Spectrum of transfer operators induced by expanding maps.
17:30-18:00 Radu Zaharopol, State University of New York, Binghampton. 
(79) Asymptotic stability and the Dobrushin constant of ergodicity.

Special Session on Field Arithmetic
16:00-16:30 Dan Haran, Tel Aviv University. 
(80) Regular realization of groups revisited.
16:40-17:15 Tammy Lefcourt, University of Pennsylvania, Philadelphia. 
(81) Galois groups over complete rings.
17:25-18:00 Helmut Voß, University of Florida, Gainesville. 
(82) GAR, GAL and GAP-realizations.

Special Session on Functional Analysis
16:00-16:25 Sean Dar, Tel Aviv University. 
(83) On the isotropic capacity of non-symmetric bodies.
16:30-16:55 Shlomo Reissner, Haifa University. 
(84) Constructing a polytope to approximate a convex body.
17:00-17:25 Carsten Schutt, Oklahoma State University, Stillwater. 
(85) On the expected volume of random polytopes.
17:30-17:55 Mark Rudelson, Hebrew University, Jerusalem. 
(86) Approximate John's decompositions.

Special Session on Game Theory and Mathematical Economics
16:00-16:40 Dov Monderer, Technion, Haifa. 
(87) Potentials and weighted values of non-atomic games.
16:40-17:20 Igal Milchtaich, Hebrew University, Jerusalem. 
(88) Generic uniqueness of equilibria in non-atomic congestion games.
17:20-18:00 Abraham Neyman, Hebrew University, Jerusalem. 
(89) Repeated games and bounded complexity.

Special Session on Geometry and Topology — Algebraic and Arithmetic Geometry
16:00-16:30 Eckart Viehweg, Universität Essen. 
(90) A discussion on moduli of singular schemes.
16:35-17:05 Vladimir G. Berkovich, Weizmann Institute, Rehovot. 
(91) The automorphism group of the Drinfeld half-plane.
17:10-17:40 Hélène Esnault, Universität Essen. 
(92) Divisibility in the Chow group and torsion in the cohomology.
17:40-18:00 Boris Kunyavski, Bar Ilan University, Ramat Gan. 
(93) Splitting fields of rational surfaces.

Special Session on Group Theory
16:00-16:50 Renato Feres, Washington University, St. Louis. 
(94) Actions of higher rank semisimple groups, differential geometry, and Zimmer's Conjecture.
17:00-17:20 Vladimir Platonov, University of Waterloo. 
(95) Proximal elements in linear groups over local fields.
17:30-17:50 Dave Witte, Williams College, Williamstown. 
(96) Products of similar matrices.

Special Session on Logic
16:00-16:30 A. Blaszczyszyn, Universiteit Slaski, Katowice. 
(97) Regular subalgebras of complete Boolean algebras.
16:40-17:10 M. Rabus, Hebrew University, Jerusalem. 
(98) Forcing Boolean algebras of cardinality $2^\omega$.
17:20-17:50 Z. Spasov, Hebrew University, Jerusalem. 
(99) $(\omega_1, \omega_1)$-gaps in $(P(\omega),\subseteq^*)$ and $(\omega^\omega,\subseteq^*)$.

Special Session on Mathematical Education
16:00-16:15 Marcia C. Linn, University of California, Berkeley. 
(100) Gender and success in mathematics.
16:20-16:35 Leonard Gillman, University of Texas, Austin. 
(101) A new look at the notion of limit.
16:40-16:55 Martin Bonsangue, California State University, Sanoma. 
(102) The effect of emerging scholars programs on minority achievements in the mathematical sciences.
17:00-17:15 Joseph W. Wimbish, Huntington College, Montgomery. 
(103) Some effects of a problem solving course on the classification of attitudes and beliefs about mathematics.
17:20-17:35 Barbara Zinn, Hebrew University, Jerusalem. 
(104) Reverse modeling of probabilistic concepts: From the model to students' texts.
17:40-17:55 Tatyana Zaslavsky, Technion, Haifa. 
(105) Secondary mathematics teachers' understanding of basic probability concepts.

Special Session on Optimization and Nonlinear Analysis
16:00-16:20 Hector J. Sussmann, Rutgers University, New Brunswick. 
(106) The finite-dimensional maximum principle of optimal control theory: Weak hypotheses, strong conclusions, and a coordinate-free formulation.
Program of the Sessions – Jerusalem, Israel, May 24–26

16:50-17:10 Pavel E. Sobolevski, Hebrew University, Jerusalem. (108) Investigation of some degenerate minimum problems.
17:15-17:35 Yosef N. Yomdin, Weizmann Institute, Rehovot. (109) High order discretization for parametric optimization problems.
17:40-18:00 Edriss S. Titi, University of California, Irvine. (110) On the minimal number of determining modes for nonlinear dissipative evolution equations.

Special Session on Partial Differential Equations
16:00-16:30 Tamir Tassa, University of California, Los Angeles. (111) On the homogenization of oscillatory solutions to nonlinear convection-diffusion equations.
16:40-17:10 Michael Solomyak, Weizmann Institute, Rehovot. (112) The eigenvalue behavior for the boundary value problems related to self-similar measures on $R^d$.
17:20-17:50 Misha Balay, Tel Aviv University. (113) A system of conservation laws arising in the study of integrable Hamiltonian systems.

Special Session on Stochastic Dynamics
16:00-16:35 Richard S. Ellis, University of Massachusetts, Amherst. (114) Large deviation analysis of queueing systems.
16:40-17:15 Liptser Robert, Tel Aviv University. (115) Convergence of conditional expectation (nonlinear filtering with contamination).

Special Session on Theoretical Computer Sciences
16:00-16:35 A. Widygerson, Hebrew University, Jerusalem. (117) Results and open problems on arithmetic complexity.
16:40-17:15 E. Gafni, University of California, Los Angeles. (118) Is distributed computing but a simple application of algebraic topology?
17:20-17:55 C. Dwork, IBM Almaden Research Center, San Jose. (119) Powerful primitives for asynchronous shared-memory algorithms.

Thursday, May 25

9:00-9:30 Business session, Israel Mathematical Union

Invited Address
9:30-10:30 Susan Montgomery, University of Southern California, Los Angeles. (120) Hopf algebras in categories.

Special Session on Associative Algebra
11:00-11:20 Issai Kantor, Bar Ilan University, Ramat Gan. (121) The algebra of polynomial invariants for the adjoint representation of the Lie superalgebra GL(m,n).

11:50-12:10 Ed Letzter, Texas A&M University, College Station. (123) Extensions of simple modules over classical Lie superalgebras.
12:40-13:00 Ayelet Lindenstrauss, Technion, Haifa. (125) Deformation retracts and the Hochschild homology of polynomial rings.

Special Session on Automorphic Forms
11:00-11:40 Jonathan Rogawski, University of California, Los Angeles. (126) Integrals of Eisenstein series over the period subgroup.
12:00-12:40 Laure Barthel, Bar Ilan University, Ramat Gan. (127) Modular representations of $GL(2)$.

Special Session on Braids and Low-Dimensional Topology
11:00-11:45 Alexander Balinsky, Technion, Haifa. (128) Symplectic actions of the braid groups and link-groups representations.
12:00-12:45 Laure Barthel, Bar Ilan University, Ramat Gan. (130) Destabilization in the braid groups.
12:30-12:55 Bruce Westbury, University of Nottingham. (131) A recipe for finite dimensional quotients of the braid group algebras.

Special Session on Combinatorics
11:00-11:25 Janos Pach, Courant Institute, New York University, and Hungarian Academy of Sciences, Budapest. (132) Geometric Ramsey theory.
11:30-11:55 Meir Katchalski, Technion, Haifa. (133) Piercing planar convex sets.
12:00-12:25 Aviezri Fraenkel, Weizmann Institute, Rehovot. (134) Elementary particle physics games and error correcting codes.
12:30-12:55 Mikhail Klin, Ben Gurion University, Beer Sheva. (135) A directed version of strongly regular graphs and coherent (cellular) algebras.

Special Session on Complex Analysis
11:00-11:20 B. Osgood, Stanford University. (136) Recent results on univalence criteria, convexity, and homeomorphic extensions.
11:30-11:50 S. Krushkal, Bar Ilan University, Ramat Gan. (137) Univalent functions and holomorphic motions.
12:00-12:20 C. Earle, Cornell University, Ithaca. (138) Metric geometry in infinite dimensional Teichmüller spaces.
12:30-12:50 B. Abikoff, University of Connecticut, Storrs. (139) Adapted metrics for hyperbolic manifolds.

Special Session on Ergodic Theory
11:00-11:40 Meir Smorodinsky, Tel Aviv University. (140) Processes which cannot be parametrized by independent random variables.
11:50-12:20 Ben-Zion Rubinstein, Ben Gurion University, Beer Sheva. (141) Classification of measurable partitions with respect to certain ergodic equivalence relations.
12:30-13:00 Mordechai Levin, Tel Aviv University. (142) On the upper bounds of discrepancy of completely uniform distributed and normal sequences.
Special Session on Field Arithmetic

11:00-11:30 Moshe Jarden, Tel Aviv University.
(143) PSC Galois extensions of global fields.
11:40-12:15 Konrad Neumann, University of Erlangen.
(144) All fields are stable.
12:25-13:00 Pirres Debes, Universite Lille.
(145) Algebraic covers: Field of moduli versus field of definition.

Special Session on Functional Analysis

11:00-11:25 Thomas Schlumprecht, Texas A&M University, College Station.
(146) On a Gaussian correlation problem.
11:30-11:55 Joel Zinn, Texas A&M University, College Station.
(147) Hypercontractivity and a Gaussian correlation inequality.
12:00-12:25 Elisabeth Werner, Case Western Reserve University, Cleveland.
(148) On a Gaussian correlation inequality.
12:30-12:55 Fima Gluskin, Tel Aviv University.
(149) On subspaces of $L_p$ spanned by independent random variables.

Special Session on Geometry and Topology — Geometry and Physics

11:00-11:30 Igor V. Dolgachev, University of Michigan, Ann Arbor.
(150) Mirror symmetry for algebraic K3-surfaces.
11:30-12:00 Ron Donagi, University of Pennsylvania, Philadelphia.
(151) Quantum cohomologies, integrable systems and normal functions.
12:05-12:35 M. Shubin, Northeastern University, Boston.
(152) Semiclassical asymptotics and Morse-type inequalities.
12:35-13:00 J. Weitsman, University of California, Santa Cruz.
(153) Geometry of the intersection ring of the moduli space of flat connections and the conjectures of Newstead and Witten.

Special Session on Group Theory

11:00-11:20 Oleg Tavgen, Belarus Academy of Science, Minsk.
(154) Some applications of the profinite and algebraic group theories in the combinatorial Group Theory.
11:30-11:50 Andrei Rapinchuk, Universität Bielefeld.
(155) The normal subgroup structure of $\text{SL}(1,D)$ and the classification of finite simple groups.
12:00-12:20 Marcus Du Sautoy, Oxford University.
(156) Zeta functions of groups.
12:30-13:00 Avinoam Mann, Hebrew University, Jerusalem.
(157) Zeta functions of residually finite groups.

Special Session on Logic

11:00-11:30 S. Friedman, MIT, Cambridge, and Université de Paris VII.
(158) Fine structure and class forcing.
11:40-12:10 T. Bartoszynski, Boise State University.
(159) Cardinal invariants and sets of reals.
(160) On ideals with Borel base.

Special Session on Mathematical Education

11:00-11:15 Michael Fried, University of California, Irvine.
(161) Interactive questionnaires: Retrograde learning.
11:20-11:35 Rina Herschkowitz, Weizmann Institute, Rehovot.
(162) Enhancing the construction of mathematical hypotheses in a technology based classroom environment.
11:40-11:55 Hanna Perl, Hebrew University, Jerusalem.
(163) The impact of graphic calculators on the learning of mathematics.
12:00-12:15 Gerald J. Porter, University of Pennsylvania, Philadelphia.
(164) Interactive linear algebra in Mathcad: A text for teaching linear algebra as a lab course.
12:20-12:35 Nirit Zehavi, Weizmann Institute, Rehovot.
(165) Challenging prospective teachers to create mathematical projects with Derive.
12:40-12:55 Gideon Zwas, Tel Aviv University.
(166) Precollege numerical mathematics.

Special Session on Operator Theory and Applications

11:00-11:30 H. J. Landau, AT&T Bell Labs, Murray Hill.
(167) The inverse eigenvalue problem for real symmetric Toeplitz matrices.
11:35-12:00 D. Alpay, Ben Gurion University, Beer Sheva.
(168) Tangential interpolation in matrix-valued Hardy spaces.
12:05-12:30 M. Gekhtman, Weizmann Institute, Rehovot.
(169) Inverse spectral problems for difference operators and nonlinear integrable equations.
12:35-13:00 P. Lancaster, University of Calgary.
(170) Perturbations of strongly definitizable operators and quasihyperbolic operator polynomials.

Special Session on Optimization and Nonlinear Analysis

11:00-11:20 Shiu-Nee Chow, Georgia Institute of Technology, Atlanta.
(171) Spatial chaos in reaction-diffusion systems.
11:25-11:45 Francis H. Clarke, Université de Montréal.
(172) The proximal Hamilton-Jacobi equation.
11:50-12:10 Athanassios G. Kartsatos, University of Southern Florida, Tampa.
(173) Functional evolutions, elliptic inclusions, and control problems involving accretive and monotone operators.
12:15-12:35 Abbas Bahri, Rutgers University, New Brunswick.
(174) Variations on the same theme.
12:40-13:00 Zuhair M. Nashed, University of Delaware, Newark.
(175) Newton’s method for singular smooth and non-smooth equations using adaptive outer inverses.

Special Session on Partial Differential Equations

11:00-11:30 Amy Cohen-Novick, Technion, Haifa.
(176) The Cahn-Hilliard equation: Degenerate diffusion and energy separation.
11:40-12:10 Eitan Tadmor, Tel Aviv University.
(177) Regularizing effect in nonlinear 2nd order PDEs with kinetic formulations.
12:20-12:50 Edriss Titi, University of California, Irvine.
(178) Global existence for 3-D Navier-Stokes in the presence of symmetry.
Program of the Sessions – Jerusalem, Israel, May 24–26

Invited Address

Special Session on Algebraic Number Theory
16:00–16:35 Henry Darmon, McGill University, Montreal. (183) Rigid analytic Gross–Zagier formulae.
16:40–17:15 Ehud de Shalit, Hebrew University, Jerusalem. (184) Metabelian local class field theory.
17:20–17:55 Glenn Stevens, Boston University. (185) Rigid analytic modular symbols.

Special Session on Applied Mathematics
16:00–16:20 Philip Rosenau, Tel Aviv University. (186) On soliton-compaction duality.
17:15–17:35 Tamar Schlick, Courant Institute and Chemistry Department, New York University. (189) On simulating the dynamics of biomolecules.
17:40–18:00 Jean Marc Vanden-Broeck, University of Wisconsin, Madison. (190) Some effects of vorticity on nonlinear free surface flows.

Special Session on Approximation Theory
16:00–16:30 E. B. Saff, University of South Florida, Tampa. (191) Asymptotically optimal rational functions for the Zolotarev problem.

Special Session on Associative Algebra
16:00–16:20 Susan Montgomery, University of Southern California, Los Angeles. (194) Hoch algebra in categories.
16:25–16:45 Earl Taft, Rutgers University, New Brunswick. (195) Quantized linearly recursive sequences.
16:50–17:10 Sara Westreich, Bar Ilan University, Ramat Gan. (196) Quasitrivial Hopf algebras with Abelian group of grouplike elements.
17:15–17:35 Hans-Juergen Schneider, University of Munich. (197) Frobenius extensions of left coideal algebras of Hopf algebras.
17:40–18:00 Zhu Shengli, Fudan University, Shanghai. (198) On integrality of (quantum) module algebras over their invariants.
18:00–18:20 Miriam Cohen, Ben Gurion University, Beer Sheva. (199) Quantum commutative H-module algebras.

Special Session on Braids and Low-Dimensional Topology
17:00–17:25 Jonathan Simon, University of Iowa, Iowa City. (200) Energy functions for knots.
16:30–16:55 Thomas Fiedler, Université Paul Sabatier, Toulouse. (201) The discriminant of the space of diagrams and knot invariants.
17:00–17:25 Richard Randell, University of Iowa, Iowa City. (202) The Pl. knot space.
17:30–17:55 Charilaos Aneziris, DESY-Ih, Zeuthen. (203) Is a knot classification possible?

Special Session on Combinatorics
16:00–16:25 Jeff Kahn, Rutgers University, New Brunswick. (204) Asymptotics of the chromatic index for multigraphs.
17:00–17:25 Ron Adin, Bar Ilan University, Ramat Gan. (206) Cubical polytope.

Special Session on Complex Analysis
16:00–16:20 D. Aharonov, Technion, Haifa. (207) The hexagonal packing lemma and Rodin-Sullivan conjecture.
16:30–16:50 V. Tkachenko, Ben Gurion University, Beer Sheva. (208) Spectral properties of periodic Dirac operator with skew-symmetric potential matrix.
17:00–17:20 J. Arazy, University of Haifa. (209) Invariant spaces of analytic functions on bounded symmetric domains.
17:30–17:50 L. Aizenberg, Bar Ilan University, Ramat Gan. (210) Mean-value characterization of pluriharmonic and separately harmonic functions.

Contributed Paper Session
16:00–16:10 Leonid Berezansky, Ben Gurion University, Beer Sheva. (211) Impulsive stabilization of linear delay differential equations.
16:30–16:40 Seymour Haber, Temple University, Philadelphia. (213) Quadrature formulas through conformal mapping.
16:45–16:55 V. A. Kaminsky, Bar Ilan University, Ramat Gan. (214) On approximation of a convex function of two variables by the sum of two functions of one variable.
17:50–18:00 Peter Turbek, Purdue University, West Lafayette. (218) Automorphisms of Riemann surfaces.

Special Session on Ergodic Theory
16:00–16:40 Wolfgang Krieger, Universität Heidelberg. (219) Transformations that behave like stationary adic transformations.
17:30–18:00 Elon Lindenstrauss, Hebrew University, Jerusalem. (221) Lowering topological entropy.

Special Session on Field Arithmetic
16:00–16:25 Ido Efrat, Hebrew University, Jerusalem. (222) The Neukirch-Pop conjecture.
Special Session on Functional Analysis

16:00 - 16:25 Haskell Rosenthal, University of Texas, Austin.
(226) On the structure of differences of bounded semi-continuous functions.

16:30 - 16:55 Alvaro Arias, University of Texas, San Antonio.
(227) Non-commutative inner and outer functions.

17:00 - 17:25 Yaakov Ben-Natan, Hebrew University, Jerusalem.
(228) Wiener Tauberian theorem for $L^1(G/K)$ and harmonic functions in the unit disk.

17:30 - 17:55 Ya. Alber, Technion, Haifa.
(229) Principle of weakly contractive maps in Hilbert and Banach spaces.

Special Session on Geometry and Topology — Topology

16:00 - 16:40 S. Cappell, New York University.
(230) A topological comparison of lattice sums and integration.

(231) Characteristic classes, singularities, and algebraic varieties.

17:25 - 18:00 S. Weinberger, University of Pennsylvania, Philadelphia.
(232) The small scale structure of "manifolds".

Special Session on Group Theory

16:00 - 16:20 Sergey Schpectorov, Michigan State University, East Lansing.
(233) Singular subgroups in $M, B, J$.

16:30 - 16:50 Yoav Segev, Ben Gurion University, Beer Sheva.
(234) On a simplicial complex homotopic to the Brown and Quillen $p$ subcomplex.

17:00 - 17:20 Aner Shalev, Hebrew University, Jerusalem.
(235) Finite simple groups and probabilistic methods.

17:30 - 17:50 Brian Parshall, University of Virginia, Charlottesville.
(236) Gradings in representation theory.

Special Session on Logic

16:00 - 16:30 P. Dehornoy, Caen Université.
(237) An application of set theory to the topology of braids.

16:40 - 17:10 A. Szymanski, Slippery Rock University of Pennsylvania.
(238) The metrizability number of compact spaces and related invariants.

17:20 - 18:00 Saharon Shelah, Hebrew University, Jerusalem.
(239) Recent developments in set theory.

Special Session on Mathematical Education

16:00 - 16:15 Hamutal David, Technion, Haifa.
(240) Making sense out of a written proof.

16:20 - 16:35 Dan Fendel, San Francisco State University.
(241) Trigonometry on the ferris wheel: A constructivist approach to the circular functions.

16:40 - 16:55 Roza Leikin, Technion, Haifa.
(242) The role of symmetry in mathematical problem solving.

17:00 - 17:15 David Rimer, Weizmann Institute, Rehovot.
(243) Tetrabeda with the "seven mean" property.

17:20 - 17:35 Martha J. Siegel, Towson State University.
(244) Industrial mathematics for the undergraduate.

17:40 - 17:55 Uri Wilensky, Tufts University, Medford.
(245) Learning probability through parallel modeling.

Special Session on Operator Theory and Applications

16:00 - 16:30 Yu. Lyubich, Technion, Haifa.
(246) A new development of the Perron-Frobenius theory.

16:35 - 17:00 V. V. Peller, Kansas State University, Manhattan.
(247) Approximation by matrix analytic functions.

17:05 - 17:30 E. Pustylnik, Technion, Haifa.
(248) Generalized potential type operator on rearrangement invariant spaces.

17:35 - 18:00 V. Vinnikov, Weizmann Institute, Rehovot.
(249) Commuting nonselfadjoint operators and algebraic curves.

Special Session on Optimization and Nonlinear Analysis

16:00 - 16:20 Roger D. Nussbaum, Rutgers University, New Brunswick.
(250) Periodic points of nonexpansive operators: Theorems and conjectures.

16:25 - 16:45 Isao Miyadera, Waseda University, Tokyo.
(251) Asymptotic behavior of almost-orbits of asymptotically nonexpansive semigroups in Banach spaces.

16:50 - 17:10 Stephen Simons, University of California, Santa Barbara.
(252) Swimming below icebergs.

17:15 - 17:35 Dan Butnariu, University of Haifa.

17:40 - 18:00 Ron Stern, Concordia University, Montreal.
(254) Fixed points and equilibria in nonconvex sets.

Special Session on Partial Differential Equations

16:00 - 16:30 Galia Dafni, University of California, Berkeley.
(255) Hardy spaces and elliptic boundary value problems for smooth domains in $R^n$.

16:40 - 17:10 Mark Agranovsky, Bar Ilan University, Ramat Gan.
(256) Uniqueness sets for spherical Radon transform.

17:20 - 17:50 Aleksy Drozdo, Ben Gurion University, Beer Sheva.
(257) Stability of partial integro-differential equations with applications to problems in viscoelasticity.

Special Session on Stochastic Dynamics

16:00 - 16:35 Dan Stroock, MIT, Cambridge.
(258) Perturbations of Brownian paths on a manifold.

16:40 - 17:15 Zeev Schuss, Tel Aviv University.
(259) An asymptotic theory of large deviations.

17:20 - 17:55 Ofer Zeitouni, Technion, Haifa.
(260) Decay rates for one dimensional random walk in random environment.

Special Session on Theoretical Computer Sciences

16:00 - 16:35 M. Rabin, Hebrew University, Jerusalem.
(261) A new paradigm for hash functions.

16:40 - 17:15 H. Karloff, Georgia Tech, Atlanta.
(262) New results for an old algorithm for the TSP.

17:20 - 17:55 S. Even, Technion, Haifa.
(263) Layered cross product — a technique to construct interconnection networks.

19:00 - 23:00 Reception, Meyersdorf House, Mount Scopus.
**Friday, May 26**

**Invited Address**

9:30-10:30  
**John W. Neuberger**, University of North Texas, Denton.  
(264) Three recent results on one-parameter semigroups.

**Special Session on Algebraic Number Theory**

11:00-11:40  
**J. Teitelbaum**, University of Illinois at Chicago.  
(265) Numerical applications of Koeke's formula.

12:00-12:40  
**Y. Varshavsky**, Hebrew University, Jerusalem.  
(266) $p$-adic uniformization of Shimura varieties.

**Special Session on Approximation Theory**

11:00-11:30  
**H. N. Mhaskar**, California State University, Los Angeles.  
(267) Approximation capability of generalized translation networks.

11:40-12:10  
**G. Derfel**, Ben Gurion University, Beer Sheva.  
(268) Two-scale difference equation and its generalizations.

12:20-12:50  
**D. Levin**, Tel Aviv University.  
(269) Near best scattered-data approximations in $R^d$.

**Special Session on Associative Algebra**

11:00-11:20  
**Wallace S. Martindale III**, University of Massachusetts, Amherst.  
(270) Lie mappings in prime rings.

11:25-11:45  
**Quanshi Wu**, Fudan University, Shanghai.  
(271) Algebraic microlocalizations and holonomic modules.

11:50-12:10  
**Yonghua Xu**, Fudan University, Shanghai.  
(272) Duality theorems for graded rings in double crossed products.

12:15-12:35  
**S. K. Jain**, University of Ohio, Athens.  
(273) When is a simple ring Noetherian?

12:40-13:00  
**V. Dlab**, Carleton University, Ottawa.  
(274) Yoneda function algebras.

**Special Session on Automorphic Forms**

11:00-11:40  
**Zel'ev Rudnicki**, Tel Aviv University.  
(275) Zeros of $L$-functions and random matrix theory.

12:10-12:40  
**Ehud Moshe Baruch**, Yale University, New Haven.  
(276) On the gamma factor attached to representations of $p$-adic groups and strong multiplicity one.

**Special Session on Braid Groups and Low-Dimensional Topology**

11:00-11:25  
**Kyoji Saito**, RIMS, Kyoto University.  
(277) Teichmuller space defined over $\mathbb Z$.

11:30-11:55  
**Tositake Kanno**, Nagoya University.  
(278) Vassiliev invariants for braids, Chern-Simons perturbation theory and the graph complex.

12:00-12:25  
**Micha Sageev**, Technion, Haifa.  
(279) The k-plane intersection property for immersed incompressible surfaces in $3$-manifolds.

12:30-12:55  
(280) 3-fold invariants at roots of unity.

**Special Session on Combinatorics**

11:00-11:25  
(281) Graph colorings and symmetric functions.

11:30-11:55  
**Michael Tarsi**, Tel Aviv University.  
(282) Graph coloring, nowhere zero flows and the lonely runner problem.

12:00-12:25  
(283) On a new method based on the regularity lemma.

12:30-12:55  
**Raphael Yuster**, Tel Aviv University.  
(284) Graph packing problems.

**Special Session on Complex Analysis**

11:00-11:40  
**J. Jorgenson**, Yale University, New Haven.  
(285) Spectral asymptotics of degenerating hyperbolic 3-manifolds (joint with J. Dodziuk).

11:30-11:50  
**R. Brooks**, University of Southern California, Los Angeles.  
(286) The first eigenvalue of the Platonic surfaces.

12:00-12:20  
**B. Rodin**, University of California, San Diego, La Jolla.  
(287) Circle packing rigidity constants.

12:30-12:50  
**B. Pinchuk**, Bar Ilan University, Ramat Gan.  
(288) Extremal functions and contractive divisors in $A^m$.

**Special Session on Ergodic Theory**

11:00-11:40  
**Jonathan King**, University of Florida, Gainesville.  
(289) Brick tilings and monotone Boolean functions.

12:00-12:40  
**Eli Glasner**, Tel Aviv University.  
(290) A simple characterisation of measure entropy pairs and applications.

**Special Session on Field Arithmetic**

11:00-11:40  
**Noam Elkies**, Harvard University, Cambridge.  
(291) How many points can a curve have?

11:40-12:15  
**Gerhard Frey**, Essen University.  
(292) On curves of genus 2 with elliptic differentials.

12:25-13:00  
**Michael Fried**, University of California, Irvine.  
(293) Modular stacks.

**Special Session on Functional Analysis**

11:00-11:25  
**Dale Alspach**, Oklahoma State University, Stillwater.  
(294) Linear topological properties of tensor products and independent sums of $L_p$-spaces.

11:30-11:55  
**Vladimir Fonf**, Ben Gurion University, Beer Sheva.  
(295) Tangential polytopes and smooth approximation in separable polyhedral Banach spaces.

12:00-12:25  
**Pete Casazza**, University of Missouri, Columbia.  
(296) Complemented unconditional basic sequences in Banach lattices.

**Special Session on Geometry and Topology — Geometry and Analysis**

11:00-11:35  
**D. Freed**, University of Texas, Austin.  
(297)Eta invariants and determinant lines.

11:35-12:00  
**B. Shapiro**, Weizmann Institute, Rehovot.  
(298) Stratification of Hermitian matrices, the Alexander mapping, and the bundle over eigenvalues.

12:05-12:30  
**Vladislav V. Goldberg**, New Jersey Institute for Technology, Newark.  
(299) Conformal and Grassman structures.

12:35-13:00  
**Alexander Nabutovsky**, New York University.  
(300) Disconnectedness of sublevel sets of some Riemannian functionals.

**Special Session on Group Theory**

11:00-11:20  
**Leonard Scott**, University of Virginia, Charlottesville.  
(301) Theoretical and computational methods in representation theory.

11:30-11:50  
**Dan Rockmore**, Dartmouth College, Hanover.  
(302) Separation of variables for FFT's on finite groups.
12:30-13:00 Grisha Soifer, Bar Ilan University, Ramat Gan.  
(303) On the Zarisky closure of the linear part of discontinuous groups of finite transformations.

Special Session on Logic

11:00-11:30 J. P. Ressayre, CNRS and Université de Paris VII.  
(304) Stretchings.
11:40-12:10 Z. Mijajlović, University of Belgrade.  
(305) Continuous quotients in nonstandard analysis.
12:20-12:50 K. Tent, Hebrew University, Jerusalem.  
(306) Algebraic polygons.

Special Session on Mathematical Education

11:00-11:15 Michael Brook, University of Delaware, Newark.  
(307) Adi erian psychology and mathematics education.
11:20-11:35 Orit Hazzan, Technion, Haifa.  
(308) How undergraduate students reduce abstraction level during abstract algebra course.
11:40-11:55 Uri Leron, Technion, Haifa.  
(309) Students’ use and misuse of mathematical theorems: The case of Lagrange’s theorem.
12:00-12:15 Gilli Shama, Technion, Haifa.  
(310) Identifying non-periodic phenomena as periodic.
12:20-12:35 Dina Tirosh, Tel Aviv University.  
(311) Intuitive rules: A common core to students’ conceptions in science and mathematics.
12:40-13:55 Pessia Tsamir, Tel Aviv University.  
(312) The role of representations in comparing infinite sets.

Special Session on Operator Theory and Applications

11:00-11:30 J. Pejsachowicz, Polytechnic Institute, Turin.  
(313) Spectral flow for families of selfadjoint Fredholm operators and bifurcation of critical points of strongly indefinite functionals.
11:35-12:00 A. Ben-Artzi, Tel Aviv University.  
(314) Inertia theorems for operator pencils and applications.
12:05-12:30 L. Rodman, The College of William and Mary, Williamsburg.  
(315) Inertia of operator polynomials.
12:35-13:00 M. V. Shapiro, ESFM del IPN, Mexico City.  
(316) Hilbert operators associated with solutions of the three-dimensional Helmholtz equation.

Special Session on Optimization and Nonlinear Analysis

11:00-11:20 Adi Ben-Israel, Rutgers University, New Brunswick.  
(317) Generalized convexity in numerical analysis and optimization.
11:25-11:45 Åke Björck, University of Linkoping.  
(318) Stability of methods for solving augmented systems.
11:50-12:10 Arkadi Nemirovski, Technion, Haifa.  
(319) Polynomial-time method of analytic centers for the generalized eigenvalue problem.
12:15-12:35 Alexander Rubinov, Ben Gurion University, Beer Sheva.  
(320) Some applications of convex analysis to global optimization.

Special Session on Probability Theory

11:00-11:25 M. L. Esquivel, Universidade Nova de Lisboa.  
(321) A characterization of the class of random Schwartz distributions having a mean.
11:30-11:55 E. Merzbach, Bar Ilan University, Ramat Gan.  
(322) Weak convergence of set-indexed point processes and the Poisson process.
Please complete a separate form for each individual attending.

# Personal Participant Information

**Name**

**Mailing Address**

**Telephone**

**Fax**

# Registration for Tours

Please check the box for all tours you wish to attend

- [ ] Stowe Area Tour
- [ ] Shelburne Museum
- [ ] VT Teddy Bear/Shelburne Farms
- [ ] Ausable Chasm

**Deadline**

Tour registration forms must be received by

**July 5, 1995**

# Fees for Tours

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<td>Stowe Area Tour</td>
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<td>Shelburne Museum</td>
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<td>VT Teddy Bear/Shelburne Farms</td>
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<td>Ausable Chasm</td>
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**Payment Method**

**Check Only**

**Name**

**Mailing Address**

**Telephone**

**Fax**

**Authorization Signature**

# Terms

**Cancellation Penalty**

Prior to July 19, 1995, refunds will be made subject to a $25.00 non-refundable penalty fee.

After July 19, 1995, all payments are non-refundable.

Return only this form and payment to:

Accent Travel/CTN
P. O. Box 753
Williston, VT 05495

**For further information**

on tours contact

Accent Travel/CTN:

**Telephone**

802-679-6903 x3

**Fax**

802-678-9129
Personal Information

Name ________________________________  Membership □ all that apply

Mailing Address ____________________________

Telephone ___________________________ e-mail ______________________

Badge Information

Affiliation ________________________________

(Please limit affiliation to 35 characters – one line only)

Name to appear on badge _______________________  MR field of interest ______

If you do not wish your program and badge to be mailed to you on July 12, place a check in the box. □

Registration Fees

Mathfest by July 14 at meeting

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Total Payment

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TOTAL Amount Due $ ______

Make checks payable to the AMS. Canadian checks must be marked "U.S. Funds". You may charge this total to your VISA or MasterCard.

Card Number: ________________________ Expiration Date: _______

Card Type: _______ Signature: ________________________

Name on Card: ________________________

Please complete this form and return it to:

Mathematical Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, Rhode Island 02940
U.S.A.
401-455-4143 or 1-800-321-4267 x 4143

For Office Use Only

Codes: ________________________

Options: ________________________

Hotel: ________________________

Dates: ________________________

Dorm: ________________________

Room Type: ________________________

Hotel Deposit: ________________________

Dorm Payment: ________________________

TOTAL Amt. Paid: ________________________

Room/Board Paid: $ ______

Room/Board Due: $ ______

Remarks: ________________________

Event Tickets

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TOTAL for Event Tickets $ ______

See separate tour form in this issue.

Deadlines

Advance Registration/Residence Hall Reser. June 15, 1995
Hotel changes/cancellation thru MMSB July 5, 1995
Final Advance Registration (no housing) July 14, 1995
90% Refund on Residence Hall Package July 25, 1995*
50% Refund on Events July 31, 1995*
50% Refund on Registration Cancellation August 4, 1995*

*no refunds after this date
General Information

Where applicable, please check off one of the following

- I will be making my own reservations. Name of hotel or motel: ____________________________
- I live in the area or will be staying privately with family or friends.
- I plan to share a room with ____________________________, who is making our reservations.

University Reservations

Full prepayment for room and board is required. Purchase of a room and board package (breakfast and lunch) is required, and it is included in the rates listed below. All rates are per person. Mathfest participants may occupy the residence halls from Saturday, August 5 to Wednesday, August 9 only.

Acknowledgment of your residence hall reservations will be sent to the address indicated on the reverse side of this application. Please mark applicable rates listed below and enter the totals where applicable. There is no children’s rate, but sleeping bags are allowed.

<table>
<thead>
<tr>
<th>Description</th>
<th># Staying</th>
<th>At</th>
<th># of Days</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td></td>
<td>$36</td>
<td></td>
<td>$____</td>
</tr>
<tr>
<td>Double</td>
<td></td>
<td>$32</td>
<td></td>
<td>$____</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>$____</td>
</tr>
</tbody>
</table>

Rates are per person.

Please mark all that apply:
- Male
- Female
- Smoker
- Nonsmoker

Date and Time of Arrival: ____________________________
Date and Time of Departure: ____________________________

Names of Other Occupants

<table>
<thead>
<tr>
<th>Arrival Date</th>
<th>Departure Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child? (give age)</td>
<td>____________________________</td>
</tr>
<tr>
<td>Child? (give age)</td>
<td>____________________________</td>
</tr>
<tr>
<td>Child? (give age)</td>
<td>____________________________</td>
</tr>
</tbody>
</table>

Majority of rooms will be assigned in the Living/Learning Complex; Marsh/Austin/Tupper will be used for overflow.

Hotel Reservations

Please indicate type of room:
- Single $89
- Double $89
- Triple $89
- Quad $89

To guarantee a room, please include $89 by check or provide a credit card number.

- Deposit enclosed
- Hold with my credit card

Card Number ____________________________ Exp. Date ____________________________

Date and Time of Arrival: ____________________________
Date and Time of Departure: ____________________________

Names of Other Occupants

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<tr>
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<td>____________________________</td>
</tr>
<tr>
<td>Child? (give age)</td>
<td>____________________________</td>
</tr>
</tbody>
</table>

All hotel reservations are for the Sheraton Burlington at 870 Williston Road, Burlington, VT.
AMERICAN MATHEMATICAL SOCIETY

Please read the reverse side of this form to determine what membership category you are eligible for. Then fill out this application and return it as soon as possible.

Family Name
First
Middle

Place of Birth
City State Country

Date of Birth
Day Month Year

If formerly a member of AMS, please indicate dates

Check here if you are now a member of either MAA □ or SIAM □

Degrees, with institutions and dates

Present position

Firm or institution

City State Zip/Country

Primary Fields of Interest (choose five from the list at right)

Secondary Fields of Interest (choose from the list at right)

Address for all mail

Telephone number(s)

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Signature

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Application for Membership 1995

Fields of Interest

Date (January–December)

If you wish to be on the mailing lists to receive information about publications in fields of mathematics in which you have an interest, please consult the list of major headings below. These categories will be added to your computer record so that you will be informed of new publications or special sales in the fields you have indicated:

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

Please read the following to determine what membership category you are eligible for, and then indicate below the category for which you are applying.

**For ordinary members** whose annual professional income is below $45,000, the dues are $87; for those whose annual professional income is $45,000 or more, the dues are $116.

The **CMS cooperative rate** applies to ordinary members of the AMS who are also members of the Canadian Mathematical Society and reside outside of the U.S. For members whose annual professional income is $45,000 or less, the dues are $74; for those whose annual professional income is above $45,000, the dues are $99.

For a **joint family membership**, one member pays ordinary dues, based on his or her income; the other pays ordinary dues based on his or her income, less $20. (Only the member paying full dues will receive the Notices and the Bulletin as a privilege of membership, but both members will be accorded all privileges of membership.)

Minimum dues for contributing members are $174.

For **either students or unemployed individuals**, dues are $29, and annual verification is required.

The annual dues for **reciprocity members** who reside outside the U.S. and Canada are $58. To be eligible for this classification, members must belong to one of those foreign societies with which the AMS has established a reciprocity agreement, and annual verification is required. Reciprocity members who reside in the U.S. or Canada must pay ordinary member dues ($87 or $116).

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

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

**1995 Dues Schedule (January through December)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Dues Schedule</th>
</tr>
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<tbody>
<tr>
<td>Ordinary member</td>
<td>$87 (minimum) $116</td>
</tr>
<tr>
<td>CMS Cooperative</td>
<td>$74 (minimum) $99</td>
</tr>
<tr>
<td>Joint family</td>
<td>$87 (minimum) $116</td>
</tr>
<tr>
<td>Reduced rate</td>
<td>$67 (minimum) $96</td>
</tr>
<tr>
<td>Contributing</td>
<td>$174</td>
</tr>
<tr>
<td>Student member</td>
<td>$29</td>
</tr>
<tr>
<td>Unemployed member</td>
<td>$29</td>
</tr>
<tr>
<td>Reciprocity</td>
<td>$58 $87 $116</td>
</tr>
<tr>
<td>Category-S member</td>
<td>$16</td>
</tr>
<tr>
<td>Multi-year</td>
<td>$ for years</td>
</tr>
</tbody>
</table>

1 **Student Verification** (sign below)

I am a full-time student at ____________________________ currently working toward a degree.  

2 **Unemployment Verification** (sign below) I am currently unemployed and actively seeking employment. My unemployment status is not a result of voluntary resignation or of retirement from my last position.

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

**Signature**

4 ☐ send NOTICES ☐ send BULLETIN

---

**Reciprocating Societies**

- Allahabad Mathematical Society
- Asociación Matemática Española
- Australian Mathematical Society
- Berliner Mathematische Gesellschaft e.V.
- Calcutta Mathematical Society
- Croatian Mathematical Society
- Danish Mathematical Society
- Deutsche Mathematiker-Vereinigung e.V.
- Edinburgh Mathematical Society
- Egyptian Mathematical Society
- Gesellschaft für Angewandte Mathematik und Mechanik
- Glasgow Mathematical Association
- Hellenic Mathematical Society
- Indian Mathematical Society
- Iranian Mathematical Society
- Irish Mathematical Society
- Islenzka Staertrietafslagið
- Israel Mathematical Union
- János Bolyai Mathematical Society
- Korean Mathematical Society
- London Mathematical Society
- Malaysian Mathematical Society
- Mathematical Society of Japan
- Mathematical Society of the Philippines
- Mathematical Society of the Republic of China
- Mongolian Mathematical Society
- Nepal Mathematical Society
- New Zealand Mathematical Society
- Nigerian Mathematical Society
- Norsk Matematisk Forening
- Österreichische Mathematische Gesellschaft
- Polskie Towarzystwo Matematyczne
- Punjab Mathematical Society
- Ramanujan Mathematical Society
- Real Sociedad Matemática Española
- Saudi Association for Mathematical Sciences
- Sociedad Colombiana de Matemática
- Sociedad de Matemática de Chile
- Sociedad Matemática de la República Dominicana
- Sociedade Matemática Mexicana
- Sociedade Brasileira de Matemática
- Aplicada e Computational
- Sociedade Paranaense de Matemática
- Sociedade Portuguesa de Matemática
- Societat Catalana de Matemàtiques
- Societatea Matematicienilor din România
- Société des Mathématiques Appliquées et Industrielles
- Société Mathématique de Belgique
- Société Mathématique de France
- Société Mathématique Suisse
- Society of Associations of Mathematicians & Computer Science of Macedonia
- Society of Mathematicians, Physicists, and Astronomers of Slovenia
- South African Mathematical Society
- Southeast Asian Mathematical Society
- Suomen Matemaatikkojen Yhdistys
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- Address
- City
- State
- Zip
- Country
- Code
- e-mail

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Code</th>
<th>Title</th>
<th>Price</th>
<th>Total</th>
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</table>

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