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*Nancy Kopell*

This article, based on the 1999 Josiah Willard Gibbs Lecture, discusses mathematical models for the rhythms that are observed in certain kinds of brain activity, as well as transitions between different rhythms.

**Geometry of Solitons**

*Chuu-Lian Terng and Karen Uhlenbeck*

Some classical nonlinear PDEs have solutions that are asymptotic to nontrivial linear combinations of solitary waves. The authors show how to make the study of these equations more systematic by introducing actions of loop groups on the spaces of solutions.

**Harmonic Analysis and Group Representations**

*James Arthur*

Arthur gives a short introduction to the work of Harish-Chandra and then provides hints of the nature of the Langlands program, offering a sense of the role played by Harish-Chandra’s work in the Langlands Program.

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AMS in the Twentieth Century

The Start of the New Notices

The November column in this series told of the inclusion in the Notices of occasional "special articles" starting in 1982. These were expository articles intended for a broad audience of mathematicians. Most of the leaders of the AMS wanted to have even more exposition—partly to showcase current mathematical developments, partly to help mathematicians be able to have a broader view of the subject, and partly to move toward communicating about mathematics to the general public. This desire was seen to affect both the Notices and the Bulletin.

By the early 1990s the content of the Notices and the Bulletin had become a more and more frequent subject of discussion. Each of these journals had several parts. The questions were whether all of these parts were appropriate in journals sent to all members, whether any parts were missing, and whether some different mix might serve the goals of the AMS better. In the spring of 1992 the Executive Committee and Board of Trustees (ECBT) established the Committee to Review Member Publications (CRMP), with Hugo Rossi as chair. Although this committee studied several AMS publications, it concentrated on the Notices and the Bulletin. It reported to the ECBT in May 1993, and its recommendations were adopted by the Council in August 1993. An abridged version of the report and commentary by Rossi appear in the September 1993 Notices, pp. 843-847.

CRMP sought opinions in various ways from a significant fraction of the AMS membership. The committee agreed that three major objectives of the "member publications" are, in Rossi's words, "to communicate information to the membership on • the current state of the discipline and the directions in which it is advancing; • mathematical meetings, activities, and programs, especially...those of the AMS; and • the status of the profession."

Rossi continued, "Mathematicians join the AMS because they support its goals of fostering research, but we found that they join also to have access to this information in the above order of priority. Beyond this, the level of interest and depth of involvement is very highly varied....

"From the beginning we agreed that the AMS should, through its member publications, become much more involved in the exposition of mathematics....It became clear that we were not talking about exposition in the common sense of presentation of mathematical ideas to lay people...but rather discussion with and explanation for...members of the mathematical community, of new advances achieved together with the new techniques involved, putting it all in an appropriate context within the whole body of mathematics....We also maintain that authors should write, not just for the record, but to an audience. We recognize that because of the highly diverse nature of the membership, there are many selections of an 'audience,' and this of course will vary greatly from article to article. But the principle to which we hope to see adherence is that the author of each article demonstrates a consistent conception of an intended audience."

The recommendations of the CRMP included a proposal for an "enhanced" Notices, saying, "The goal of the enhanced Notices of the American Mathematical Society is to serve all mathematicians by providing a lively and informative magazine, which contains news about mathematics and mathematicians, as well as information about the Society and the profession."

The recommended purpose was as follows: "The Notices shall communicate information and commentary on the discipline, the profession, and the Society and its activities; be a privilege of membership in the AMS; and serve as the journal of record of the Society. We envision that the journal will contain significant sections on mathematics, ranging from brief, timely paragraphs on new breakthroughs (tentatively called Research News), through expositions of some of those breakthroughs and their context, to broad discursive surveys of the status of contemporary mathematics."

The Bulletin was revised too. Research announcements were dropped, and exposition was increased. It was recognized that the Notices and Bulletin would have overlapping functions and that continuing dialog would be necessary.

The search for a founding editor of the Notices led, by a circuitous route, back to Hugo Rossi, who began work in 1994. A completely new design was needed, and professional advice was obtained. After lengthy preparations the first issue appeared in January 1995. The new Notices had an auspicious start, receiving an award in 1996 from the Society of National Association Publications for general excellence in a scholarly journal. The state of the Notices at the end of the twentieth century is planned as the subject of a later column in this series.

—Anthony W. Knapp
Commentary

In My Opinion

Revising the NCTM Standards

When the first volume of the National Council of Teachers of Mathematics's Standards for K-12 mathematics education came out in 1989, no one, including the authors, imagined how influential it would be. Mathematicians had been asked to participate in the project but, with few exceptions, had declined. The U.S. had never had national standards in any subject. Who could have predicted that the 1989 Standards would matter? But it did. State standards were rewritten, major curriculum projects were funded, assessments were radically overhauled, and, once people realized what was going on, a backlash movement began whose greatest effect has perhaps been a rather astonishing politicization of mathematics education.

People learn. Three years ago, when I was asked to help with the Standards revision (later titled Principles and Standards of School Mathematics), I jumped at the chance, as did several of my colleagues: five of the twenty-six Principles and Standards writers are mathematicians. What did we jump into?

Nothing we were used to. Mathematics may be, as Barbie said before she was reprogrammed, hard, but this was much harder. It was hard because (a) this was education, with fractured communities (including our community of mathematicians), each speaking a different dialect; (b) we were necessarily, not of our own choosing, going to be embroiled in politics largely not of our own making; and (c) it wasn't a question of what we personally wanted to say, but of distilling direction and consensus out of a fractured and varied field.

It was also hard because of its public nature. Work like this is eventually very public, but Principles and Standards was public before it began. There was an oversight committee, the Commission on the Future of the Standards. There was the NCTM Board, which had to agree that what we wrote represented the organization. And there were the ARGs, the Association Review Groups—the AMS had one—which responded to formative questions and later provided extensive critiques of the draft.

And, after a first draft was widely distributed in the fall of 1998, there was feedback: about 630 individual responses, scores of organizational responses, and commissioned reviews from a wide range of people, including outspoken critics of the 1989 Standards.

The responses were, of course, conflicting. If one person liked a particular sentence, another person hated it. If one person had a suggestion for change, another person had a different, incompatible suggestion. Making sense of all this took a good computer program and, more important, classification and coding by an intelligent and careful staff. Broad feedback summaries, variously organized, were distributed.

To focus us as we went through this maze, Principles and Standards was put through the National Research Council (NRC) review process, concentrating on our response to nineteen issues drawn, by the Commission, from the feedback. These issues largely were the flashpoint issues of the feedback; they encapsulated areas of concern and contradiction in what we were hearing. These nineteen issues with NRC comments were presented to us before we wrote the final draft, along with representative, generally contradictory, comments from the feedback process. We then had to present the NRC with a plan of response for each issue. And, ultimately, we had to write a final draft.

As we began to absorb the feedback and respond to the NRC, it became clear that not only were we not speaking for our individual selves, we were not even speaking for our writing group or for the constituencies we represented. Our primary job had become to respond to the varied and conflicting opinions we were presented with, to try to understand the deep concerns underlying specific comments, and to try to honor them. It is much easier to give your own opinion than to distill the conflicting opinions of others into comprehensible form.

Would I do it again? Yes, in a heartbeat, and no, not in the same lifetime. I learned an enormous amount about kids, schools, how people learn, and how people teach. I think about school mathematics very differently. I have tremendous respect for my Principles and Standards colleagues and will miss not only our personal collaboration but collaboration with people of their professional interests. It is vital that the mathematics community be involved in this kind of work. It should be seen as a major area of our responsibility, and I am continually astonished that it is not. Our community generally does not reward or honor this sort of time-consuming, challenging, socially important, and intellectually interesting work. Until it does we should not complain that our students come to us unprepared or wonder why so few mathematicians are involved in educational policy.

—Judith Roitman
Associate Editor
Introduction
The nervous system is perpetually active, in waking and sleep, creating its own dynamics as well as reacting to the world around it. Among the dynamics are many periodic rhythms. Some of these are associated with periodic motor behavior, such as walking, chewing, and breathing. Others—the ones I am going to be discussing here—are much more mysterious. They occur in a wide range of frequencies and are associated with mental processing, including sensory activity and cognitive states [1]. These dynamical phenomena raise many mathematical questions, and I shall be focusing on a role for mathematics in the attempt to understand the origin and uses of dynamics in the nervous system.

A previous Gibbs Lecturer, Norbert Wiener, was also intrigued by "brain waves" and wrote about it in his famous book Cybernetics (2nd Edition). At that time, almost forty years ago, the technology for data acquisition and analysis was primitive; it was a breakthrough to be able to make measurements amenable to the use of autocorrelations so as to be able to document the existence of rhythms. Now there are powerful computers and very sophisticated technology for measurements of activity of individual neurons and collections of them. However, the wealth of data acts to underscore the limitations of data gathering alone: in addition to the technology for measurements, there must be a way to understand how the observations fit together and a guide to which kinds of data are most important to gather. It is here that mathematics can play a central role in the part of neuroscience that has to do with dynamics.

The mammalian nervous system is extraordinarily complicated, with interconnected neocortex, hippocampus, thalamus, cerebellum, and other structures, each of which has its own special anatomy and many substructures. The dynamics have different features in different substructures and can be highly localized in time and space. Although the ultimate goal is to understand the interconnections and how they organize mental processing, the current state of the art generally focuses on some small subset of the nervous system and the connections within that subset.

The Mathware
The framework for thinking about electrical activity in the brain was introduced in the 1950s by A. L. Hodgkin and A. F. Huxley and won them a Nobel Prize. A good mathematical introduction to these ideas is in [2]. The general theory that they developed plays a role in neurophysiology similar to the one that the Navier-Stokes equations play in fluid mechanics. The equations for each neuron are based on an analogy with electrical circuit theory. The primary equation is for conservation of charge across the membrane of a cell:

\[ \frac{dv}{dt} = - \sum I_{ion} + D \nabla^2 v - \sum I_{synapse} + I_{appl}. \]
Here $v$ is the voltage difference across the membrane and $I_{\text{ion}}$ denotes an ionic current that passes across the cellular membrane. Each ionic current is like an element in parallel in an electric circuit. Each has its own special “battery”, known as the electrochemical driving force, $v - v_R$, where $v_R$ is the “reversal potential” for that current. Each current also has its own “conductance”, which is the reciprocal of resistance. This conductance comes about because ionic channels in the membranes can open to allow the passage of particular kinds of ions in particular directions.

It is the dependence of the conductances on the voltage (and sometimes on other quantities as well) that adds more equations to the full set of Hodgkin-Huxley equations and makes them so mathematically challenging. The mathematical representation of the conductance usually involves terms describing up to two molecular “gates”, each of which must be open for the current to flow. One of these gates, known as “activation”, generally opens more as the voltage increases. The other, known as “inactivation”, generally closes more as voltage increases. The full conductance is usually represented as a product $\bar{g}m^j h$, where $\bar{g}$ is the maximal conductance; $m$ and $h$, both functions of time, are the fraction of the activation and inactivation gates that are open; and $j$ is a positive integer. (For the classical sodium channel involved in producing spikes, $j = 3$.) Each ionic current is the product of the conductance and the driving force, i.e.,

$$I_{\text{ion}} = \bar{g}m^j h (v - v_R).$$

For each gate there is an auxiliary equation for the kinetics which describes how fast the fraction of open channels changes as membrane voltage changes. The equations for the two kinds of gates have the same form:

$$dx/dt = (x_{\infty}(v) - x)/\tau_x(v),$$

where $x = m$ or $h$ and $x_{\infty}(v) = m_{\infty}(v)$ or $h_{\infty}(v)$. The difference between the two kinds of gates is in the form of the function $x_{\infty}(v)$. For most currents the function $m_{\infty}(v)$ is a monotonically increasing function that saturates for low and high values of $v$, while $h_{\infty}(v)$ is monotone decreasing with $v$. These functions give the asymptotic values of the fraction of channels open for a given value of the voltage if the voltage were to be held forever at that value. The functions $\tau_x(v)$ give the voltage-dependent time constants for the gating. The full Hodgkin-Huxley equations are (1-3). Note that they are a family of equations with many possible currents and many possible parameters rather than a single fixed equation. Depending on the type of neuron, a mathematical representation may use as few as three or as many as a dozen currents, differing in reversal potential, maximal conductance, and gating kinetics. An extremely important feature of these equations is that there is a very large spread of time constants, leading to equations that have many simultaneous time scales.

The above description focuses on the change in voltage due to currents across the membrane. The full equation for $dv/dt$ has extra terms as well. One of these reflects the fact that a neuron need not be concentrated near a spatial point, but may have processes (dendrites and axons) that spread out in space in a pattern that is characteristic of that cell. In such a case the voltage need not be the same throughout the cell, and the equation is a partial differential equation with diffusion across the parts of the cell. The other two terms in (1) reflect influences from the rest of the system to which that cell is connected. $I_{\text{syn}}$ is the current that flows into the cell due to interactions with other cells. Like the intrinsic currents, they can be inward (depolarizing, or pushing the voltage toward the threshold for firing an action potential) or outward (hyperpolarizing, or pushing the voltage away from the threshold); it is the reversal potential of the current that determines whether it is inward or outward. $I_{\text{app}}$ is a current that can be injected by a scientist studying the effects of perturbations.

**Strategy and the Spherical Cow**

Even without the architectural complexity of the entire brain, the dynamical complexity of even a piece of a brain is daunting. Here we get immediately to an issue of strategy: what sets of equations are appropriate to represent the dynamics? As mathematicians, we are drawn to the simplest descriptions that might be relevant. In the case of periodic dynamics, the simplest description is the one for uniform angular motion, namely,

$$\frac{d\theta}{dt} = \omega.$$

A person steeped in the culture of biology is much more likely to look for a representation that describes her reality: since there can be thousands of cells even in a small slice of tissue, and it may take on the order of fifty “compartments” for each cell to capture the spatial voltage differences, and the currents expressed can differ from cell to cell and between compartments, even when these equations are written as ordinary rather than partial, they can form an immensely large system [1].

Both of these approaches have major difficulties. The problem with the first is the analogue of the well-known “spherical cow”: if the cow is not giving milk, its representation as a sphere makes it impossible to address the interesting questions about why that might be. In our case, (4) does not capture enough of the interesting detail to allow us to make relevant distinctions and to answer questions such as why the same group of cells is able to be coherent in multiple frequency ranges and whether the different frequency bands have different dynamical properties. The representa-
tion as “realistic” equations leads to a system that is about as complicated as the original wetware. Even with today’s massive computers, which allow such mega systems to be solved numerically, very few people are able to look at the output and figure out what is going on.

The case studies discussed in this article present an intermediate strategy, one that focuses on the structure of the equations. Once some behavior has been identified in both the experiments and the large-scale simulations, the mathematics serves to clarify the behavior and identify the key dynamical features underlying that behavior. There are three case studies, two of which are short. Together they give some feel for the variety of questions and methods in this area of research. More details about the mathematical issues in these case studies can be found in chapters by N. Kopell and G. B. Ermentrout, and by J. Rubin and D. Terman in [3]. These chapters also contain many further references.

**Synchrony and Cognition**

The rhythms discussed in this section are usually referred to as gamma (30–80 Hz) and beta (12–30 Hz). These rhythms are mysterious and controversial, partly because they are technically difficult to induce and to spot; they can appear for epochs under a second and require appropriate data filtering to see. The stakes in the controversy are high, since some investigators have been marshaling evidence that these rhythms are associated with key cognitive states (attention, perception) as well as with memory. There is also tantalizing new evidence that pathologies in these rhythms are associated with thought disorders such as schizophrenia.

It remains an open question how the brain makes use of these rhythms. The most general, and controversial, idea is that synchrony facilitates coordination between distant parts of the nervous system that need to work together to create a movement or a percept [4]. Though rhythms are not needed to produce synchrony, there are data from P. König and collaborators (1995) that suggest that synchrony across a distance of more than a few millimeters does not happen in the absence of rhythms. An important concrete consequence of synchronous rhythms is plasticity: cells that fire within some window of time of one another are known to be able to increase the strength of the synaptic connections between them. This gives a way to encode the effects of past firing experience in future behavior. Synchronous activity also affects the gating of incoming signals and the strength of the downstream effects.

Though no one is yet sure of the uses of synchronous rhythms in the nervous system, there are many clues suggesting that a further study can provide insights about function. The clues come from the reproducible nature of the circumstances that evoke the rhythms, the spatial locations in which they are found, and the synchronization properties of the different rhythms. For example, the 1989 work by W. Singer and colleagues that led to a huge burst of scientific activity showed that exposing cats to moving bars of light can lead to gamma rhythms in the visual cortex. These rhythms synchronize over a few millimeters of tissue, and the synchronization properties have been reported to be related to the global geometric properties of the stimulus, e.g., whether the stimulus is one bar or two and whether the two bars are moved in the same direction. There is another scientific literature, reviewed in [5], dealing with sensory-motor tasks; here the investigators have mainly found rhythms in the lower-frequency beta range. The rhythms appear in the parts of the cortex expected to be participating in those sensory-motor tasks. The appearance of the rhythms is task dependent: e.g., P. R. Roelfsema and colleagues showed (1997) that at the end of a task, when the animal is rewarded, there was a shift from the beta rhythm to the still lower-frequency alpha rhythm (8–12 Hz).

The synchronization properties of the rhythms appear to be related to the frequency band. For example, in the work of Roelfsema and colleagues, one sees that both gamma and beta rhythms display very precise (within a millisecond or two) synchronization across distances of at least a few millimeters. The alpha rhythm, however, has some coherence but very sloopy synchronization, with changeable phase lags between pairs of sites.

These data raise a number of questions: what determines frequency? That is, why does the same collection of cells sometimes display a 50 Hz rhythm and sometimes an 18 Hz rhythm? Even more fundamental, what causes activity in some subsets of the brain to be, at least temporarily, coherent? Note that the rhythms we are considering here involve self-organization, not the result of outside coordination as by an orchestra conductor, making coherence a puzzle. Are the rhythms associated with distinct frequencies different in structural ways, not just in their time scale? Can the structure of rhythms tell us anything about how synchronization is accomplished across significant distances?

The above questions are very far from straightforward because of the complexity of the underlying equations and the large number of interacting dynamic processes with a large range of time scales. It is not only the properties of the individual cells that can affect the outcome but also the dynamics of the synapses that connect the cells. Thus the objective of the mathematics is to tease out how the biophysics of the cells and synapses work together to create coherent synchronous rhythms. An overview of related experimental
results and large-scale numerical modeling can be found in [1].

Slicing the Problem: Clues from the Hippocampus

To be able to think carefully about the origin of rhythms, it is helpful to slice away at the biological and mathematical complexity. For the biological complexity this is done quite literally by preparing slices of living tissue, usually from a rat; this allows an experimenter to deal with intrinsic dynamics without the confounding input from the rest of the brain. In the context of rhythms, one of the most studied slice preparations is from the hippocampus, believed to be important for the formation of memories.

A slice is still a complicated piece of wetware; it has many substructures and different kinds of cells. For the purpose of this case study, I am focusing on one substructure (the CA1 region) and lumping together the different kinds of cells into “excitatory” (E-cells) and “inhibitory” (I-cells). In general, excitatory cells use a transmitter whose downstream effect is to push cells toward threshold; i.e., make it easier for them to fire. Inhibitory cells use transmitters that have the opposite effect. The signals from these transmitters create currents that are mathematically similar to those in (2), but with the gates dependent on the voltage of the “presynaptic” cell, or cell giving input to the cell in question. Whether the presynaptic cell is inhibitory or excitatory is encoded in the mathematics by the value of the reversal potential of the driving force associated with the synaptic current in the postsynaptic cell.

In 1995 M. A. Whittington and collaborators showed that it is possible to induce a rat hippocampal slice to display a gamma rhythm. The most surprising thing about this work was that the rhythms were obtained when the signals from the excitatory cells were entirely blocked, leaving a network containing only inhibitory cells. This led to a pair of related mysteries: how can inhibition alone lead to synchronization, and why does the rhythm appear in the gamma frequency range? The latter question is especially puzzling, because the inhibitory neurons participating in the rhythm are individually capable of firing at any frequency between 0 and 200+ Hz.

Inhibition-Based Rhythms

An essential clue about the frequency came from pharmacology: it was found that substances applied to the slice that changed the frequency significantly were ones (e.g., barbiturates) known to change the time course of the decay of the inhibition. It is important to mention here that signals that come from synapses are not point events; they have time courses that turn out to be very important in the behavior of the system.

These and related data led various groups to look at networks of inhibitory neurons to try to understand both coherence and frequency. Some of the authors are C. van Vreeswijk, L. Abbott, and G. B. Ermentrout; W. Gerstner, L. van Hemmen, and J. Cowan. Several different mathematical techniques were used; these are described in the chapter by Ermentrout and Kopell in [3]. The ideas can be most easily illustrated by the “spike response method” originated by Gerstner. The cells involved are relatively simple, almost linear between spikes. Thus they are reasonable candidates to be described by one of the simplest reductions of the Hodgkin-Huxley equations, the so-called “integrate and fire” model. These equations, which combine the gating variables with the voltage, have the form

\[
\frac{dv}{dt} = I - g_m(v - v_R) - I_{syn};
\]

the voltage is reset to some specified point when it reaches a specified threshold. The spike-response method works with an integrated version of this or a somewhat more general equation, using kernels to keep track of effects of spikes from a given cell and from the other cells in the network on the voltage of that cell.

From this work and related work it could be seen that spiking cells can form coherent rhythms with signals that are only inhibitory. The mathematics showed that, if the time course of the onset and offset of the inhibitory signal is long enough, inhibition alone can stabilize a synchronous solution. However, this made the mystery of gamma even deeper, since the range of frequencies for which stable synchrony is possible is much broader than the gamma range, even for a fixed, physiologically reasonable inhibitory signal.

The central clue turned out to be a major difference between networks of identical cells and networks in which the cells are heterogeneous, e.g., in drive, modeled by the parameter \( I \) in (5). X.-J. Wang and G. Buzsaki gave simulations to show that the coherence is fragile if there is even mild heterogeneity in the network. J. White, C. Chow, J. Ritt, and I analyzed the breakdown and found that it occurs in different ways in different parameter regimes. Furthermore, those parameter regimes are closely related to control of frequency; in different parts of parameter space, the frequency of the coupled network can be primarily governed by different parameters, including the decay rate of the inhibition, the membrane time constant, or the drive to the cell. The conclusion of the analysis was that coherence is most robust to disruption from heterogeneity when the system is in a parameter regime in which the period of the network is proportional to the time constant for the decay of the inhibition. Since a real slice network that exhibits this interneuron gamma rhythm is very likely to have some heterogeneity, this strongly suggests that one should expect the period to be proportional to the inhibition decay time. This
Figure 1. A simple circuit suitable for investigating synchronization of E- and I-cells.

For the gamma rhythm, each I-cell receives input from both E-cells and the other I-cell. The E-cells get input from the I-cells, but not from the other E-cell (circuit without the dashed line); during the time that the beta rhythm is displayed, there are extra connections between the E-cells (dashed lines).

was verified using data from the lab of J. G. R. Jefferys. So the mathematics was able to reveal where the frequency of the gamma rhythm comes from and that it takes some heterogeneity to see it.

Transition between Two Rhythms
The same piece of tissue may be capable of multiple rhythms, with transitions between them, and the hippocampal slice provides a striking example, as shown by the 1997 work of Whittington and collaborators. If the slice is stimulated, provoking activity in both excitatory and inhibitory cells, it displays a transient gamma rhythm. The more surprising observation is that, at a higher level of stimulation, the rhythm starts off at gamma, undergoes a period of 150-200 ms (milliseconds) of incoherence, and then switches to a slower beta frequency rhythm. Such transitions have been seen using EEGs (electroencephalograms) to measure neural activity in humans and have been recently shown by the group of J. Gruzelier to correlate with the presentation of novel auditory stimuli.

In the slice, where it is possible to make detailed measurements from single cells, it can be seen that the beta rhythm is not just a slower version of the gamma rhythm. Indeed, it is a nested rhythm, with the inhibitory cells continuing to fire at a gamma frequency and the excitatory cells missing cycles. Furthermore, on the whole, they miss the same cycles, so that population averages reveal the slower rhythm.

The most significant thing about the transition of rhythms in the slice is that it has semipermanent traces. After stimulations of intensity high enough to produce the gamma to beta switch, later stimulation that would only have induced the gamma rhythm now is capable of inducing the entire gamma-to-beta sequence. Thus, beta gives a way to read back at a later time that some experience has happened.

The experimental manipulations yielded some evidence of what physiological changes are involved in this transition. One of these concerns is which ionic currents are expressed during each rhythm. Mathematically, this means which terms should be included in \( I_{\text{ion}} \) in (1). Some currents in the excitatory cells that are suppressed by the consequences of the stimulation return and participate during the beta phase. These currents are outward currents that pull the voltage away from the firing threshold and hence tend to slow down those cells. The more surprising and more permanent change is the growth of new functional connections among the cells. These connections are between pairs of excitatory cells and are fostered by the synchrony between those cells during the gamma phase. A much-used phrase, attributed to work of D. O. Hebb, is that “cells that fire together wire together.”

One mathematical question is whether the above changes in ionic currents and synaptic connections are sufficient to produce the transition between the rhythms. This was recently addressed by R. D. Traub, Whittington, Ermentrout, and me. Understanding this required having a working definition of beta; indeed, one critical role of mathematics in science is the creation of idealizations that allows one to conceptualize what is in fact much more messy. In the case of beta, the working definition is that the I-cells synchronize at a gamma rhythm controlled essentially by the inhibition, while the E-cells synchronize at a subharmonic.

The simplest network that embodies this idea and allows one to address how synchrony comes about has two E- and two I-cells (Figure 1). It is easy to see that if the E-cells are unable to fire quickly enough to keep up with the I-cells, each will skip cycles; what is not clear is why the E-cells skip the same cycles and synchronize with one another. The added recurrent excitation (new connections between E-cells) are critical for this, but not in a straightforward way: as Gerstner, van Vreeswijk, and their collaborators have shown, connections between excitatory cells can actively foster antisynchrony or asynchrony between those cells. In this case, the extra excitation comes in a context in which the E-cells have the slow currents described above and the network has inhibition; these factors turn out to change the synchronizing properties of connections between the E-cells.

Long Distance Coordination and Feedback Loops
A central question associated with both beta and gamma rhythms is how synchronization is possible between sites with a conduction delay between
them that is a significant fraction (e.g., 20%-40%) of the period of the cycle. The long-distance coordination can be mimicked in the hippocampal slice by stimulating at two different sites in the slice, separated by a distance yielding a conduction delay of 6-8 ms. In simulations and experiments on stimulation-induced gamma rhythms in the hippocampal slice, Traub and collaborators (1996) noted that there was a strikingly regular structure in the order of the spikes when the two sites synchronized: the I-cells almost always displayed “doublets”, i.e., a pair of spikes in each cycle; any parameter range in the simulations in which those doublets were absent led to nonsynchronous dynamics. The mathematical questions addressed by Ermentrout and me were how the synchronization comes about and what the role of the doublets is in this. There had been earlier (1991) simulations by König and T. B. Schillen showing that synchronization can take place in the presence of conduction delays. However, the models in those simulations used “activity” (essentially firing rate) as a variable instead of voltage; this kind of description is valid when one can average many spikes over a relevant period of time. In the current case, with the E-cells firing at most one spike per cycle, a rate model is not an appropriate description, and a different mathematical representation is needed. As discussed below, it is possible to develop low-dimensional maps (i.e., maps with a low-dimensional domain) that capture the essential parts of the physiology and screen out the rest.

A minimal network for analyzing long-distance connections lumps together all the cells at each site that fire synchronously. Such a network has one E- and one I-cell per site, a total of four cells. Each E-I pair oscillates: a spike from the E-cell induces a spike in the I cell, which inhibits the E-cell. The latter fires again when the inhibition wears off and, in the gamma rhythm, the I-cell waits for this excitation to spike again. The essential long-distance connections are the ones from the E- to I-cells. (Figure 2).

Analyzing networks of spiking cells: treating high-dimensional systems as a collection of low-dimensional maps. The simple four-cell network can be written as Hodgkin-Huxley equations, with extra equations for the synaptic currents. To include the minimal number of currents to get action potentials, plus the slow outward current in the E-cells, plus the equations for the synaptic gating variables requires a system of at least twenty highly nonlinear differential equations. Since it is almost impossible to analyze systems of that size, it is very helpful to find an analytical technique that captures the essence of the high-dimensional model in a faithful enough way that one can ask about effects of biophysical parameters. This cannot be done by reducing the number of cells or equations, since the network and resulting equations already constitute a “minimal” model. The central idea for analyzing stability of a periodic network behavior is to construct a low-dimensional approximation to the Poincaré map, valid only in a neighborhood of a particular periodic trajectory.

The construction starts with a fixed order of the cells firing in the periodic trajectory, allowing some cells to be simultaneous. The neighborhood of allowable initial conditions and allowable parameter ranges is constrained so that the firing order is not changed. In principle the Poincaré map around a periodic trajectory has dimension only one less than that of the system. However, the spread of time scales now enters as a simplifying factor. In the relevant neighborhood of parameters and initial conditions, most of the degrees of freedom of the system do not affect the timing of the spikes in a significant way—in general, they involve processes fast enough to relax away before another slower process determines a spike time. The construction of the map requires identifying the relevant degrees of freedom and ignoring the others. This will be illustrated below. So far it has not been proved that this method gives correct approximations, though predictions of the method have been tested successfully on the minimal biophysical networks and on ones that are large and biologically realistic. The conjecture is that the method works because it corresponds to identification of a center manifold in the dynamics, one containing the periodic trajectory in question.

Synchronization of gamma and beta: different feedback loops. Using the above minimal model (Figure 2), we look in the parameter range in which the first spike in the doublet of each I-cell is induced by excitation from the local E-cell; the second is a consequence of the distant excitation. With more excitable I-cells or stronger synapses, a single pulse of excitation can produce the doublet; however, such a doublet does not help with synchronization for reasons to be seen below.

Figure 2. A simple circuit for investigating synchronization across distances. Each pair of E-I cells is an oscillator, with long connection from each E-cell to the distant I-cell, with signals arriving after a conduction delay.
It turns out that, with these assumptions, there is only one important degree of freedom in the system: the time between the two E-cells on a given cycle. Nevertheless, it requires insight into the full network of Figure 2 to see where in the dynamics the synchronization signal is. The key feature turns out to be a property of many kinds of neurons, including the fast-firing I-cells of this network. Hodgkin-Huxley models of these cells have a property related to what is sometimes known as "relative refractory period". If the cell receives excitation shortly after it has fired, it may wait to fire again, with the delay to firing decreasing with the time between the first firing and the new excitation. In the doublets configuration the first spike in a cycle of the I-cell results from local excitation, and the second from the distant one. Thus the delay in the time to fire the second spike encodes information about the relative phases of the two E-cells, and the decreasing nature of that function turns out to synchronize the E-cells. The delay function, which depends on other inputs to the I-cells as well as on the intrinsic properties of those cells, can be computed numerically from the network. This gives a way to understand conceptually how changes in physiological parameters change the synchronization properties of the network by understanding how they affect the critical synchronization signal. More mathematical details and generalizations are in [6].

The minimal network described above is rigged, both in the architecture and parameter range, so that the doublet configuration is a solution; the mathematics then addresses the issue of stability. However, in a large, distributed network the I-cells can get excitation from many cells at many times, and even the existence of a solution with the doublet configuration is at issue. J. Karbowski and I recently addressed this question in the context of a large lattice of oscillators, with signals arriving at each I-cell from many neighbors at many times. Use of methods like those in statistical physics showed that the doublet configuration is a stable one for a significant parameter range. Furthermore, though there is a parameter range in which other solutions (e.g., one with a triplet configuration) are stable, the doublet configuration is stable over a larger parameter regime. The work suggested that the messiness of a real network might actually be helpful to synchronization: in the model distributed network some disorder in the arrival times of the signals increased the parameter range over which synchrony is stable.

When the local rhythms at the two sites are beat-skipping beta rhythms as described above, there are more dynamical processes that can be called into play to create the synchronization. For the gamma rhythm the essential synchronization signal comes from the timing between the spikes of the doublets. For the beta rhythm the extra time scale associated to the slow outward current creates new nonlinear interactions with the potential to help the synchronization.

In recent work the contrast between the synchronization properties of gamma and beta was investigated by Ermentrout and me. Since the E-cells all synchronize in the idealized version of the beta rhythm as well as the gamma rhythm, the same anatomical network as above (Figure 2) can be used to analyze the long-distance synchronization. Once again the relevant approximation to the Poincaré map is one-dimensional, but the map changes, with the timing information coming from the distant cell interacting nonlinearly with timing information carried by the slow outward current. The result is that the beta rhythm can tolerate significantly longer conduction delays than can gamma and still synchronize robustly. This conclusion was tested by Traub in very large-scale models (as in [1]) and was shown to hold. Current work by S. R. Jones and collaborators is showing that other rhythms with still lower frequency need not be able to synchronize over distances, underscoring the need to look at how detailed biophysical structure—specifically which ionic currents are involved, what kinetics they have—translates into mathematical structure in the associated maps.

Within this framework Ermentrout and I also looked at the role of the long-range connections between the E-cells in the synchronizing process (Figure 3) for the beta rhythm. The analysis and simulations of the biophysically based networks show that these connections are not needed to create stable synchrony and indeed do not much change the dynamical behavior in a neighborhood of that trajectory. However, without those connections there are other stable solutions, and a critical role for the long E-E connections in the beta regime is to make other competing solutions unstable or nonexistent.

These results have implications for differential uses of the gamma and beta rhythms in the nervous system. They are consistent with data from electrophysiology on animals and human EEG recordings, suggesting that coherence in the
The gamma range is used in the nervous system for relatively local processing (e.g., within the primary visual cortex), while the beta range is used for coordination among sites that have a longer conduction delay between them. Relevant data include work of A. von Stein and collaborators and Gruzelier and collaborators. The analysis shows why the ionic currents and network connectivity associated with the beta rhythm have the nonlinear properties appropriate to this behavior and why other rhythms can lack those properties.

**Sleep Rhythms**

We now focus on other parts of the nervous system to discuss rhythms that are associated with different stages of sleep. The thalamus is deep in the brain and has traditionally been considered the gateway between the sensory organs and the neocortex. Unlike the earlier descriptions of the thalamus as a relay station during wakefulness and a wall during sleep, it has been discovered that the thalamus is the origin of many complex dynamical behaviors that are state dependent.

From a mathematical point of view, the study of thalamic rhythms creates new issues, because, at least during sleep rhythms, many of the cells undergo “bursting.” That is, they have a succession of spikes followed by a quiet period. In bursting cells there are more nonlinearities associated with the ionic currents, and the mathematical techniques that work for spiking cells are not in general usable. The major cellular players in the sleep rhythms are thalamocortical cells (TC) that are excitatory and reticular cells (RE) that are inhibitory; both are bursting neurons.

Two of the main rhythms in sleep are known as “spindling” and “delta.” Spindling occurs in early and light sleep and has a population rhythm of 8-14 Hz. J. Rinzel and A. Destexhe have written extensively about models of this rhythm. Delta occurs in deep sleep. It is more regular and has a population rhythm of 1-4 Hz. These rhythms have very different dynamical structures, and the focus of this case study is the insights that mathematics provides in understanding the origins of those structures and the transitions between them.

If we temporarily bracket the physiology and just think about structure, there is a useful way to characterize the main differences between these two rhythms. The delta rhythm corresponds to synchrony of the TC cells, while spindling corresponds to “clustering” of the TC cells. In the latter the population of TC cells breaks down into subsets called clusters. Within a cluster the cells synchronize while the different clusters fire at different phases. In the clustered state the frequency of the population rhythm is several times that of any given cell; it is the frequency of a cell times the number of clusters. In the delta rhythm the TC cells fire on each cycle in a synchronous manner.

**Figure 4. Schematic drawing of a bursting neuron with a set of spikes. If the spikes are removed, the resulting envelope has the shape of a relaxation oscillator.**

In spindling each TC cell fires once per several population cycles, and the population rhythm is higher. Unlike the beta rhythm described above, in the spindling rhythm the excitatory cells miss different cycles, not the same cycle.

The network that produces these two rhythms is anatomically the same. The mathematical question is what kind of change gives rise to a transition between these rhythms or, equivalently, a transition between clustering and synchrony. As in the other case studies in this lecture, the physiology gives clues to the mathematics. In this case the clue is in what is happening to the inhibition on a cycle-by-cycle basis. For spindling it was shown by M. Steriade and his collaborators that the RE cells fire on each cycle. In the delta rhythm the RE cells fire only at the beginning of an episode of this rhythm and then are silent until another episode is induced by excitation from the cortex.

We know from the work in spiking cells that inhibition can be important to synchronization. But it can also be the enemy of synchronization. In the context of bursting cells, one can understand the complexities of inhibition in geometrical ways, especially by methods associated with singularly perturbed systems. Such methods have been developed by many people over the last decade. A recent review is the chapter by Rubin and Terman in [1]. Here I discuss a simple version of some of these ideas to give the flavor of these techniques.

When dealing with bursting neurons, one commonly used simplification is to airbrush out the individual spikes and to work with the envelope of the voltages of the burst. In such an envelope the voltage trace has some slowly changing periods, interspersed with rapid transitions (Figure 4). The geometrical methods used to study these systems exploit the difference in the time scales.

One simple idea that is useful even in large, complicated networks can be seen most easily in two dimensions. It deals with the effects of long-lasting inhibition. In singularly perturbed systems, parts of the trajectory hug the nullsurface (nullcline in two dimensions) of the fast variable. A constant source of inhibition changes the effective phase space by moving the voltage nullclines, which moves the trajectory to a different rest point.
Figure 5. Post-inhibitory rebound. Inhibition lowers the nullcline of the voltage variable. If the inhibition is held long enough, the system goes toward the new stable rest point $P$. When the inhibition is released, the trajectory from the initial condition $P$ moves around the original nullcline before returning to the old rest point.

Figure 6. A schematic diagram showing synchrony and clustering in a network of 4 cells. In A the cells are synchronous; i.e., they fire at the same time. In B there are two clusters of 2 cells each, synchronous within a cluster but not between them. The population frequency of B is twice that of A. (Figure 5). When the inhibition is released, the trajectory makes a long excursion corresponding to a burst before returning to rest. This is known as "post-inhibitory rebound". Now consider many cells, all receiving the same inhibition. They are each pushed to a neighborhood of the same point and, on release, follow nearby trajectories. Estimates, either in phase space or using time-based metrics, show that the trajectories are pulled closer together. Thus, simultaneous release from inhibition can be a synchronizing mechanism.

In some parameter regimes, inhibition need not be synchronizing and can lead to the formation of clusters (Figure 6). Whether there will be synchronization or some other network behavior is a subtle issue depending on interactions of time scales. Geometric methods give a powerful framework for understanding and predicting emergent network behavior, as Terman and Rubin have shown in recent work. These methods help to explain, for example, why fast onset of inhibition works actively to prevent synchrony.

We now use the mathematics to go back to the rhythms in the thalamocortical network. In that neuronal network there are two kinds of inhibition, known as $\text{GABA}_A$ and $\text{GABA}_B$. The first has a fast onset and a short-lived effect; the second has a much longer time to onset and a longer decay time. Insights from the mathematics suggests that a key feature in the transition from spindling to delta rhythms, i.e., clustering to synchrony, is the removal of the fast-onset inhibition, which prevents the synchrony of the TC cells. Indeed, data show that the cells providing the fast inhibition do not participate in the synchronous delta after the initial burst in some episode, while they do take part, cycle by cycle, in the spindling rhythm. How those cells might get functionally removed from the network is discussed in [7]. The role of the mathematics is to indicate what kinds of changes in the network are sufficient to produce the transition. This kind of "functional reorganization", in which networks switch to very different behavior, appears to be widespread in neural dynamics and could be important in pathology. For example, a model by Destexhe with a similar flavor describes the transition from normal thalamic dynamics to certain kinds of seizure activity.

**Dynamics in a Spatially Extended Neuron**

The rhythms associated with cognition and sleep are by no means all the rhythms in the nervous system. The last example comes from a different part of the nervous system and illustrates very different mathematical ideas. The neurons involved in this example, from the subcortical structure called the substantia nigra, provide the neurotransmitter dopamine to other parts of the brain; degeneration of these cells leads to Parkinson's disease.

Unlike many cells in the brain, these cells never appear to be in relay mode, faithfully reporting on their inputs. Instead, they have a set of predetermined patterns in their dynamics. The switches among these patterns are mysterious, but so is the formation of the patterns themselves. For example, a pattern of bursting associated with reward signals has not been replicated by injecting any pattern of electrical signals into the cell body of the neuron in a slice. Some current thinking about the origin of the dynamical patterns focuses on the dendrites, the part of the neuron where most of the inputs arrive. So far in this article I have been talking about cells as if the spatial structure does not matter; in this case the spatial structure may be a critical part of the dynamics.
C. J. Wilson and J. C. Callaway have done experiments using a combination of electrophysiology and imaging of calcium concentrations to help illuminate the origin of the cellular dynamics. They found that pharmacologically isolated cells in a slice can oscillate at 1-2 Hz. Furthermore, there is evidence that there are differences between the cell body and the dendrites in the rates at which calcium goes into and out of the cell. This has led them to a model in which the parts of the cell are treated as separate oscillators, with a gradient in natural (uncoupled) frequency along the dendrite. If we think of the dendrite as broken up into spatial compartments, then a rough mathematical description of a single cell is that of a chain of oscillators with a gradient in frequency. The coupling is electrical rather than via chemical synapses; mathematically, this is written as a discretization of a Laplacian.

Simulations of this model were able to reproduce various experimentally produced dynamical behaviors, including the observation that the frequency slows down over time. The latter phenomenon occurs in many neural systems but is usually associated with special ionic currents such as the slow outward current discussed in connection with the beta rhythm. In this model the description of the local oscillators has no feature that could account for the slowdown. The mathematical issue here is to understand the origin of the slowdown, which is believed by some to be related to the origin of the bursting in vivo.

The simple, biophysically based model belongs to a class of equations of the form

\[
\begin{align*}
\frac{dv_i}{dt} &= f_i(v_i, w_i) + d(v_{i+1} - 2v_i + v_{i-1}) \\
\frac{dw_i}{dt} &= \varepsilon g_i(v_i, w_i).
\end{align*}
\]

Here the uncoupled equations for the \(i\)th compartment describe a relaxation oscillator, with the fast variable \(v_i\) denoting the voltage of that compartment and \(w_i\) the concentration of calcium in the \(i\)th compartment. The uncoupled oscillators have a gradient in frequency along the chain, and \(d\) is much greater than 1.

To get a sense of how the spatial structure of the network affects the transient frequency behavior, G. Medvedev and I recently considered a simple version of equations of this type, namely, the van der Pol equations in Lienard form. He and I discovered that the equations had some unexpected mathematical properties. The coupling between the compartments is very strong, so that the voltages are essentially the same throughout the chain. Nevertheless, because the different compartments in the chain have calcium dynamics with different rates, the \(w_i\) are not the same in the different compartments. The most unexpected outcome was the observation that, for very large electrical coupling \((d > 1)\), the system has an invariant manifold on which it behaves like a perturbed conservative system; in the \(d \to \infty\) limit, the system has a family of periodic solutions, and for \(d < \infty\) there is a drift along the invariant manifold toward a final state (Figure 7), accompanied by a slowly changing frequency, as in the experimental data. Thus the mathematics shows how the strong electrical coupling translates into a Lyapunov function defined on an invariant manifold and how this spatial interaction between the compartments produces the observed frequency modulation. The mathematics also makes the unintuitive prediction that the stronger the coupling, the slower the drift toward the final state.

### What Next?

There are several kinds of challenges I see in trying to understand neural dynamics and their functional importance. The first is to build a vocabulary of examples, in the spirit of the ones I discussed, to try to understand in a clear and conceptual way the mechanisms for producing intrinsic dynamics in parts of the nervous system. This is best done in the context of specific examples, especially since the biology gives generous hints about mathematical structure. The biological structure (time scales of synapses and intrinsic currents, spatial effects, slow modulators, etc.) creates mathematical structure (invariant manifolds, Lyapunov functions, singularly perturbed systems, etc.), which can, in turn, illuminate the biology.

The second challenge is to take the ideas understood in idealized situations and explore...
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whether they work in larger and more realistic but messier circumstances. This may involve statistical and probabilistic notions, a kind of statistical mechanics for neurons. I believe it will be critical for such a theory to respect the structure of the smaller idealized building blocks, not simply mimic the concepts developed for statistical physics. An example in which a simple and rigorous analysis was "scaled up" in this way was given above in the case study on synchronization of the gamma rhythm across distances.

Finally, in a working brain that is listening to a lecture, taking notes, daydreaming, or thinking about the next theorem to be proved, parts of the brain are not isolated from one another and the outside world. A very large challenge is to make use of knowledge about dynamics of parts of the nervous system to understand what role dynamics plays in filtering and processing the inputs from other parts of the brain and the outside world, including inputs that are not periodic. In all of these questions, by exploring the origin and functional implications of dynamics, mathematics can play a significant role in helping us to understand how the brain organizes itself.

References
Geometry of Solitons

Chuu-Lian Terng and Karen Uhlenbeck

A solitary wave is a traveling wave of the form \( u(x,t) = f(x-ct) \) for some smooth function \( f \) that decays rapidly at infinity. It is relatively easy to find nonlinear wave equations that admit solitary wave solutions. For example, 

\[
  u_{tt} - u_{xx} = u(2u^2 - 1)
\]

has a family of solitary wave solutions 

\[
  u(x,t) = \text{sech}(x \cos \theta + t \sinh \theta),
\]

parameterized by \( \theta \in \mathbb{R} \). But we do not expect that the "sum" of two such solutions will again be a solution. However, the special class of soliton equations, the subject of this article, does have a form of nonlinear superposition. An \( n \)-soliton solution is a solution that is asymptotic to a nontrivial sum of \( n \) solitary waves \( \sum_{i=1}^{n} f_i(x-ct_i) \) as \( t \to -\infty \) and to the sum of the same waves \( \sum_{i=1}^{n} f_i(x-ct_i + r_i) \) with some nonzero phase shifts \( r_i \) as \( t \to \infty \). In other words, after nonlinear interaction the individual solitary waves pass through each other, keeping their velocities and shapes but with phase shifts. Equations with multisoliton solutions are very rare (they occur nearly always in one space dimension); these equations are called soliton equations.

The Korteweg-de Vries equation

(KdV) \[
  q_t = -(q_{xxx} + 6qq_x)
\]

is a well-known example of a soliton equation. If \( q(x,t) = f(x-ct) \) solves KdV, then \( f'''' + 6ff'' - cf' = 0 \). The asymptotic condition on \( f \), 

\[
  \lim_{|x| \to \infty} f(x) = 0,
\]

implies that \( f(x) = \frac{c}{2} \text{sech}^2\left( \frac{\sqrt{c}}{2} x \right) \). So

\[
  q(x,t) = \frac{c}{2} \text{sech}^2\left( \frac{\sqrt{c}}{2} (x-ct) \right)
\]

is a family of solitary wave solutions for KdV parameterized by \( c \in \mathbb{R} \).

Figure 1. Wave profile for KdV 1-soliton.

KdV does have multisoliton solutions. In Figure 2 we graphically show the wave profiles of a 2-soliton solution of KdV by showing the graph of \( q_i(x) = q(x,t_i) \) for a sequence of increasing times \( t_i \). The asymptotic behavior and phase shifts can be seen in these pictures.

In classical mechanics a Hamiltonian system in \( 2n \)-dimensions is called integrable if it has \( n \) independent constants of the motion whose Poisson brackets are all zero. The concept of complete integrability can be extended to infinite dimensions or partial differential equations (PDE), but is only one part of the rich structure found in the class of "completely integrable" or "soliton" equations. These equations are best described by their prototypes: KdV, nonlinear Schrödinger, and sine-Gordon equation (SGE). Phenomena that have been identified include:

- multisoliton solutions,
- Hamiltonian formulations,
- a hierarchy of commuting flows described by partial differential equations,
- formulation in terms of a Lax pair of operators,
- a scattering theory,
Figure 2. KdV 2-soliton.

- inverse scattering transforms,
- the Painlevé property,
- an algebraic geometric description of solutions periodic in space variable,
- formal algebraic solutions in terms of loop-group data.

In this article, after giving a little historical background on how soliton equations arose in classical differential geometry, we reinterpret the classical Bäcklund transformations in terms of actions of loop groups, or dressing transformations; we outline how different categories of solutions to the equations come about due to different choices of scattering data; and we finish with two of the most challenging open problems in the area.

A detailed list of references can be found in the Journal of Differential Geometry Survey, volume 4, on integrable systems [9] and in an expository article on solitons by R. Palais [7].

Solitons and the Classical Differential Geometry of Surfaces in $\mathbb{R}^3$

Most expositions of soliton theory outline the history of the Korteweg de Vries (KdV) equation, beginning with the physical observation of S. Russell of a bow wave in a canal in 1834. The equations were first written down by Boussinesq in 1871 and in 1895 by Korteweg and de Vries. In addition to describing water waves, the KdV equation also arises as a universal limit of lattice vibrations as the spacing goes to zero. The surprising numerical experiments of Fermi, Pasta, and Ulam in 1955 on an anharmonic lattice and the ingenious explanation by Zabusky and Kruskal in 1965 in terms of solitons of the KdV equation were quickly followed by a ground-breaking paper of Gardner, Greene, Kruskal, and Miura [3], which introduced the method of solving KdV using the inverse scattering transform for the Hill's operator. This brings us into the modern era. However, there is a separate circle of ideas that originates in geometry.

A central theme in the nineteenth century geometry was the local theory of surfaces in $\mathbb{R}^3$, which we might regard as the prehistory of modern constructions in soliton theory. The SGE arose first through the theory of surfaces of constant Gauss curvature $-1$ in $\mathbb{R}^3$, and the reduced 3-wave equation can be found in Darboux's work on triply orthogonal systems of $\mathbb{R}^3$. In 1906 a student of Levi-Civita, da Rios, wrote a master's thesis in which he modeled the movement of a thin vortex by the motion of a curve propagating in $\mathbb{R}^3$ along its binormal. It was much later, in 1971, that Hasimoto showed the equivalence of this system with the nonlinear Schrödinger equation

$$\frac{q_t}{q_t} = \frac{1}{2} (q_{xx} + 2 |q|^2 q).$$

These equations were rediscovered independently of their geometric history. The main contribution of the classical geometers lies in their methods for constructing explicit solutions of these equations rather than in their discovery of the equations themselves.

A few of the basic ideas from classical geometry of surfaces are needed to describe the geometric problems. Let $M$ be a surface in $\mathbb{R}^3$. The first fundamental form $I$ is the induced metric on tangent planes of $M$, i.e.,

$$I(v, w) = \langle v, w \rangle,$$

the dot product of $v, w$ in $\mathbb{R}^3$. The negative of the unit normal $e_3$ is a map from $M$ to the unit sphere $S^2$ of $\mathbb{R}^3$. Its differential $A$ at a point maps the tangent space at that point to itself and is given by a symmetric map relative to $I$. $A$ is called the shape operator. The second fundamental form is the canonical bilinear form defined by $A$, i.e.,
$H(v, w) = A(v) \cdot w$. If $v$ is a unit tangent vector at $p$, then $H(v, v)$ is the curvature of the plane curve $\sigma$ at $p$, where $\sigma$ is the intersection of $M$ and the plane spanned by $v$ and the normal line at $p$. The principal curvatures of $M$ are the eigenvalues of $H$ with respect to $I$, which is the same thing as the eigenvalues of the shape operator $A$. The mean curvature is the arithmetic mean of the principal curvatures. The Gaussian curvature is the intrinsic curvature of the surface and is given by the product of the principal curvatures.

In regions where the principal curvatures are never equal, it is possible to choose line of curvature coordinates, which are coordinates along the eigendirections of $A$, or the directions of principal curvature. If the Gauss curvature is negative, it is possible to choose a special set of asymptotic coordinates in which the two fundamental forms are

$}\left(\begin{array}{c} E(x,v) \\ F(x,v) \end{array}\right) = \left(\begin{array}{c} x_1(x,v) \\ x_2(x,v) \end{array}\right)$

where $A = \left(\begin{array}{cc} p & P \\ 0 & 0 \end{array}\right)$, $B = \left(\begin{array}{cc} q & Q \\ 0 & 0 \end{array}\right)$ are elements of the Lie algebra of the group of rigid motions of $\mathbb{R}^3$.

The compatibility conditions for the above first-order system for $X$ and $E$ are called the Gauss and Codazzi equations. This is a system of second-order partial differential equations involving six functions (the coefficients of $I$ and $II$). As we will see later, the number of functions involved in the Gauss and Codazzi equations can be reduced by special coordinate choices. The Fundamental Theorem of Surfaces says that two fundamental forms that satisfy the Gauss and Codazzi equations determine a surface in $\mathbb{R}^3$ up to rigid motion.

**Pseudospherical Surfaces and Bäcklund Transformations**

An important contribution of the classical geometer's is the study of pseudospherical surfaces, which led to SGE. A pseudospherical surface is a surface of Gaussian curvature $-1$ in $\mathbb{R}^3$. Such a surface has a special set of asymptotic coordinates in which the two fundamental forms are

$I = dx^2 + \cos q (dx dt + dt dx) + dt^2,$

$II = \sin q (dx dt + dt dx),$

where $q$ is the angle between the $x$ and $t$-curves. With this special choice of coordinates, the Gauss and Codazzi equations boil down to a single equation in $q$

\[(SGE) \quad q_{xt} = \sin q.\]

The Fundamental Theorem of Surfaces gives us a local correspondence between solutions of SGE and surfaces of constant Gaussian curvature $-1$ in $\mathbb{R}^3$ up to rigid motions. Although SGE has many global solutions defined on $\mathbb{R}^2$, the corresponding surfaces always have singularities. In fact, Hilbert proved that there is no complete immersed surface in $\mathbb{R}^3$ with sectional curvature $-1$.

The idea of Bäcklund transformations comes from a construction on pseudospherical surfaces called a line congruence. A line congruence in $\mathbb{R}^3$ is a two-parameter family of lines

$L(u, v) : \quad x(u, v) + t \xi(u, v), \quad -\infty < t < \infty.$

A surface $M$ given by $Y(u, v) = x(u, v) + t(u, v)\xi(u, v)$ for some smooth function $t$ is called a focal surface of the line congruence if the line $L(u, v)$ is tangent to $M$ at $Y(u, v)$ for all $(u, v)$. Hence $\xi(u, v)$ lies in the tangent plane of $M$ at $Y(u, v)$, which is spanned by $x_u + t_u \xi + t_\xi u$ and $x_v + t_v \xi + t_\xi v$. This implies that $t$ satisfies the following quadratic equation:

$\det(\xi, x_u + t_u \xi + t_\xi u, x_v + t_v \xi + t_\xi v) = 0.$

In general, this quadratic equation has two distinct solutions for $t$. Hence generically each line congruence has two focal surfaces, $M$ and $M^*$.

This results in a diffeomorphism $t : M \rightarrow M^*$ such that the line joining $p$ and $p^* = \ell(p)$ is tangent to

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both $M$ and $M^*$. We will call $\ell$ also a line congruence.

A line congruence $\ell : M \to M^*$ is called pseudospherical with constant $\theta$ if the angle between the normal of $M$ at $p$ and the normal of $M^*$ at $p^* = \ell(p)$ is $\theta$ and the distance between $p$ and $p^*$ is $\sin \theta$ for all $p \in M$ (see Figure 3).

In 1883 A. Bäcklund showed that if $\ell$ is a pseudospherical line congruence, then both $M$ and $M^*$ are pseudospherical and $\ell$ maps asymptotic lines to asymptotic lines. However, the transformations come about from showing that this construction can always be realized. For any pseudospherical surface $M$, constant $\theta$, and unit vector $V_0 \in TM_p$, not a principal direction, there exist a unique surface $M^*$ and a pseudospherical congruence $\ell : M \to M^*$ with constant $\theta$ such that $p_0 p_0^{*} = (\sin \theta)V_0$. Analytically this is equivalent to the statement that if $q$ is a solution of SGE, then the following overdetermined system of ordinary differential equations is solvable for $q^*$:

\[
\begin{align*}
q_x^* &= q_x + 4s \sin(\frac{q_{x} - \theta}{2}), \\
q_t^* &= -q_t + \frac{2}{s} \sin(\frac{q_{t} - \theta}{2}),
\end{align*}
\]

where $s = \tan \frac{\theta}{2}$. Moreover, a solution $q^*$ is again a solution of SGE. We will call both $\ell$ and the transform from $q$ to $q^*$ a Bäcklund transformation.

This description of Bäcklund transformations gives us an algorithm for generating families of solutions of the PDE by solving a pair of ordinary differential equations. The procedure can be repeated, but the miracle is that after the first step, the procedure can be carried out algebraically. This is the Bianchi Permutability Theorem. Let $\ell_1 : M_0 \to M_1$ be two pseudospherical congruences with angles $\theta_1$ respectively and with $\sin \theta_1^2 = \sin \theta_2^2$. Then there exist an algebraic construction of a unique surface $M_2$, and pseudospherical congruences $\ell_1 : M_2 \to M_3$ and $\ell_2 : M_1 \to M_3$ with angles $\theta_1$ and $\theta_2$ respectively such that $\ell_2 \ell_1 = \ell_1 \ell_2$. The analytic reformulation of this theorem is the following: Suppose $q$ is a solution of the SGE and $q_1, q_2$ are two solutions of the above system (3) with angles $s_1 = \tan \frac{\theta_1}{2}$ and $s_2 = \tan \frac{\theta_2}{2}$ respectively. The Bianchi Permutability Theorem gives a third local solution $q_3$ to the SGE

\[
\tan \frac{q_3 - q}{4} = \frac{s_1 + s_2}{s_1 - s_2} \tan \frac{q_1 - q_2}{4}.
\]

To see how the scheme works, we start with the trivial solution $q = 0$ of SGE. Then (3) can be solved explicitly to get $q^*(x, t) = 4\tan^{-1}([e^{sx} + 1]^{-1})$, which is the 1-soliton solution of SGE. Application of the Bianchi Permutability Theorem gives the 2-soliton solutions

\[
q(x, t) = 4\tan^{-1}\left(\frac{s_1 + s_2}{s_1 - s_2} \frac{e^{s_1 x + \frac{1}{2} t} - e^{s_2 x + \frac{1}{2} t}}{1 + e^{s_1 x + s_2 t} e^{s_1 x + s_2 t}}\right).
\]

Repeated applications of the theorem give complicated but explicit $n$-soliton solutions. Note that the parameters $s_1, s_2$ in the above formula for 2-solitons are real. But for $s_1 = e^{i\theta}$ and $s_2 = e^{-i\theta}$, although $q_1, q_2$ are not real valued,

\[
q_3(x, t) = 4\tan^{-1}\left(\frac{\sin \theta \sin(T \cos \theta)}{\cos \theta \cosh(X \sin \theta)}\right)
\]

is real and a solution of SGE, where $X = x - t$ and $T = x + t$ are the laboratory coordinates. This solution is periodic in $T$ and is called a breather.

The surface corresponding to $q = 0$ degenerates to a straight line. In Figure 4 we show the wave profile $\frac{\partial q}{\partial X}(x, T)$ of a 1-soliton of SGE and the corresponding surfaces for a sequence of different $s_1$. We show in Figures 5 and 6 wave profiles $\frac{\partial q}{\partial X}(x, T)$ of a 2-soliton and a breather of SGE for a sequence of increasing times $T_i$. Alongside each is the corresponding pseudospherical surface. We use $s_1 = 1$ and $s_2 = 1/\sqrt{3}$ for the 2-soliton, and we use $s_1 = \frac{1}{2}(4 + 3i)$ and $s_2 = -\frac{1}{2}$ for the breather. The time sequence $T_i$ for the breather covers a half period.

**Lie Transformations and Lax Pairs**

A key development in the understanding of soliton theory occurred in 1968 when P. Lax observed that many properties of KdV are explained from an associated linear isospectral problem [4]. This associated linear system has come to be called a “Lax pair”.

If a PDE is given with $q$ as dependent variable, a linear system depending on a parameter

\[
E_x = EA, \quad E_t = EB
\]

in which $A$ and $B$ are $n \times n$ matrix-valued functions of $q$ and $x$-derivatives of $q$ is called a Lax pair of the PDE if the compatibility condition $A_t - B_x = [A, B] = 0$ is the PDE in question. Fix $t$, and let $L(t)$ denote the operator $\frac{\partial}{\partial X} + A$. The compatibility condition can be rewritten as a Lax equation...
This implies that $L(t)$ is conjugate to $L(0)$ for all $t$. In other words, $L(t)$ is isospectral.

A Lax pair for SGE was constructed by M. Ablowitz, D. Kaup, A. Newell, and H. Segur in 1973. We will explain how this Lax pair can be obtained from the classical Lie transformations. Sophus Lie observed that the SGE is invariant under Lorentz transformations. In asymptotic coordinates, which correspond to light cone coordinates, a Lorentz transformation is $(x, t) \rightarrow (\frac{1}{\lambda} x, \lambda t)$. If $q$ is a solution of the SGE, then so is $q^\lambda(x, t) = q(\frac{1}{\lambda} x, \lambda t)$ for any nonzero real constant $\lambda$. Let $M^\lambda$ denote the pseudospherical surface corresponding to $q^\lambda$.

There is a relation between Lie transformations and the modern notion of a Lax pair. Namely, choose for each $\lambda$ a local orthonormal frame $e^1_\lambda, e^2_\lambda, e^3_\lambda$ on $M^\lambda$ such that $e^1_\lambda$ is $\partial_x$ and $e^2_\lambda$ is normal to $M^\lambda$. Let $E^\lambda$ be the $O(3)$-valued map such that $e^1_\lambda, e^2_\lambda, e^3_\lambda$ are the columns, and $\omega^\lambda = (E^\lambda)^{-1} dE^\lambda$ the $so(3)$-valued 1-form. Substitute $(\frac{1}{\lambda} x, 2\lambda t)$ for $(x, t)$ in $\omega^\lambda$ to get a one-parameter family of flat $so(3)$-valued 1-forms. Here a $n \times n$-valued 1-form $w$ is flat if $dw + w \wedge w = 0$. To get the Lax pair of SGE, we need to identify the Lie algebra $so(3)$ with the Lie algebra $su(2)$ of skew Hermitian $2 \times 2$ matrices of trace 0. This allows us to rewrite the family of the flat $so(3)$-connections as a family of flat $su(2)$-valued 1-forms:

$$
\begin{pmatrix}
-i\lambda & -\frac{\partial_x}{2} \\
\frac{\partial_x}{2} & i\lambda
\end{pmatrix} dx + \frac{i}{4\lambda} \begin{pmatrix}
\cos q & -\sin q \\
-\sin q & -\cos q
\end{pmatrix} dt.
$$

Flatness is equivalent to the solvability of the following first-order system for all $\lambda$:

$$
\begin{cases}
E_x = E \begin{pmatrix}
-i\lambda & -\frac{\partial_x}{2} \\
\frac{\partial_x}{2} & i\lambda
\end{pmatrix}, \\
E_t = \frac{i}{4\lambda} E \begin{pmatrix}
\cos q & -\sin q \\
-\sin q & -\cos q
\end{pmatrix}.
\end{cases}
$$

The compatibility condition for this system is exactly that $q_{xt} = \sin q$. System (4) is the Lax pair for the SGE.

**Bäcklund Transformations and Dressing Actions**

Many beautiful transformations constructed by classical geometers play an important role in constructing solutions to various soliton equations. In addition to Bäcklund and Lie transformations, there are Ribaucour, Bianchi, and Darboux transformations. They were natural to the classical geometers, but seem to come from nowhere from the point of view of partial differential equations.

The modern explanation begins with "dressing transformations", which appeared first in an article by Zakharov and Shabat [12]. Bäcklund transformations will be the simplest kind of dressing transformations. Let $E(x, t, \lambda)$ be the solution of (4) satisfying the initial condition $E(0, 0, \lambda) = I$. We will call this $E$ the frame for the solution $q$ (it is also called a wave function). Since the coefficients of system (4) depend holomorphically on the parameter $\lambda \in \mathbb{C}^* \setminus \{0\}$, the solution $E(x, t, \lambda)$ depends holomorphically on $\lambda \in \mathbb{C}^* \setminus \{0\}$.

Let $G$ denote the group of meromorphic maps $f : \mathbb{C} \rightarrow SL(2, \mathbb{C})$ that are regular at $\lambda = 0$ and $\infty$ and satisfy

$$
(\ast) \quad f(\lambda)^* f(\lambda) = I, \quad f(-\lambda) = f(\lambda).
$$

We can factor the product $f(\lambda) E(x, t, \lambda)$ as the product $E(x, t, \lambda) f(x, t, \lambda)$ so that $E(x, t, \lambda)$ is
holomorphic for \( \lambda \in \mathbb{C} \setminus 0 \) and \( \hat{f}(x, t, \cdot) \) is in \( G \). (Note we reverse the order.) A direct computation shows that \( \hat{E} \) satisfies an equation of the form \( (4) \) for some \( \hat{q} \). Hence \( \hat{E} \) is the frame for a new solution \( \hat{q} \) of SGE. The transformation
\[
q \rightarrow f \# q := \hat{q}
\]
defines an action of \( G \) on the space of solutions of SGE and is an example of a dressing transformation.

A meromorphic map \( f \) with a single simple pole is called a simple factor, and the dressing transformation given by a simple factor can be obtained algebraically. Let \( s \) be a nonzero real number, \( V_0 \) a one-dimensional linear subspace of \( \mathbb{R}^2 \), \( \pi_0 \) the orthogonal projection of \( \mathbb{R}^2 \) onto \( V_0 \), and \( \pi_0^\perp = I - \pi_0 \). Then
\[
f_{is, \pi_0}(\lambda) = \pi_0 + \frac{\lambda - is}{\lambda + is} \pi_0^\perp
\]
is a simple factor. Note that \( f_{is, \pi_0}(\lambda)^{-1} = f_{-is, \pi_0}(\lambda) \).

By residue calculus, we see that if we can factor \( f_{is, \pi_0}E \) as \( \hat{E} \), then \( \hat{f}(x, t, \lambda) \) must be of the form \( f_{is, \pi}(x, t) \) for some projection \( \pi(x, t) \). So we need to find \( \pi(x, t) \) such that
\[
\hat{E}(x, t, \lambda) = \left( \pi_0 + \frac{\lambda - is}{\lambda + is} \pi_0^\perp \right)
\times \ E(x, t, \lambda) \left( \pi(x, t) + \frac{\lambda + is}{\lambda - is} \pi^+(x, t) \right)
\]
is holomorphic for \( \lambda \in \mathbb{C} \setminus 0 \). Hence the residue of the right-hand side at \( \pm is \) should be zero. This implies that \( \pi(x, t) \) has to be the projection of \( \mathbb{R}^2 \) onto the subspace
\[
V(x, t) = E(x, t, is)^T(V_0).
\]

Moreover, \( \hat{E} \) turns out to be the frame for a new solution \( \hat{q} \) of the SGE. Set \( A = E^{-1}dE \) and \( \tilde{A} = \hat{E}^{-1}d\hat{E} \). The formula for \( \hat{E} \) implies that
\[
\hat{f}A - df = \tilde{A} \hat{f}.
\]

We obtain the pair of ordinary differential equations \( (3) \) relating \( q \) and \( \hat{q} \) by comparing the residues at \( \lambda = \pm is \).

The Bianchi Permutability Theorem also follows naturally from this point of view. Given nonzero real numbers \( s_1, s_2 \) such that \( s_1^2 \neq s_2^2 \) and two projections \( \pi_1, \pi_2 \) of \( \mathbb{R}^2 \), we can find two projections \( \xi_1, \xi_2 \) and \( g \) such that
\[
g = f_{is_1, \xi_1}f_{is_2, \pi_1} = f_{is_2, \xi_2}f_{is_1, \pi_1}.
\]

Moreover, \( \xi_1, \xi_2 \) can be written algebraically in terms of \( s_1, s_2, \pi_1, \) and \( \pi_2 \) and hence \( g \). By the same reasoning, if \( gE = \hat{E}g \), then \( g \) is algebraic in \( f_1(x, t, \lambda) \) and \( f_2(x, t, \lambda) \). This reinterprets the classical permutability formulas as being the consequence of the noncommutativity of simple factors. Moreover, this procedure works for any
equations with Lax pairs. Hence it gives a general scheme for constructing Bäcklund transformations for any soliton equations. A detailed description of this can be found in [10].

**Types of Solutions**

Given a rapidly decaying function $u$ on the line, consider the first equation of (4) with asymptotic and boundedness conditions:

$$\begin{align*}
\psi_x &= \psi(a\lambda + u), \\
\lim_{x \to -\infty} e^{-a\lambda x} \psi(x, \lambda) &= I, \\
e^{-a\lambda x} \psi(x, \lambda) &\text{ bounded in } x.
\end{align*}$$

(5)

Beals and Coifman showed that this system has a unique solution $\psi^u(x, \lambda)$ and

$$m^u(x, \lambda) = e^{-a\lambda x} \psi^u(x, \lambda)$$

is meromorphic for $\lambda \in \mathbb{C} \setminus \mathbb{R}$, has asymptotic expansion at $\lambda = \infty$, and may have a discontinuity along the real line in the $\lambda$-plane. The singularity data $S^u$ of $m^u$ is the scattering data for $u$, and the map from $u$ to $S^u$ is called the scattering transform. The inverse of this map is the inverse scattering transform. Let $f(\lambda) = m^u(0, \lambda)$, and define

$$E(x, \lambda) = f(\lambda)^{-1} e^{a\lambda x} m^u(x, \lambda) = f(\lambda)^{-1} \psi^u(x, t, \lambda).$$

(6)

Since $\psi^u$ is a solution of $\psi_x = \lambda \psi + u$ and since $E(x, \lambda)$ and $\psi^u(x, \lambda)$ differ by a multiplicative constant matrix $f(\lambda)$,

$$f(\lambda)^{-1} e^{a\lambda x} = E(x, \lambda) m^u(x, \lambda)^{-1}. $$

(7)

This means that we have replaced the inverse scattering transform by a factorization problem. Namely, to obtain $u(x)$ from $f(\lambda)$, we first factor $f(\lambda)^{-1} e^{a\lambda x}$ as a product $E(x, \lambda) m^{-1}(x, \lambda)$ so that $E(x, \lambda)$ is holomorphic for $\lambda \in \mathbb{C} \setminus 0$ and $m(x, \lambda)$ has the same type of singularities as $f(\lambda)$. Then $u = E^{-1} E_x - a\lambda$. Moreover, if $u(x, t)$ is a solution of SGE, then use of the Lax pair shows that the scattering data of $u(\cdot, t)$ can be expressed explicitly in terms of that of $u(\cdot, 0)$. Therefore, the inverse scattering transform can be used to solve Cauchy problems with rapidly decaying initial data. This motivates us to introduce a more general notion of scattering data to include many different classes of solutions other than the rapidly decaying class.

In the language of this article, the goal of scattering theory is to identify from a given solution $q$ an $f$ such that $q = f^{-1} q_0$. In other words, for the frame $E$ of $q$, we wish to solve

$$f(\lambda)^{-1} e^{a(\lambda - \frac{1}{\lambda} t)} = E(x, t, \lambda) \tilde{f}(x, t, \lambda)^{-1}$$

(8)

for some $f$ and $\tilde{f}$ so that $\tilde{f}$ and $\tilde{f}$ have power series expansion at 0 and $\infty$. Here $a = \text{diag}(-i, i)$, and $e^{a(\lambda - \frac{1}{\lambda} t)}$ is the frame for the trivial solution $\frac{1}{\lambda}$. This frame is constructed from the Lax pair in (4), and it is used to transform the solution $q = f^{-1} q_0$ back to the original coordinates.
\( q = 0 \) of SGE. We will call \( f \) scattering data for the solution \( q \).

Inverse scattering theory concerns reconstructing solutions \( q \) from \( f \). There are classical methods in complex variables that in principle accomplish this. For example, Birkhoff factorizations and Riemann-Hilbert problems are two of the techniques. The text by Pressley and Segal [8] and the paper by Beals and Coffman [1] are good basic references.

To make the theory rigorous, it is necessary to identify exactly the class of solutions one wishes to construct. Here are some examples. In the following, we assume \( f \) satisfies condition (*) and is regular at 0 and \( \infty \).

- **Soliton solutions.** Choose \( f \) as a rational map. This is the case of applying Bäcklund transformations repeatedly, starting with the trivial solution.
- **Local analytic solutions.** Choose \( f \) as a local holomorphic map on a neighborhood of 0 and \( \infty \). Solutions obtained from such \( f \) are locally defined analytic functions.
- **Algebraic geometry solutions.** Choose \( f \) as for the local analytic solutions but require that \( f^{-1}(\lambda)q f(\lambda) \) is a finite Laurent polynomial. The factorization can be done by solving a system of ordinary differential equations. This class of solutions includes the so-called "finite-gap" periodic solutions obtained by theta function theory on Riemann surfaces. McKean's article [5] gives an exposition of this type of solution.
- **Formal algebraic solutions.** Choose \( f \) as a pair of formal power series based at 0 and \( \infty \). The factorization can be done formally, and hence many formal solutions can be constructed. Solutions from this class appear in conformal field theory and string theory. Van Moerbeke has a nice set of expository lectures on this [6].
- **Scaling invariant solutions.** Each soliton equation has an action of the multiplicative group \( \mathbb{R}^* \) of nonzero real numbers on the space of solutions. For example, the \( \mathbb{R}^* \)-action for SGE is the Lie transformation, i.e., \( r \cdot q(x, t) = q(rx, \frac{t}{r}) \). A scaling invariant solution is a solution that is invariant under the \( \mathbb{R}^* \)-action. These solutions can be understood by isomonodromy methods. Beals and Sattinger give a good description of this in [2]. Solutions of this type appear in quantum cohomology.
- **Schwartz class (rapidly decaying) solutions.** Here \( f \) is meromorphic with finitely many poles on \( \mathbb{C} \setminus \mathbb{R} \), \( f \) has an asymptotic expansion at \( \lambda = 0 \) and \( \infty \), and the limits \( \lim_{\lambda \to 0} f(r \pm is) \) are smooth functions. Soliton solutions are a subclass of this class.

We have not explained in detail the role of condition \( f(\lambda)^* f(\lambda) = I \), which is a reality condition for both SGE and nonlinear Schrödinger equations. It is a condition associated to the compact group \( SU(2) \). This condition can be dropped or replaced by conditions describing a real form of any complex simple Lie group or one of the symmetric spaces. In general, inverse scattering transforms, \( f \to f \neq 0 \), have singularities unless the scattering data \( f \) are chosen carefully. It is one of our contributions to observe that if the reality conditions contain those associated to a compact Lie group, then the inverse scattering transforms yield solitons and Schwartz class solutions.

### Some Intriguing Open Problems

The recent interest of geometers in integrable systems was initiated by S. S. Chern in the 1970s. Chern and his coworkers were interested in using submanifold geometry to find new examples of soliton equations. Both E. Calabi and Chern had used geometric methods to describe minimal surfaces in spheres. In the early 1980s physicists discovered that 2-dimensional Einstein equations, harmonic maps, and self-dual Yang-Mills all had formulations in terms of Lax pairs. Wente's construction of a counterexample to the Hopf conjecture, an immersed torus in \( \mathbb{R}^3 \) with constant mean curvature, was later observed to be constructible by methods from soliton theory. This has led to several decades of work by both mathematicians and physicists on a new class of problems that can be static (elliptic) or evolution equations, depending on the signature of space-time. We describe two different open problems at this interface.

A map \( s : \mathbb{C} \to SU(n) \) is harmonic if it is a critical point for the energy functional

\[
E(s) = \int_{\mathbb{C}} \text{tr}
(s^{-1} s_x)^2 + (s^{-1} s_y)^2
\, dx \, dy.
\]

The Euler-Lagrange equation written in terms of \( P := \frac{i}{2} s^{-1} \frac{\partial s}{\partial x} \) and \( Q := \frac{i}{2} s^{-1} \frac{\partial s}{\partial y} = -P^* \) is

\[
\frac{\partial P}{\partial z} = \frac{\partial Q}{\partial \bar{z}} = -[P, Q].
\]

K. Pohlmeyer was the first to find the Lax pair for this equation:

\[
E^{-1} E_z = (1 - \lambda) P, \quad E^{-1} E_{\bar{z}} = (1 - \lambda^{-1}) Q.
\]

The first definite progress in understanding this equation was due to the physicists A. Din, V. Glaser, R. Stora, and W. Zakrzewski. Their work was publicized among mathematicians by Eells and his coworkers and led to a good understanding of harmonic maps from \( S^2 \) to \( SU(n) \). Perhaps it is not so surprising that information on the solutions on \( T^2 \) is recovered via the algebraic geometry methods that were developed for periodic solutions for soliton equations. The Gauss map of a constant mean curvature surface in \( \mathbb{R}^3 \) is harmonic, and these methods have been applied to constant mean curvature tori in \( \mathbb{R}^3 \). The recent survey article by N. Hitchin discusses the state of knowledge about...
these geometric problems in [9], as well as the Euclidean monopoles we mention below.

On the other hand, one does not understand the type of scattering data \( f(\lambda) \) that will give a harmonic map from a surface of genus greater than one to \( SU(n) \). To characterize these scattering data, one needs a more complete understanding of periodic solutions than is currently available.

The anti-self-dual Yang-Mills equations in \( \mathbb{R}^4 = \mathbb{C}^2 \) can be described rather simply in terms of their Lax pairs. The equations are for an \( SU(2) \)-connection, which we write in complex coordinates in terms of two \( 2 \times 2 \) traceless complex matrices \( A_2, A_\bar{S} \) and their Hermitian adjoints \( A_\bar{z} = -A_{\bar{z}}^T, A_w = -A_{\bar{w}}^T \). The commutator of two complex operators

\[
D_\lambda = \frac{\partial}{\partial \lambda} + A_w + \lambda \frac{\partial}{\partial \bar{z}} + A_{\bar{z}},
\]

\[
D_\lambda' = \frac{\partial}{\partial \lambda} + A_w + \lambda^{-1} \frac{\partial}{\partial z} + A_z
\]

encode the equation in its Lax pair

\[
[D_\lambda, D_\lambda'] = 0.
\]

The choice of minus sign in \( D_\lambda \) gives the elliptic equation on \( \mathbb{R}^4 \) familiar to mathematicians, while the choice of plus sign gives an equation on \( \mathbb{C}^2 \).

The monopole equations are obtained by letting \( w = t + i u \) and assuming all the fields are independent of \( u \). If the minus sign is used, a monopole equation on \( \mathbb{R}^3 \) is obtained, which has been analyzed in a beautiful sequence of papers by Nahm, Donaldson, and Hitchin. If the plus sign is used, a wave equation on \( \mathbb{R}^{2,1} \) is obtained, and multisoliton solutions have been found by R. Ward and his coworkers. The cover image shows some features of a 3-soliton solution. This is an interesting and natural equation, which is gauge invariant and has both solitons and solutions of the linear wave equation as special solutions. Further investigation of scattering and inverse scattering theory for this equation may lead to some new ideas about integrable systems.

Acknowledgments

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Bibliography


About the Cover

Solitons are usually associated with certain so-called integrable nonlinear wave equations in one space dimension (in particular the Korteweg-de Vries, Sine-Gordon, and nonlinear Schrödinger equations), and for a long time it was not clear whether soliton behavior was possible in higher space dimensions. Indeed, a simple scaling argument (“Derrick’s Theorem”) showed that in more dimensions, wave equations that arise from classical field theories could not have soliton solutions. But Richard Ward’s Modified Chiral Model is a dimension reduction of the self-dual Yang-Mills gauge theory model, and Derrick’s Theorem does not apply. In fact, Ward was able to use twistor methods to prove the existence of soliton solutions of his model, and Christopher Anand devised an algorithm for writing down explicit \( n \)-soliton solutions. The cover picture shows twelve frames of a flipbook animation of an Anand-Ward 3-soliton interaction, and was produced by R. Palais’s 3D-Filmsip visualization program using Pascal routines provided by Anand.

— R. Palais
Harmonic analysis can be interpreted broadly as a general principle that relates geometric objects and spectral objects. The two kinds of objects are sometimes related by explicit formulas, and sometimes simply by parallel theories. This principle runs throughout much of mathematics. The rather impressionistic table at the top of the opposite page provides illustrations from different areas.

The table gives me a pretext to say a word about the Langlands program. In very general terms, the Langlands program can be viewed as a series of far-reaching but quite precise conjectures, which describe relationships among two kinds of spectral objects—motives and automorphic representations—at the end of the table. Wiles's spectacular work on the Shimura-Taniyama-Weil conjecture, which established the proof of Fermat's Last Theorem, can be regarded as confirmation of such a relationship in the case of elliptic curves. In general, the arithmetic information wrapped up in motives comes from solutions of polynomial equations with rational coefficients. It would not seem to be amenable to any sort of classification. The analytic information from automorphic representations, on the other hand, is backed up by the rigid structure of Lie theory. The Langlands program represents a profound organizing scheme for fundamental arithmetic data in terms of highly structured analytic data.

I am going to devote most of this article to a short introduction to the work of Harish-Chandra. I have been motivated by the following three considerations.

(i) Harish-Chandra's monumental contributions to representation theory are the analytic foundation of the Langlands program. For many people, they are the most serious obstacle to being able to work on the many problems that arise from Langlands's conjectures.

(ii) The view of harmonic analysis introduced above, at least insofar as it pertains to group representations, was a cornerstone of Harish-Chandra's philosophy.

(iii) It is more than fifteen years since the death of Harish-Chandra. As the creation of one of the great mathematicians of our time, his work deserves to be much better known.

I shall spend most of the article discussing Harish-Chandra's ultimate solution of what he long regarded as the central problem of representation theory, the Plancherel formula for real groups. I shall then return briefly to the Langlands program, where I shall try to give a sense of the role played by Harish-Chandra's work.

Representations

A representation of a group $G$ is a homomorphism $R : G \rightarrow GL(V)$, where $V = V_R$ is a complex vector space that one often takes to be a Hilbert space. We take for granted the notions of irreducible, unitary, direct sum, and equivalence, all applied to representations of a fixed group $G$. Representations of a finite group $G$ were studied by Frobenius, as a tool for investigating $G$. More recently, it was the representations themselves that became the primary objects of study. From this point of view, there are...
always two general problems to consider, for any given $G$.

1. Classify the set $\Pi(G)$ of equivalence classes of irreducible unitary representations of $G$.

2. If $R$ is some natural unitary representation of $G$, decompose $R$ explicitly into irreducible representations; that is, find a $G$-equivariant isomorphism $V_R = V_{\hat{R}}$, where $V_{\hat{R}} = \mathcal{V}$ is a space built explicitly out of irreducible representations, as a direct sum

$$\bigoplus_{\pi \in \Pi(G)} n_{\pi} V_{\pi}, \quad n_{\pi} \in \{0, 1, 2, \ldots, \infty\},$$

or possibly in some more general fashion.

**Example 1.** $G = \mathbb{R}/\mathbb{Z}$, $V_R = L^2(\mathbb{R}/\mathbb{Z})$, and

$$(R(y)f)(x) = f(x+y), \quad y \in G, f \in V_R.$$

This is the regular representation that underlies classical Fourier analysis. The set $\Pi(G)$ is parametrized by $\mathbb{Z}$ as follows:

$$\pi \in \Pi(G) \iff V_{\pi} = \mathbb{C},$$

$$\pi(y)v = e^{-2\pi iny}v, \quad v \in V_{\pi}, n \in \mathbb{Z}.$$

The space

$$\mathcal{V} = L^2(\mathbb{Z}) = \left\{ c = (c_n) : \Sigma |c_n|^2 < \infty \right\}$$

supports a representation

$$(\hat{R}(y)c)_n = e^{2\pi iny}c_n,$$

of $G$ that is a direct sum of all irreducible representations, each occurring with multiplicity one. The Fourier coefficients

$$f \rightarrow \hat{f}_n = \int_{\mathbb{R}/\mathbb{Z}} f(x)e^{-2\pi inx}dx,$$

then provide an isomorphism from $V$ to $\mathcal{V}$ that makes $R$ equivalent to $\hat{R}$. Moreover, this isomorphism satisfies the Plancherel formula

$$\int_{\mathbb{R}/\mathbb{Z}} |f(x)|^2 dx = \sum_n |\hat{f}_n|^2.$$

**Example 2.** $G = \mathbb{R}$, $V_R = L^2(\mathbb{R})$, and

$$(R(y)f)(x) = f(x+y), \quad y \in G, f \in V_R.$$

In this case $\Pi(G)$ is parametrized by $\mathbb{R}$:

$$\pi \in \Pi(G) \iff V_{\pi} = \mathbb{C},$$

$$\pi(y)v = e^{-iy\lambda}v, \quad v \in V_{\pi}, \lambda \in \mathbb{R}.$$

Here we define $\mathcal{V} = L^2(\mathbb{R})$ and

$$(\hat{R}(y)f)(\lambda) = e^{iy\lambda}f(\lambda), \quad f \in V_R.$$

Then $\mathcal{V}$ is a "continuous direct sum", or direct integral of irreducible representations. The Fourier transform

$$f \rightarrow \hat{f}(\lambda) = \int_{\mathbb{R}} f(x)e^{-i\lambda x}dx, \quad f \in C_c^\infty(\mathbb{R}),$$

extends to an isomorphism from $V$ to $\mathcal{V}$ that satisfies the relevant Plancherel formula

$$\int_{\mathbb{R}} |f(x)|^2 dx = \frac{1}{2\pi} \int_{\mathbb{R}} |\hat{f}(\lambda)|^2 d\lambda.$$

These two examples were the starting point for a general theory of representations of locally compact abelian groups, which was established in the earlier part of the twentieth century. Attention then turned to the study of general nonabelian locally compact groups. Representations of nonabelian groups have the following new features.
Problem of the Plancherel Formula

Against the prevailing opinion of the time, Harish-Chandra realized early in his career that a rich theory would require the study of a more restricted class of nonabelian groups. From the very beginning, he confined his attention to the class of semisimple Lie groups, or slightly more generally, reductive Lie groups. These include the general linear groups $GL(n, \mathbb{R})$, the special orthogonal groups $SO(p, q; \mathbb{R})$, the symplectic groups $Sp(2n, \mathbb{R})$, and the unitary groups $U(p, q; \mathbb{C})$. For the purposes of the present article, the reader can in fact take $G$ to be one of these familiar matrix groups.

Harish-Chandra's long-term goal became that of finding an explicit Plancherel formula for any such $G$. As in the two examples above, one takes $V_{\mathcal{R}} = L^2(G)$, with respect to a fixed Haar measure on $G$. One can then take $R$ to be the 2-sided regular representation

$$(R(y_1, y_2)f)(x) = f(y_1^{-1}xy_2),$$

$y_1, y_2 \in G, f \in V_{\mathcal{R}},$

of $G \times G$ on $V$. The regular representation is special among arbitrary representations in that it already comes with a candidate for an isomorphism with a direct integral. This is provided by the general Fourier transform

$$f \rightarrow \hat{f}(\pi) = \int_G f(x)\pi(x) \, dx, \quad f \in C_c^\infty(G), \pi \in \Pi(G),$$

which is defined on a dense subspace $C_c^\infty(G)$ of $L^2(G)$, and takes values in the vector space of families of operators on the spaces $\{V_{\pi}\}$.

The problem of the Plancherel formula is to compute the measure $d\pi$ on $\Pi(G)$ such that the norm

$$\|f\|_2^2 = \int_G |f(x)|^2 \, dx$$

equals the dual norm

$$\|\hat{f}\|_2^2 = \int_{\Pi(G)} \|\hat{f}(\pi)\|_2^2 \, d\pi,$$

for any function $f \in C_c^\infty(G)$. In the second integrand, $\|\hat{f}(\pi)\|_2$ denotes the Hilbert-Schmidt norm of the operator $\hat{f}(\pi)$. The norm $\|\hat{f}\|_2$ then defines a Hilbert space $\hat{V}$, on which $G \times G$ acts pointwise by left and right translation on the spaces of Hilbert-Schmidt operators on $\{V_{\pi}\}$. The problem was known to be well posed. A general theorem of I. Segal from 1950, together with Harish-Chandra's proof in 1953 that $G$ is of "type I", ensures that the Plancherel measure $d\pi$ exists and is unique.

The point is to calculate $d\pi$ explicitly. This includes the problem of giving a parametrization of $\Pi(G)$, at least up to a set of Plancherel measure zero.

The first person to consider the problem and to make significant progress was I. M. Gelfand. He established Plancherel formulas for a number of matrix groups, and laid foundations for much of the later work in representation theory and automorphic forms. However, some of the most severe difficulties arose in groups that he did not consider. Harish-Chandra worked in the category of general semisimple (or reductive) groups. His eventual proof of the Plancherel formula for these groups was the culmination of twenty-five years of work. It includes many beautiful papers, and many ideas and constructions that are of great importance in their own right. I shall describe, in briefest terms, a few of the main points of Harish-Chandra's overall strategy, as it applies to the example $G = GL(n, \mathbb{R})$.

Geometric Objects

In Harish-Chandra's theory of the Plancherel formula, the geometric objects are parametrized by the regular, semisimple conjugacy classes in $G$. In the example $G = GL(n, \mathbb{R})$ we are considering, these conjugacy classes are the ones that lie in the open dense subset

$$G_{\text{reg}} = \left\{ \gamma \in G : \text{the eigenvalues } \gamma_i \in \mathbb{C} \text{ of } \gamma \text{ are distinct} \right\}$$

of $G$. They are classified by the characteristic polynomial as a disjoint union of orbits

$$\bigsqcup_P \left( T_{P, \text{reg}}/W_P \right),$$

where $P$ ranges over certain partitions

$$\left\{ P = (1, \ldots, 1, 2, \ldots, 2) : r_1 + 2r_2 = n \right\}$$
of \( n \). For a given \( P \),

\[
T_P = \begin{pmatrix} y = \begin{pmatrix} t_1 & \ldots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \ldots & t_{r_1 + r_2} \end{pmatrix} \end{pmatrix},
\]

where \( t_k \) belongs to \( \mathbb{R}^n \) if \( 1 \leq k \leq r_1 \), and is of the form

\[
\begin{pmatrix} \rho_k \cos \theta_k & \rho_k \sin \theta_k \\ -\rho_k \sin \theta_k & \rho_k \cos \theta_k \end{pmatrix}
\]

if \( r_1 + 1 \leq k \leq r_1 + r_2 \), while \( T_{P, \text{reg}} \) stands for the intersection of \( T_P \) with \( G_{\text{reg}} \). The group

\[
W_P = S_{r_1} \times S_{r_2} \times (\mathbb{Z}/2\mathbb{Z})^2,
\]

in which \( S_k \) denotes the symmetric group on \( k \) letters, acts in the obvious way by permutation of the elements \( \{ t_k : 1 \leq k \leq r_1 + r_2 \} \) and by sign changes in the coordinates \( \{ \theta_k : r_1 + 1 \leq k \leq r_1 + r_2 \} \).

The complement of \( G_{\text{reg}} \) in \( G \) has Haar measure 0. By calculating a Jacobian determinant, Harish-Chandra decomposed the restriction of the Haar measure to \( G_{\text{reg}} \) into measures on the coordinates defined by conjugacy classes. The resulting formula is

\[
\int_{G} f(x)dx = \sum_{P} |W_P|^{-1} \int_{T_{P, \text{reg}}} \left( |D(y)| \int_{T_{P \setminus G}} f(x^{-1}yx)dx \right) dy,
\]

for any \( f \in C^\infty_o(G) \). Here \( dy \) is a Haar measure on \( T_P \), and \( T_P \setminus G \) represents the right cosets of \( T_P \) in \( G \), a set that can be identified with the conjugacy class of any \( y \in T_{P, \text{reg}} \). The function

\[
D(y) = \prod_{1 \leq i < j \leq n} (y_i - y_j)^2
\]

is the discriminant of the characteristic polynomial of \( y \). This generalizes the integration formula proved by Weyl in his elegant classification of the irreducible representations of compact Lie groups. We can regard it as a starting point for Harish-Chandra's study of the much more difficult case of noncompact groups.

Motivated by the integration formula, Harish-Chandra introduced a distribution

\[
f_c(y) = |D(y)|^{\frac{1}{2}} \int_{T_{P \setminus G}} f(x^{-1}yx)dx,
\]

for any element \( y \) in \( T_{P, \text{reg}} \). This distribution is now known as Harish-Chandra's \textit{orbital integral}, and is at the heart of much of his work. Harish-Chandra needed to prove many deep theorems about orbital integrals. The questions concern the extension of these linear forms to the Schwartz space \( C(G) \) on \( G \) (which he later defined), and their behavior as \( y \) approaches the singular set in \( T_P \). What is perhaps surprising at first glance is that the problems are not always amenable to direct attack. Harish-Chandra often established concrete inequalities by deep and remarkably indirect methods, that fully exploited the duality between the geometric objects \( f_c(y) \) and their corresponding spectral analogues.

**Spectral Objects**

The \textit{spectral objects} for Harish-Chandra were the characters of representations \( \pi \) in \( \Pi(G) \). Here, he was immediately faced with the problem that the space \( V_{\pi} \) is generally infinite dimensional, in which case the sum determining the trace of the unitary operators \( \pi(x) \) on \( V_{\pi} \) can diverge. His answer was to prove that the average \( \langle f(\pi) \rangle \) of these operators against a function \( f \in C^\infty_o(G) \) is in fact of trace class. He then defined the \textit{character} of \( \pi \) to be the distribution

\[
f_c(\pi) = \text{tr}(\hat{f}(\pi)), \quad f \in C^\infty_o(G).
\]

However, this was by no means sufficient for the purposes he had in mind.

\textit{Differential equations} play a central role in Harish-Chandra's analysis of both characters and orbital integrals. Let \( Z \) be the algebra of differential operators on \( G \) that commute with both left and right translation. One of Harish-Chandra's earliest theorems, for which he won the AMS Cole Prize in 1954, was to describe the structure of \( Z \) as an algebra over \( \mathbb{C} \). Let \( \mathfrak{t}_P \cong \mathbb{C}^n \) be the complexification of the Lie algebra of the Cartan subgroup \( T_P \) of \( G = GL(n, \mathbb{R}) \). By definition there is then a canonical isomorphism \( \partial \) from the symmetric algebra \( S(\mathfrak{t}_P) \) to the algebra of invariant differential operators on \( T_P \).

The following theorem combines several results of Harish-Chandra on differential equations, including the basic structure theorem.

**Theorem.** There is an isomorphism \( z \leftrightarrow h_P(z) \), from \( Z \) onto the subalgebra of elements in \( S(\mathfrak{t}_P) \) that are invariant under the symmetric group \( S_n \), such that

(i) \( (zf)_G(y) = \partial(h_P(z))f_c(y), \quad y \in T_{P, \text{reg}} \).

Moreover,

(ii) \( (zf)_G(\pi) = \langle h_P(z), \lambda_{\pi} \rangle f_c(\pi), \quad \pi \in \Pi(G) \),

for some linear functional \( \lambda_{\pi} \) on \( \mathfrak{t}_P \cong \mathbb{C}^n \) that is unique up to the action of \( S_n \).

The equation (i) can be interpreted in terms of the traditional technique of separation of variables. The relevant differential operators are of course the elements in \( Z \), while the variables of separation are defined by the coordinates of conjugacy classes in \( G_{\text{reg}} \). The equation (ii) is a variant of Schur's lemma, which says that any operator
commuting with the action of a finite group under an irreducible representation is a scalar. The functional \( \lambda_\pi \) comes from the characterization of homomorphisms \( Z \to \mathbb{C} \) that is given by the isomorphism \( z \to h_p(z) \).

Harish-Chandra also used the separation of variables technique to study the distribution on \( G_{\text{reg}} \) obtained by restricting the character of any \( \pi \). It is easy to see that many of the differential operators \( \partial (h_p(z)) \) on a given \( T_P \) are actually elliptic. This allowed him to apply the well known theorem that eigen-distributions of elliptic operators are actually real analytic functions. In this way, he was able to prove that

\[
f_G(\pi) = \int_{G_{\text{reg}}} f(x) \Theta_\pi(x) \, dx, \quad f \in C^\infty_c(G_{\text{reg}}),
\]

for a real analytic function \( \Theta_\pi \) on \( G_{\text{reg}} \). The separation of variables that is part of his argument then implies that for any \( T_P \), the function

\[
\Phi_\pi(y) = |D(y)|^{1/2} \Theta_\pi(y), \quad y \in T_{P,\text{reg}},
\]

satisfies the differential equations

\[
\partial (h_p(z)) \Phi_\pi(y) = \langle h_p(z), \lambda_\pi \rangle \Phi_\pi(y), \quad z \in Z.
\]

Thus, \( \Phi_\pi(y) \) is a simultaneous eigenfunction of a large family of invariant differential operators on the abelian group \( T_P \). From this, it is not hard to deduce, at least in the case that the coordinates of \( \lambda_\pi \) in \( C^\infty \) are distinct, that the restriction of \( \Phi_\pi(y) \) to any connected component of \( T_{P,\text{reg}} \) has a simple formula of the form

\[
\Phi_\pi(y) = \sum_{c \in S_n} \epsilon(c) e^{(\lambda_\pi)(H)}, \quad y = \exp H,
\]

for complex coefficients \( \{\epsilon(c)\} \).

We can see that the differential equations give detailed information about characters. To be able to apply this information to the study of the Plancherel formula, however, Harish-Chandra required the following fundamental theorem.

**Theorem.** The character of any representation \( \pi \in \Pi(G) \) is actually a function on \( G \). In other words, \( \Theta_\pi \) extends to a locally integrable function on \( G \) such that

\[
f_G(\pi) = \int_G f(x) \Theta_\pi(x) \, dx, \quad f \in C^\infty_c(G).
\]

The proof of this theorem required many new ideas, which Harish-Chandra developed over the course of nine years. Atiyah and Schmid later gave a different proof of the theorem, by combining some of Harish-Chandra’s techniques with methods from geometry.

The theorem provides a more concrete formula for the character of \( \pi \). It follows from the original integration formula, and the invariance of \( \Theta_\pi \) under conjugation by \( G \), that

\[
f_G(\pi) = \sum_{P} |W_p|^{-1} \int_{T_{p,\text{reg}}} f_G(y) \Theta_\pi(y) \, dy',
\]

\[
f \in C^\infty_c(G).
\]

This is a particularly vivid illustration of the duality between the geometric objects \( f_G(y) \) and the spectral objects \( f_G(\pi) \). The formula becomes more explicit if we substitute the expansion above for \( \Phi_\pi(y) \). The resulting expression reduces the study of characters to the determination of the linear functionals \( \lambda_\pi \) and the families of coefficients \( \{\epsilon(c)\} \).

**Plancherel Formula and Discrete Series**

We can now state Harish-Chandra’s Plancherel formula (for the group \( G = GL_n(\mathbb{R}) \)) as follows.

**Theorem (Plancherel formula).** For each character \( c \) in the dual group

\[
\hat{T}_P \cong (\mathbb{R} \times \mathbb{Z} / 2\mathbb{Z})^n \times (\mathbb{Z} \times \mathbb{R})^2,
\]

there is an irreducible representation \( \pi_c \) of \( G \) such that

\[
\int_G |f(x)|^2 \, dx = \sum_P |W_p|^{-1} \int_{T_p} \| \hat{f}(\pi_c) \|_2^2 \lambda(c) \, dc,
\]

\[
f \in C^\infty_c(G),
\]

for an explicit real analytic function \( m(c) \) on \( \hat{T}_P \).

**Remarks.**

1. The Plancherel density \( m(c) \) actually vanishes if the image of \( c \) in \( (\mathbb{Z} \times \mathbb{R})^2 \) has any \( \mathbb{Z} \)-component equal to zero. For any such \( c \), the representation \( \pi_c \) is not well defined by the formula, and can be taken to be 0.

2. The linear function \( \lambda_\pi \) attached to \( \pi = \pi_c \) is equal to the differential of \( c \).

3. Harish-Chandra actually stated the theorem in the form of a Fourier inversion formula

\[
f(1) = \sum_P |W_p|^{-1} \int_{T_p} f_G(\pi_c) m(c) \, dc,
\]

\[
f \in C^\infty_c(G).
\]

To recover the Plancherel formula one needs only replace \( f \) by the function

\[
(f * f^*)(x) = \int_G f(y) f(x^{-1}y) \, dy
\]

in the inversion formula. Note the duality with the earlier integration formula, which can be written in the form...
\[ \int_G f(x) \, dx = \sum_p |W_p|^{-1} \int_{T_p, \text{reg}} f_G(y) |D(y)^{1/2}| \, dy, \]
\[ f \in C_c^\infty(G). \]

This short introduction does not begin to convey a sense of the difficulties Harish-Chandra encountered, and was able to overcome. The most famous is the construction of the discrete series, the family of representations \( \pi \in \Pi(G) \) to which the Plancherel measure \( d\tau \) attaches positive mass. We ought to say something about these objects, since they are really at the heart of the Plancherel formula.

It might be helpful first to recall Weyl's classification of representations of compact groups, as it applies to the special case of the unitary group \( G = U(n, \mathbb{C}) \). By elementary linear algebra, any unitary matrix can be diagonalized, so there is only the one Cartan subgroup

\[ T = \left\{ y = \begin{pmatrix} y_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & y_n \end{pmatrix} : |y_i| = 1 \right\} \]

in \( G \) to consider. We can otherwise use notation similar to that of \( GL(n, \mathbb{R}) \). Weyl's classification is provided by a canonical bijection \( \pi \rightarrow \lambda \pi \) between the irreducible representations \( \pi \in \Pi(G) \) and the subset of points \( \lambda = (\lambda_1, \ldots, \lambda_n) \in \mathbb{Z}^n \) such that \( \lambda_i > \lambda_{i+1} \) for each \( i \). This bijection is determined uniquely by a simple formula Weyl established for the value of the character

\[ \Theta_{\pi}(y) = \text{tr}(\pi(y)), \]

at any element \( y \in T_{\text{reg}} \). (Since \( U(n, \mathbb{C}) \) is compact, \( \pi \) is in fact finite dimensional.) The Weyl character formula is the identity

\[ \Theta_{\pi}(y) = \left( D(y)^{1/2} \right)^{-1} \left( \sum_{s \in S_n} \text{sign}(s) y^{s(\lambda)} \right), \]

where for any \( \lambda \in \mathbb{Z}^n \), \( y^{\lambda} \) denotes the product \( y_1^{\lambda_1} \cdots y_n^{\lambda_n} \). (The denominator \( D(y)^{1/2} \) is the canonical square root \( \prod_i (y_i - y_j) \) of the discriminant.

One could easily write the Weyl character formula less elegantly in the framework of the previous section, as a formula for the function \( \Phi_{\pi}(y) = |D(y)^{1/2}| \Theta_{\pi}(y) \) on any connected component of \( T_{\text{reg}} \).

Harish-Chandra's construction of the discrete series is a grand generalization of Weyl's theorem, in both its final statement and its methods of proof. In particular, Harish-Chandra constructed the characters of discrete series representations explicitly, starting from the considerations of the previous section. In the classification he eventually achieved, Harish-Chandra proved that a group \( G \) has a discrete series if and only if it has a Cartan subgroup \( T \) that is compact. Moreover, he specified the representations in the discrete series uniquely by a simple expression for their characters on \( T_{\text{reg}} \) that is a striking generalization of the Weyl character formula.

The group \( GL(n, \mathbb{R}) \) does not have a discrete series. The representations that appear in its Plancherel formula are all constructed from discrete series of \( SL(2, \mathbb{R}) \) and characters of \( \mathbb{R}^* \). (For a given partition \( P \), there are \( r_2 \) copies of \( SL(2, \mathbb{R}) \) to consider; the representations \( \pi_P \) are defined by "parabolic induction" from representations of the subgroup of block diagonal matrices in \( GL(n, \mathbb{R}) \) of type \( P \).)

The example of \( GL(n, \mathbb{R}) \) is therefore relatively simple. Groups that have discrete series, such as \( Sp(2n, \mathbb{R}) \) and \( U(p, q; \mathbb{C}) \), are much more difficult. What is remarkable is that the final statement of the general Plancherel formula, suitably interpreted, is completely parallel to that of \( GL(n, \mathbb{R}) \).

After he established the Plancherel formula for real groups, Harish-Chandra worked almost exclusively on the representation theory of \( p \)-adic groups. This subject is extremely important for the analytic side of the Langlands program, but it has a more arithmetic flavor. Harish-Chandra was able to establish a version of the Plancherel formula for \( p \)-adic groups. However, it is less explicit than his formula for real groups, for the reason that he did not classify the discrete series. The problem of discrete series for general \( G \) is still wide open, in fact, as is much of the theory for \( p \)-adic groups.

**Nature of the Langlands Program**

The analytic side of the Langlands program is concerned with automorphic forms. The language of the general theory of automorphic forms, as opposed to classical modular forms, is that of the representation theory of reductive groups. It is a language created largely by Harish-Chandra. Harish-Chandra's influence on the theory of automorphic forms is pervasive. It is not so much in the actual statement of his Plancherel formula, but rather in the enormously powerful methods and constructions (including the discrete series) that he created in order to establish the Plancherel formula.

The object of interest for automorphic forms is the regular representation \( K \) of \( G \) on the Hilbert space \( V_K = L^2(\Gamma \setminus G) \), where \( \Gamma \) is a congruence subgroup of \( G(Z) \). (We assume that the real reductive...
group $G = G(\mathbb{R})$ has been equipped with structure necessary to define $G(\mathbb{Z})$. As above, one seeks information about the decomposition of $R_\Gamma$ into irreducible representations. In this case, however, there is some interesting extra structure. The space $L^2(\Gamma \backslash G)$ comes with a family of semisimple operators $\{T_{p,i}\}$, the Hecke operators, which are parametrized by a cofinite set $\{p : p \not\in \mathcal{P}_\Gamma\}$ of prime numbers, and a supplementary set of indices $\{i : 1 \leq i \leq n_p\}$ that depends on $p$ and has order bounded by the rank of $G$. These operators commute with $R_\Gamma$ and also with each other. If $\pi \in \Pi(G)$ is a representation that occurs discretely in $R_\Gamma$ with multiplicity $m(\pi)$, the Hecke operators then provide a family

$$\{T_{p,i}(\pi) : p \not\in \mathcal{P}_\Gamma, 1 \leq i \leq n_p\}$$

of mutually commuting $(m(\pi) \times m(\pi))$-matrices. It is the eigenvalues of these matrices that are thought to carry the fundamental arithmetic information.

The most powerful tool available at present for the study of $R_\Gamma$ (and the Hecke operators) is the trace formula. The trace formula plays the role here of the Plancherel formula, and is the analogue of the Poisson summation formula for the discrete subgroup $\mathbb{Z}$ of $\mathbb{R}$. It is an explicit but quite complicated formula for the trace of the restriction of the operator

$$R_\Gamma(f) = \int_G f(\gamma)R_\Gamma(\gamma) \, d\gamma, \quad f \in C_c^\infty(G),$$

and more generally, the composition of $R_\Gamma(f)$ with several Hecke operators, to the subspace of $L^2(\Gamma \backslash G)$ that decomposes discretely. The formula is really an identity of two expansions. One is a sum of terms parametrized by rational conjugacy classes, while the other is a sum of terms parametrized by automorphic representations. The trace formula is thus a clear justification of the last line of our original table. It is also a typical (if elaborate) example of the kind of explicit formula that relates geometric and spectral objects on other lines of the table.

I mention the trace formula mainly to point out its dependence on the work of Harish-Chandra. The geometric side is composed of orbital integrals, together with some more general objects. The spectral side includes the required trace, as well as some supplementary distributions. All of these terms rely in one way or another on the work of Harish-Chandra, for both their construction and their analysis in future applications of the trace formula.

I shall say no more about the trace formula. It is also not possible in the dwindling allotment of space to give any kind of introduction to the Langlands program. I shall instead comment briefly on one specific example of the influence of Harish-Chandra's work—that of the discrete series.

Assume that $G$ does have a compact Cartan subgroup. The Hecke operators $\{T_{p,i}(\pi)\}$ associated to discrete series representations $\pi$ of $G$ are expected to be related to arithmetic objects attached to algebraic varieties. In many cases, it is known how to construct algebraic varieties for which this is so. Let $K$ be a maximal compact subgroup of $G$, and assume that $G$ is such that the space of double cosets

$$S_T = \Gamma \backslash G / K$$

has a complex structure. This is the case, for example, if $G$ equals $Sp(2n, \mathbb{R})$ or $U(p, q; \mathbb{C})$. Then $S_T$ is the set of complex points of an algebraic variety. Moreover, it is known that this variety can be defined in a canonical way over some number field $F$ (equipped with an embedding $F \subset \mathbb{C}$). If $G = SL(2, \mathbb{R})$, $S_T$ is just a quotient of the upper half plane, and as $\Gamma$ varies, the varieties in this case determine the modular elliptic curves of the Shimura-Taniyama-Weil conjecture. The varieties in general were introduced and investigated extensively by Shimura. Their serious study was later taken up by Deligne, Langlands, Kottwitz, and others.

It is a key problem to describe the cohomology $H^*(S_T)$ of the space $S_T$, and more generally, various arithmetic objects associated with this cohomology. The discrete series representations $\pi$ are at the heart of the problem. There is a well defined procedure, based on differential forms, for passing from the subspace of $L^2(\Gamma \backslash G)$ defined by $\pi$ (of multiplicity $m(\pi)$) to a subspace, possibly 0, of $H^*(S_T)$. Different $\pi$ correspond to orthogonal subspaces of $H^*(S_T)$, and as $\pi$ ranges over all representations in the discrete series, these subspaces span the part of the cohomology of $H^*(S_T)$ that is primitive and is concentrated in the middle dimension. Moreover, the Hodge structure on this part of the cohomology can be read off from the parametrization of discrete series. Finally, there has been much progress on the deeper problem of establishing reciprocity laws between the eigenvalues of the Hecke operators $T_{p,i}(\pi)$ and arithmetic data attached to the corresponding subspaces of $H^*(S_T)$. These are serious results, due to Langlands and others, that I have not stated precisely, or even quite correctly. The point is that the results provide answers to fundamental questions.
which could not have been broached without Harish-Chandra's classification of discrete series.

The discussion raises further questions. What about the rest of the cohomology of $S_f$? What about the representations $\pi \in \Pi(G)$ in the complement of the discrete series? Harish-Chandra's Plancherel formula included a classification of the representations that lie in the natural support of the Plancherel measure (up to some questions of reducibility of induced representations, which were later resolved by Knapp and Zuckerman). Such representations are said to be tempered, because their characters are actually tempered distributions on $G$—they extend to continuous linear forms on the Schwartz space of $G$. Tempered representations that lie in the complement of the discrete series are certainly interesting for automorphic forms, but they do not contribute to the cohomology of $S_f$. Nontempered representations, on the other hand, have long been known to play an important role in cohomology. Can one classify the nontempered representations $\pi \in \Pi(G)$ that occur discretely in $L^2(G/G)$?

To motivate the answers, let me go back to the last line of the original table. A conjugacy class in $G(\mathbb{Q})$ has a Jordan decomposition into a semisimple part and a unipotent part. (Recall that an element $x \in GL(n, \mathbb{Q})$ is unipotent if some power of the matrix $x - 1$ equals 0. The Jordan decomposition for $GL(n, \mathbb{Q})$ is given by the elementary divisor decomposition of linear algebra.) Since automorphic representations are dual in some sense to rational conjugacy classes, it is not unreasonable to ask whether they too have some kind of Jordan decomposition.

I can no longer avoid giving at least a provisional definition of an automorphic representation. Assume for simplicity that $G(\mathbb{C})$ is simply connected. In general, one would like an object that combines a representation $\pi \in \Pi(G)$ with any one of the $m(\pi)$ families $\{\lambda_p, i \leq \mu_p\}$ of simultaneous eigenvalues of the Hecke operators. (It is these complex numbers, after all, that are supposed to carry arithmetic information.) It turns out that any such $\pi$ and any such family, as well as some (noncommutative) algebras of operators $\{U_q : q \in \mathcal{P}_G\}$ obtained from the ramified primes, can be packaged neatly together in the form of a representation of the adelic group $G(\mathbb{A})$. Here $\mathbb{A}$ is a certain locally compact ring that contains $\mathbb{R}$, and also the completions $\mathbb{Q}_p$ of $\mathbb{Q}$ with respect to $p$-adic absolute values. The rational field $\mathbb{Q}$ embeds diagonally as a subring of $\mathbb{A}$. Let us define an automorphic representation restrictively as an irreducible representation $\pi$ of $G(\mathbb{A})$ that occurs discretely in the decomposition of $L^2(G(\mathbb{Q}) \backslash G(\mathbb{A}))$.

Any such $\pi$ determines a representation $\pi = \pi_\mathbb{Q}$ in $\Pi(G)$ and a discrete subgroup $\Gamma \subset G$ such that $\pi$ occurs discretely in $L^2(\Gamma \backslash G)$. It also determines irreducible representations $\{\pi_p\}$ of the $p$-adic groups $G(\mathbb{Q}_p)$, from which one can recover the complex numbers $\{\lambda_{p,i}\}$ and the algebras $\{U_q\}$.

An automorphic representation $\pi$ is said to be tempered if its components $\pi_\mathbb{Q}$ and $\pi_p$ are all tempered. I did not give the definition of tempered representations for $p$-adic groups, but it is the same as for real groups. For the unramified primes $p \notin \mathcal{P}_R$, it is equivalent to a certain set of bounds on the absolute values of the complex numbers $\{\lambda_{p,i}\}$. The validity of these bounds for one particular automorphic representation of the group $G = SL(2)$ is equivalent to a famous conjecture of Ramanujan, which was proved by Deligne in 1973.

The conjectures of Langlands include a general parametrization of tempered automorphic representations. In the early 1980s, I gave a conjectural characterization of automorphic representations that are non tempered. Among other things, this characterization describes the failure of a representation $\pi$ to be tempered in terms of a certain unipotent conjugacy class. It is not a conjugacy class in $G(\mathbb{Q})$—such objects are only dual to automorphic representations—but rather in the complex dual group $G$ of $G$. Here $G$ is the identity component of the $L$-group $\mathbb{G} = G \times GL(2)$ that is at the center of Langlands's conjectures. In this way, one can construct a conjectural Jordan decomposition for automorphic representations that is dual to the Jordan decomposition for conjugacy classes in $G(\mathbb{Q})$. The conjectures for nontempered representations contain some character identities for the local components $\pi_\mathbb{R}$ and $\pi_p$ of representations $\pi$ of $G(\mathbb{A})$. They also include a global formula for the multiplicity of $\pi$ in $L^2(G(\mathbb{Q}) \backslash G(\mathbb{A}))$ that implies qualitative properties for the eigenvalues of Hecke operators. The local conjectures for $\pi_\mathbb{Q}$ have been established by Adams, Barbasch, and Vogan, by very interesting methods from intersection

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Robert Langlands

Photograph © 1996 Randell Hog bom, courtesy of the Institute for Advanced Study.
homology. The remaining assertions are open. However, the contribution of nontempered representations to cohomology is quite well understood. The unipotent class that measures the failure of a representation to be tempered turns out to be the same as the unipotent class obtained from the action of a Lefschetz hyperplane section on cohomology. One can in fact read off the Lefschetz structure on $H^*(\mathcal{T})$, as well as the Hodge structure, from the parametrization of representations.

**References**

For a reader who is able to invest the time, the best overall reference for Harish-Chandra's work is still his collected papers.


Harish-Chandra's papers are very carefully written, and are not difficult to follow step by step. On the other hand, they are highly interdependent (even in their notation), and it is sometimes hard to see where they are leading. The excellent technical introduction of Varadarajan goes some way towards easing this difficulty.

Weyl's classification of representations of compact groups is proved concisely (in the special case of $U(n,\mathbb{C})$), in


The following two articles are general introductions to the Langlands program


Other introductory articles on the Langlands program and on the work of Harish-Chandra are contained in the proceedings of the Edinburgh instructional conference


The general axioms for a Shimura variety are summarized in the Deligne's Bourbaki lecture


Finally, the most general conjecture relating motives with automorphic representations is stated at the end of §2 of Langlands's article

The Nonabelian Reciprocity Law for Local Fields

Jonathan Rogawski

This note reports on the Local Langlands Correspondence for $GL_n$ over a $p$-adic field, which was proved by Michael Harris and Richard Taylor in 1998. A second proof was given by Guy Henniart shortly thereafter. The Local Langlands Correspondence is a nonabelian generalization of the reciprocity law of local class field theory. It gives a remarkable relationship between nonabelian Galois groups and infinite-dimensional representation theory. Posed as an open problem thirty years ago in [L1], its proof in full generality represents a milestone in algebraic number theory. The goal of this note, aimed at the nonspecialist, is to state the main result with some motivations and necessary definitions.

Reciprocity Laws

For any positive integer $d$, the law of quadratic reciprocity describes the primes $p$ for which the congruence $x^2 = d \mod p$ has a solution. It implies, quite counterintuitively, that the existence of a solution to this congruence modulo $p$ depends only on the residue class of $p$ modulo $4d$. Despite the large number of different proofs, it remains one of the deepest and most mysterious results of elementary number theory.

The search for generalizations of quadratic reciprocity, beginning with work of Gauss and Eisenstein on cubic and higher reciprocity laws, motivated a great deal of number-theoretic research in the nineteenth century. However, it was not possible to formulate a unified and general reciprocity law until the notion of a reciprocity law itself was reformulated within the context of class field theory. This theory was initiated by Kronecker in the case of quadratic imaginary fields. It was developed into a general framework by Weber and Hilbert in the 1890s and was proven by Furtwangler, Takagi, and Artin in the first quarter of the twentieth century.

In simple terms, class field theory seeks to describe all of the finite abelian extensions of a number field $F$, that is, the finite Galois extensions $K/F$ such that $\text{Gal}(K/F)$ abelian. The theory accomplishes its goal by establishing a deep relation between generalized ideal class groups attached to $F$ and decomposition laws for prime ideals in abelian extensions $K/F$. This theory is elementary in the case $F = \mathbb{Q}$. According to the Kronecker-Weber theorem, every abelian extension of $\mathbb{Q}$ is contained in a cyclotomic extension $\mathbb{Q}(e^{2\pi i/N})$ for some integer $N$. On the other hand, the generalized ideal class groups of $\mathbb{Q}$ are just the multiplicative groups $(\mathbb{Z}/N\mathbb{Z})^*$ and their quotients. Class field theory yields the isomorphism between $(\mathbb{Z}/N\mathbb{Z})^*$ and the Galois group of $K = \mathbb{Q}(e^{2\pi i/N})$ in which a residue class $m \in (\mathbb{Z}/N\mathbb{Z})^*$ maps to the Galois automorphism sending $e^{2\pi im/N}$ to $e^{2\pi in/N}$. Implicit in this isomorphism is the decomposition law: if $p$ is a prime not dividing $N$ and $f$ is the order of $p$ in $(\mathbb{Z}/N\mathbb{Z})^*$, then $(p)$ factors in $K$ as a product of $f$ primes.

Class field theory treats all global fields, i.e., finite extensions of $\mathbb{Q}$ or of the field $\mathbb{F}_q(X)$ of rational functions over a field of $q$ elements. In this exposition, we will discuss only the number field case.

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of the form 

\[ \frac{\mathcal{O}_K}{\mathfrak{P}} \]

distinct prime ideals in the ring of integers in \( K \). Concretely, this means that \( x^N - 1 \) factors modulo \( p \) as a product of \( \frac{\mathcal{O}_K}{\mathfrak{P}} \) distinct irreducible polynomials and, in particular, the number of factors in the factorization modulo \( p \) depends only on \( p \) modulo \( N \). The law of quadratic reciprocity follows from this fact in a natural way.

For an arbitrary number field \( F \), the corresponding assertion is the Artin reciprocity law. It is most clearly stated using "ideels" in place of ideals and a maximal abelian extension \( F_{ab} \) of \( F \) in place of finite abelian extensions. Here we work inside a fixed algebraic closure \( \overline{F} \) of \( F \) and take \( F_{ab} \) to be the union of all finite abelian extensions \( K \) of \( F \). The "idele group" of \( F \) is defined in terms of the inequivalent completions of \( F \), each of which is defined by a "place". Consider first the case \( F = \mathbb{Q} \). The places \( v \) are the primes \( p = 2, 3, 5, \ldots \) and one infinite place \( v = \infty \). The completions relative to these places are the fields \( \mathbb{Q}_p \) of \( p \)-adic numbers for \( v \) finite and \( \mathbb{R} \) for \( v = \infty \). For \( p \) prime let \( \mathbb{Z}_p \) be the ring of \( p \)-adic integers within \( \mathbb{Q}_p \). The adele ring \( \mathbb{A}_\mathbb{Q} \) is the subring of tuples \( (x_v) = (x_2, x_3, x_5, \ldots) \) in the direct product \( \prod_v \mathbb{Q}_v \) (product over all \( v \)) such that \( x_v \) is in \( \mathbb{Z}_v \) for all but at most finitely many places \( v \). The idele group is the group \( \mathbb{A}_\mathbb{Q}^* \) of invertible elements in \( \mathbb{A}_\mathbb{Q} \). Locally compact topologies \([CF]\) may be defined for \( \mathbb{A}_\mathbb{Q} \) and \( \mathbb{A}_\mathbb{Q}^* \) so that \( \mathbb{A}_\mathbb{Q} \) is a topological ring and \( \mathbb{A}_\mathbb{Q}^* \) is a topological group. The definitions are such that the diagonal embedding \( x \mapsto (x, x, x, \ldots) \) identifies \( \mathbb{Q} \) and \( \mathbb{Q}^* \) with discrete subgroups of \( \mathbb{A}_\mathbb{Q} \) and \( \mathbb{A}_\mathbb{Q}^* \), respectively.

For an arbitrary number field, there are finitely many infinite places \( v \), for which \( F_v = \mathbb{R} \) or \( \mathbb{C} \), and infinitely many finite places, for which \( F_v \) is a finite extension of \( \mathbb{Q}_p \) for some prime \( p \). The adele ring \( \mathbb{A}_F \) and idele group \( \mathbb{A}_F^* \) are defined in terms of the localizations \( F_v \) as in the case \( F = \mathbb{Q} \). Again, the respective diagonal embeddings of \( F \) and \( F^* \) have discrete images.

The Artin reciprocity law is a certain continuous, surjective homomorphism

\[ \rho : \mathbb{A}_F^* / F^* \to \text{Gal}(\overline{F}/F) \]

defined explicitly in terms of "Frobenius automorphisms". It is from this explicit definition of \( \rho \) that it is possible (with some work) to deduce fundamental number-theoretic information about \( F \). In the case \( F = \mathbb{Q} \), \( \mathbb{A}_\mathbb{Q}^* / \mathbb{Q}^* \) can be identified with \( \mathbb{R}_+^\times \times \prod_p \mathbb{Z}_p^\times \), and \( \rho \) amounts to the identification of \( \prod_p \mathbb{Z}_p^\times \) with \( \text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \) coming from the construction of \( \mathbb{Q}^ab \) by adjoining all roots of unity. This formulation puts together all of the class field theory isomorphisms for the extensions \( \mathbb{Q}(e^{2\pi i/N}) \) in one package.

The theory just described is called global class field theory because it deals with a number field. Local class field theory is concerned with abelian extensions of a local field \( F \), i.e., a locally compact nondiscrete field. In characteristic zero, the only such fields are \( \mathbb{R} \) and \( \mathbb{C} \), and finite extensions of the field \( \mathbb{Q}_p \). The latter examples are called \( p \)-adic fields. For a local field \( F \), the reciprocity law takes a similar form, with the multiplicative group \( F^* \) taking the place of the idele group. More precisely, the local reciprocity law is a continuous homomorphism

\[ \rho : F^* \to \text{Gal}(\overline{F}/F) \]

As in the global number-field case, the map \( \rho \) provides tangible nontrivial information about the arithmetic object \( \text{Gal}(\overline{F}/F) \) in terms of the elementary object \( F^* \). If \( F \) is \( p \)-adic, \( \rho \) is injective and its image is dense, but it is no longer surjective. In particular, \( \rho \) extends by continuity to an identification of \( \text{Gal}(\overline{F}/F) \) with the profinite completion of \( F^* \), and thus we obtain a simple description of \( \text{Gal}(\overline{F}/F) \). For example, if \( F = \mathbb{Q}_p \), where \( p \) is an odd prime, then \( \mathbb{Q}_p^* \) is isomorphic to \( \mathbb{Z} \times (\mathbb{Z}/p)^* \times \mathbb{Z}_p^\times \) and \( \text{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}_p) \) is isomorphic to \( \mathbb{Z} \times (\mathbb{Z}/p)^* \times \mathbb{Z}_p \), where \( \mathbb{Z} \) is the profinite completion of \( F \). Of course, local class field theory consists of much more than an abstract group isomorphism. See \([S]\) for a list of the properties of \( \rho \) relating the structure of \( F^* \) to the arithmetic of \( F_{ab} \).

Nonabelian Reciprocity

In the second of his Two Lectures on Number Theory, Past and Present (\([W]\), vol. III, p. 301), André Weil summed up as follows the state of affairs in the 1920s and 1930s after the main results of class field theory had been established:

Artin's reciprocity law, which in a sense contains all previously known laws of reciprocity as special cases, deals with a strictly commutative problem. It establishes a relation between the most general extension of a number-field with a commutative Galois group on the one hand, and on the other hand the multiplicative group over that field. Where do we go from there? Well—of course we take up the noncommutative case.

The group \( \text{Gal}(\overline{F}/F) \) is equal to \( \text{Gal}(\overline{F}/F)^{ab} \), i.e., the quotient of \( \text{Gal}(\overline{F}/F) \) by the closure of its commutator subgroup. A noncommutative generalization of Artin's law would, at the least, provide a description of the full Galois group \( \text{Gal}(\overline{F}/F) \) in some way that expresses the decomposition law for primes in finite extensions of \( F \). It was a major obstacle, however, to find the right language for formulating such a law. One gets a sense of the difficulty of the problem from a remark of Weil\(^2\) to

\[ \text{Note } [1971a] \text{ in } [W], \text{ vol. III, p. 457.} \]
the effect that E. Noether, E. Artin, and H. Hasse had hoped in vain that their theory of simple algebras would lead to a nonabelian theory but that by 1947 Artin confided that he was no longer sure that such a theory existed. The breakthrough came out of Langland's discovery in the 1960s of the conjectural “Principle of Functioriality”, which included a formulation of a nonabelian reciprocity law (both global and local) as a special case.

It turns out that in the nonabelian case, a key shift of viewpoint is necessary: one describes the representations of $\text{Gal}(F/F)$ rather than $\text{Gal}(ar{F}/F)$ itself. Thus, the global reciprocity law is formulated as a general conjectural correspondence between Galois representations and automorphic forms. In fact, in the 1960s Serre and Shimura derived nonabelian reciprocity laws of this type using the cohomology of modular curves. However, the Langlands reciprocity law, like Artin’s abelian law, posits a correspondence independent of any particular geometric construction.

The Principle of Functoriality has led more generally to a web of interrelated results and conjectures which together make up the Langlands Program. This program has both a global and local aspect. See [A], [G], [L2], [K], [R] and the references they contain for a general overview of this program and its consequences. The article [D] mentions the relation between the Langlands Program and the modularity of elliptic curves.

The Weil Group

To describe the local nonabelian reciprocity law, we introduce the Weil group $W(F/F)$. Assume that $F$ is a $p$-adic local field, i.e., a finite extension of $\mathbb{Q}_p$ for some prime $p$. Let the ring of integers be $\mathcal{O}_F$. This ring has a unique maximal ideal, necessarily principal, and we let $\pi$ be any generator, a so-called prime element. Denote by $q$ the cardinality of the residue field $k_F = \mathcal{O}_F/\langle \pi \rangle$. One knows that a Galois automorphism $\tau \in \text{Gal}(F/F)$ induces an automorphism $\tau$ of the residue field $k_F$ of $F$, and the map $\tau \mapsto \tau$ from $\text{Gal}(F/F)$ to $\text{Gal}(k_F/k_F)$ is surjective. The Galois group $\text{Gal}(k_F/k_F)$ is isomorphic to $\mathbb{Z}$ and the Weil group $W(F/F)$ is defined as the dense subgroup of Galois automorphisms $\tau$ such that $\tau$ is of the form $x \mapsto x^{q^m}$ for some integer $m$.

The kernel of the map $\tau \mapsto m$ is a closed subgroup of $\text{Gal}(F/F)$ called the inertia subgroup $I_F$ of $F$. An element $\tau$ mapping to $m = 1$ is called a Frobenius automorphism. In any case, we have a (non-canonical) isomorphism $W(F/F) \cong \mathbb{Z} \times I_F$, and we use this to make $W(F/F)$ into a topological group, taking the product of the discrete topology on $\mathbb{Z}$ and relative topology from $\text{Gal}(F/F)$ on $I_F$. With this definition, the restriction $r'$ of the reciprocity map induces an isomorphism of topological groups

$$r' : F^* \rightarrow W(F/F)^{ab}.$$

The Dual Perspective

As mentioned above, the key to the nonabelian reciprocity law is to dualize the reciprocity isomorphism (1). Thus, for $F$ a $p$-adic field, we consider the isomorphism of character groups

$$\sigma_1 : \text{Hom}(F^*, \mathbb{C}^*) \rightarrow \text{Hom}(W(F/F), \mathbb{C}^*)$$

induced by $r'$.

Since the nonabelian generalization of a character is an irreducible representation, it is reasonable to consider the set $G_n$ of equivalence classes of irreducible $n$-dimensional representations of $W(F/F)$ for all $n \geq 1$. Then

$$G_1 = \text{Hom}(W(F/F), \mathbb{C}^*),$$

and so from this point of view, the generalization of (2) would be some map of the form

$$\sigma_n : G_n \rightarrow G_n$$

with target $G_n$. What is much less obvious is the correct source for $\sigma_n$.

It turns out that the source of $\sigma_n$ is the set of equivalence classes of supercuspidal representations of $GL_n(F)$, which are a type of infinite-dimensional representation that we define below. The global version relates irreducible $n$-dimensional representations of the Galois group and cuspidal representations of the group $GL_n(k_F)$. It is more difficult to state precisely [CL], [L1], [R].

In hindsight it is not surprising that the nonabelian theory was not developed until the 1960s. The theory of infinite-dimensional representations of reductive groups was first developed actively in the 1950s, and the $p$-adic case was not studied intensively until the 1960s. The existence of supercuspidal representations for $GL_2$ over a $p$-adic field was apparently first observed by F. Mautner. They were first studied in greater generality in the work of Jacquet and Harish-Chandra.
Admissible Representations

Let $G = GL_n(F)$, and let $(\pi, V)$ be a representation of $G$ on a complex vector space $V$. Since $F$ is a $p$-adic field, $G$ has a family of open compact subgroups $\{K_m\}_{m \geq 1}$, where $K_m$ consists of the integral matrices $g \in G$ such that $g \equiv 1 \mod (\omega^m)$. We say that $(\pi, V)$ is admissible if
- every vector $v \in V$ is fixed by $K_m$ for some $m$, and
- the subspace of vectors fixed by each $K_m$ is finite-dimensional.

From now on $(\pi, V)$ will denote an irreducible admissible representation. We note that to each irreducible unitary representation $(\pi', V')$ there is attached an admissible representation $(\pi, V)$ in a natural way; $V$ is the subspace of vectors $v \in V'$ fixed by $K_m$ for some $m$, and $\pi$ is the restriction of $\pi'$ to $V$. Furthermore, the space $V$ of an irreducible admissible representation is either one-dimensional or infinite-dimensional. Indeed, if $\dim V < \infty$, then $K_m$ is contained in $\ker \pi$ for some $m$, and since $\ker \pi$ is normal, it must contain $SL_n(F)$. The contragredient of $(\pi, V)$ is the representation $\pi^* \otimes V^*$ of $G$ on the admissible dual space $V^*$, that is, the space of linear functionals on $V$ that are fixed by $K_m$ for some $m$. A matrix coefficient of $(\pi, V)$ is a function $f(g) = \langle \pi(g)v, w \rangle$ with $v \in V$ and $w \in V^*$; here $\langle v, w \rangle$ is the bilinear pairing on $V \times V^*$. The representation $\pi$ is called supercuspidal if the support of every matrix coefficient is compact modulo the center $Z$ of $G$.

The Local Langlands Conjecture asserts that for all $n$, there exists a natural bijection
$$\sigma_n : C_n \rightarrow G_n,$$
where $C_n$ is the set of equivalence classes of supercuspidal representations of $G = GL_n(F)$. In the special case $n = 1$, we have $C_1 = \Hom(F^*, \mathbb{C}^*)$. Of course, to give this conjecture some content, we must specify what is meant by "natural". To do so, we exploit the fact it is possible to attach so-called admissible representations $\pi \otimes V$ for every matrix coefficient is compact modulo the center $Z$ of $G$.

The Local Langlands Conjecture asserts that for all $n$, there exists a natural bijection
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$L$ and $\epsilon$ Factors

$L$ factors generalize the individual factors of the Euler product representation of the Riemann zeta function $\zeta(s)$, which is represented for $\Re(s) > 1$ by the Euler product
$$\zeta(s) = \prod_p (1 - p^{-s})^{-1}.$$ 

There are two fundamentally different ways to make the generalization, both of which play a key role in our story. Our goal is to define more general $L$ factors and the closely related $\epsilon$ factors in the local case, but our description will be clearer if we begin with the global case. The global factors arose first historically, and it was an important theoretical step to define their local counterparts. For the moment then $F$ will denote a number field.

First of all, we can follow Hecke and attach an $L$ function $L(s, \chi)$ to each continuous homomorphism $\chi : \mathbb{A}_F^* / F^* \rightarrow \mathbb{C}^*$. Such a homomorphism is called a Hecke character. A Hecke character $\chi$ gives rise, by restriction, to a homomorphism $\chi_v : F_v^* \rightarrow \mathbb{C}^*$ for all places $v$ of $F$, and the Hecke $L$ function of $\chi$ is defined as an infinite product
$$L(s, \chi) = \prod_v L(s, \chi_v)$$
of local factors $L(s, \chi_v)$.

If $v$ is finite, we say that $\chi_v$ is unramified if the restriction of $\chi_v$ to $\mathbb{O}_v^*$ is trivial, where $\mathbb{O}_v^*$ is the group of units in the ring $\mathbb{O}_v$ of integers in $F_v$. If $v$ is a prime element of $\mathbb{O}_v$ and $q_v = \#(\mathbb{O}_v / \mathbb{O}_v)$, a ramified character $\chi_v$ is unramified if $L(s, \chi_v) = 1$. Further, if $v$ is infinite, $L(s, \chi_v)$ is defined in terms of a certain finite product of gamma functions. The continuity of $\chi$ implies that $\chi_v$ is unramified for all but finitely many $v$, and thus $L(s, \chi)$ is an Euler product. The product converges absolutely and uniformly for $\Re(s)$ sufficiently large, and it thus defines an analytic function in a suitable right half plane. The Riemann zeta function is the Hecke $L$ function corresponding to the trivial Hecke character of $\mathbb{A}_Q^* / Q^*$. The Dirichlet $L$ functions that arise in the proof that there are infinitely many primes in arithmetic progressions are also Hecke $L$ functions, apart from a contribution to a finite product arising from the infinite places.

Hecke proved that his $L$ functions $L(s, \chi)$ can be meromorphically continued to the entire complex plane and that they satisfy a global functional equation of the form
$$L(s, \chi) = \epsilon(s, \chi) L(1 - s, \chi^{-1}),$$
where $\epsilon(s, \chi)$ is a factor of the form $A \cdot B^s$ for some constants $A$ and $B$. This generalizes the functional equation of the Riemann zeta function. An important method for proving Hecke's results using Fourier analysis on local fields and adele rings was developed in 1950 by J. Tate in his well-known Ph.D. thesis and also by K. Iwasawa. The great virtue of this method is that it provides a local interpretation of the local factors and, equally important, a factorization of $\epsilon(s, \chi)$ into local $\epsilon$ factors as described below.

What emerges clearly in the work of Langlands and Jacquet-Langlands is that the nonabelian
generalization of a Hecke character is a cuspidal representation \([BK]\), \([CO]\), \([G]\), \([L1]\) of the adelic group \(GL_n(A_F)\) or, more generally, of the adelic points of any reductive group over \(F\). Just as a Hecke character \(\chi\) has local components \(\chi_v\), a cuspidal representation \(\pi\) has local components \(\pi_v\) that are irreducible admissible representations of \(GL_n(F_v)\). In this light, Tate's thesis concerns the case \(n=1\), and one can then ask if there exists a generalization of it to \(n>1\). In the late 1950s and early 1960s the analogous problem for the multiplicative group of a division algebra in place of \(GL_n\) was considered by Godement and Tamagawa. Shimura also considered the quaternion algebra case in connection with the analytic continuation of the zeta-functions attached to arithmetic quotients of the upper half-plane (Shimura curves). A full representation-theoretic treatment of the problem for \(GL_n\) containing, in particular, a detailed local theory was given by Godement and Jacquet.

We shall focus only on the local part of the theory that is relevant to the statement of the Local Langlands Correspondence. Let \(F\) be a \(p\)-adic field. The Godement-Jacquet theory attaches local \(L\) and \(\epsilon\) factors to any irreducible admissible representation \((\pi, V)\) of \(GL_n(F)\) in the following way. One introduces the so-called zeta integrals:

\[
Z(s, f, \Phi) = \int_{GL_n(F)} f(g)\Phi(g)|\text{det}(g)|^s\, dg
\]

where \(dg\) is a Haar measure on \(GL_n(F)\), \(f\) is a matrix coefficient of \(\pi\), and \(\Phi\) is a locally constant function of compact support on the vector space \(M_n(F)\) of \(n\times n\) matrices over \(F\). Although the integral converges for \(\Re(s)\) sufficiently large, it can be shown that \(Z(s, f, \Phi)\) extends to a rational function in \(q^{-s}\). Furthermore, there is a unique zeta integral of the form \(L(s, \pi) = P(q^{-s})^{-1}\), where \(P\) is a polynomial of degree at most \(n\) with \(P(0) = 1\), such that \(Z(s, f, \Phi)/L(s, \pi)\) is entire for all \(\Phi\) and \(f\). Finally, the choice of a nontrivial additive character \(\psi : F \to \mathbb{C}^\times\) plays a role: one proves that for each choice \(\psi\) there is a unique factor \(\epsilon(s, \pi, \psi)\) such that the following local functional equation holds for all \(\Phi\):

\[
Z(s, f, \Phi) = \epsilon(s, \pi, \psi)Z(1-s, \Phi^*) L(1-s, \pi^*)
\]

Here \(\Phi^*(g) = f(g^{-1})\), \(\Phi\) is the Fourier transform of \(\Phi\) relative to the character \(\psi : F \to \mathbb{C}^\times\), and \(\pi^*\) is the contragredient representation of \(\pi\). Furthermore, \(\epsilon(s, \pi, \psi)\) is of the form \(\epsilon q^{as}\), where \(\epsilon\) and \(a\) are constants.

The second generalization of the Riemann zeta function is due to E. Artin, who defined an \(L\) function \(L(s, \rho)\) for any (continuous) finite-dimensional representation of the Galois group

\[
\rho : \text{Gal}(\bar{F}/F) \to GL_n(\mathbb{C})
\]

of a number field \(F\). Every such \(\rho\) factors through \(\text{Gal}(K/F)\) for some finite Galois extension \(K/F\). For each finite place \(v\), the choice of an embedding \(\bar{F} \to \bar{K}\) induces an embedding \(\text{Gal}(\bar{F}_v/F_v) \to \text{Gal}(\bar{F}/F)\), uniquely defined up to conjugation. The pullback \(\rho_v\) of \(\rho\) to \(\text{Gal}(\bar{F}_v/F_v)\) is thus well defined up to equivalence, and we may define a local factor

\[
L(s, \rho_v) = \det(I - q_v^{-s}\rho_v(\Phi)|V^{I_v})^{-1}.
\]

Here \(V^{I_v}\) denotes the subspace of invariants under the inertia subgroup \(I_v\) of \(F_v\), and \(\Phi\) is a Frobenius element. For infinite \(v\) the local factor is a finite product of gamma functions, as in the case of Hecke \(L\) functions. The Artin \(L\) function is defined as an infinite product \(L(s, \rho) = \prod_v L(s, \rho_v)\).

The infinite product defines \(L(s, \rho)\) as a meromorphic function for \(\Re(s) > 1\). R. Brauer proved that \(L(s, \rho)\) extends meromorphically to the complex plane and satisfies a functional equation of the form \(L(s, \rho) = \epsilon(s, \rho)L(1-s, \rho^*)\), where \(\rho^*\) is the contragredient of \(\rho\). The existence of a factorization \(\epsilon(s, \rho)\) as a product of local factors was established by Langlands using local methods (unpublished, but now available on the Web site in footnote 4). Deligne published a shorter proof using global methods. The factorization, which depends on the choice of a nontrivial additive character \(\psi : A_F/F - \mathbb{C}^\times\), has the form \(\epsilon(s, \rho) = \prod_v \epsilon(s, \psi_v, \rho_v)\) in analogy with the factorization provided by the theory of Tate and Godement-Jacquet. The local factor \(\epsilon(s, \psi_v, \rho_v)\) depends only on the restriction \(\psi_v\) of \(\psi\) to \(F_v\) and is characterized by suitable compatibility requirements.

The Local Langlands Correspondence

Once the local factors are known to exist, it is tempting to define the map \(\sigma\) by requiring that \(L(s, \pi) = L(s, \sigma(\pi))\) and \(\epsilon(s, \pi) = \epsilon(s, \sigma(\pi))\) for all supercuspidal \(\pi\). Unfortunately, this does not determine \(\sigma\) uniquely. Henniart proved, however, that \(\sigma\) can be characterized by matching a more general type of local factors. Thus we introduce the final ingredient needed in order to state the correspondence precisely: the local factors attached to pairs. Again let \(F\) be a \(p\)-adic field.

If \(\rho\) and \(\rho'\) are representations of \(\text{Gal}(\bar{F}/F)\) of dimensions \(n\) and \(n'\) respectively, the results quoted in the previous paragraph allow us to attach local factors \(L(s, \rho \circ \rho')\) and \(\epsilon(s, \psi, \rho \circ \rho')\) to the tensor product \(\rho \otimes \rho'\), which is a representation of dimension \(nn'\). The analogue of this construction for admissible representations was carried out by Jacquet, Piatetski-Shapiro, and Shalika. They defined local factors \(L(s, \pi \times \pi')\) and \(\epsilon(s, \psi, \pi \times \pi')\) for any pair \(\pi\) and \(\pi'\) of irreducible admissible representations of \(GL_n(F)\) and \(GL_{n'}(F)\) respectively. These reduce to the Godement-Jacquet
factors when \( \pi' \) is the trivial representation of \( GL_1(F) \).

The center \( Z \) of \( GL_n(F) \) consists of scalar matrices and thus is isomorphic to \( F^* \). If \( \pi \) is an irreducible representation of \( GL_n(F) \), then there is a character \( \omega_\pi \) of \( Z \), called the central character of \( \pi \), such that \( \pi(z) = \omega_\pi(z) \mathbf{1} \) for all \( z \in Z \). We regard \( \omega_\pi \) as a character of \( F^* \).

**Main Theorem.** There exists a unique family of bijections

\[
\sigma_n : C_n \rightarrow \mathcal{G}_n
\]

for \( n \geq 1 \) satisfying the following conditions:

(a) \( \sigma_1 \) is the correspondence (1) of abelian local class field theory.

(b) For all \( \pi \in C_n \) and \( \pi' \in C_n' \), we have

\[
L(s, \pi \times \pi') = L(s, \sigma_n(\pi) \otimes \sigma_n(\pi'))
\]

and

\[
e(s, \pi \times \pi') = e(s, \sigma_n(\pi) \otimes \sigma_n(\pi')).
\]

(c) For all \( \pi, \sigma_\omega(\omega_\pi) = \det(\sigma_n(\pi)).
\]

As mentioned above, the uniqueness assertion had been established earlier by Henniart (1993). The articles [HT] and [H] establish existence in full generality, relying heavily on global results and methods coming from the theory of Shimura varieties and automorphic forms. Prior to that, Harris had proved the local correspondence for \( n \neq p \) and introduced a key technique of “non-Galois automorphic induction” used in both [HT] and [H]. The proof by Henniart is the shorter of the two. However, Harris and Taylor carry out a deep study of certain Shimura varieties at primes of bad reduction, thus generalizing an approach invented by Deligne for the case of modular curves. This represents important progress independent of its application to the local correspondence. Work of Arthur, Berkovich, Carayol, Clozel, Deligne, Drinfeld, Kottwitz, Langlands, and others also plays a fundamental role.

The problem is to define a representation \( \sigma_n(\pi) \) of the Weil group given a supercuspidal representation \( \pi \). The strategy is to embed the local problem in a global one. Roughly speaking, one chooses a suitable number field \( F' \) having \( F \) as one of its localizations and attempts to construct \( \sigma_n(\pi) \) by restricting certain representations of the global Galois group of \( F' \) to the local Weil group \( W(F'/F) \). The global representations are constructed geometrically. In the case \( n = 2 \) and \( F' = Q \), they arise from the theory of modular curves, which yields a correspondence between cuspidal representations of \( GL_2(k_Q) \) of a certain type and irreducible representations of the Galois group of \( Q \) occurring in the \( \ell \)-adic cohomology spaces of the modular curves. Since, as is easily shown, every supercuspidal representation \( \pi \) occurs as the local component of (infinitely many) cuspidal representations of the appropriate type, the modular curves provide natural candidates for \( \sigma_2(\pi) \). The difficulty lies in showing that all of these candidates coincide and satisfy the conditions of the Main Theorem.

One would like to employ the same strategy in the case \( n > 2 \). However, there are no analogues of the modular curves for \( GL_n \) in this case. The way around this, according to a suggestion first made by H. Carayol, is to exploit the fact that the group \( GL_n \) over a \( p \)-adic field can be obtained as the localization at a \( p \)-adic place of certain “twisted” unitary groups over a suitable totally real number field \( F' \). The unitary groups do give rise to a family of “Shimura varieties” that are analogous to the family of modular curves, and one obtains candidates for the representations \( \sigma_n(\pi) \) as in the case \( n = 2 \).

Carrying out this strategy is a difficult task. We refer to [C] for an excellent technical overview of the strategy of the proofs. The articles [C] and [Ku] describe also how the Main Theorem can be extended to a correspondence between the set of equivalence classes of all irreducible admissible representations and the set of finite-dimensional representations of the so-called Weil-Deligne group.

Many cases of the Local Langlands Correspondence had been established previously. We mention only the case \( n = 2 \) which, of course, was handled first. Jacquet and Langlands verified the local correspondence for \( GL_2(F) \) for local fields of residual characteristic different from 2. The case \( n = 2 \) and residual characteristic 2 was settled using local methods in full generality by P. Kutzko in 1980, following work of J. Tunnell, who used global results to treat \( Q \) itself and fields of residual characteristic 2 containing a cube root of unity. We also mention that the full Local Langlands Correspondence for \( GL_n \) over local fields of characteristic \( p \) (fields of Laurent series in one variable over a finite field) was proved by Laumon, Rapoport, and Stuhler in 1991.

Although the Main Theorem establishes an intimate relation between two dissimilar kinds of objects, neither the statement nor its proof provides a direct method for construction of either type of object explicitly. A local approach to the theory of admissible representations of \( GL_n(F) \) has been developed by C. Bushnell and Kutzko. Although this approach does not yet provide a proof of the local correspondence, it does provide important insight into the internal structure of the representations themselves.

As mentioned above, the global reciprocity law is a statement relating Galois representations and cuspidal representations [CL]. It seems out of reach at present in the number-field case. However, for global fields of positive characteristic, Drinfeld established the global correspondence for \( GL_2 \) using his theory of shtukas. In an exciting recent
breakthrough, Laurent Lafforgue succeeded in generalizing Drinfeld's approach and established the "global Langlands correspondence" in full generality for $GL_n$ over a global field of positive characteristic.

References

In the past five years the landscape of federal funding for mathematical sciences research has changed a good deal. While funding from the National Science Foundation (NSF) has steadily increased, there have been steep declines in the research funding agencies of the Department of Defense (DoD). The agencies of the three branches of the armed services used to account for around a third of total federal funding for mathematics; today they account for only about a quarter. The mathematical community has become more active in pressing the government for increases for research. However, such efforts sometimes have little effect on the DoD funding agencies, most of which are embedded in a military bureaucracy that can be hard to influence.

Mathematics Funding at the DoD

The main DoD agencies funding scientific research are aligned with the three branches of the armed forces: the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), and the Office of Naval Research (ONR). The Defense Advanced Research Projects Agency (DARPA), which also funds research in the mathematical sciences, reports directly to the Pentagon rather than to any specific branch of the military. The National Security Agency (NSA) performs much of the mathematical research it needs by hiring its own staff, but it also has a small program of grants to fund outside research, mostly at universities.

The mathematics programs at these agencies all have a common mission, which is to support mathematical sciences research in areas of interest to the DoD. The military designates research as 6.1 (basic research), 6.2 (applied research), and 6.3 (advanced technology development). AFOSR and ARO fund only 6.1 work, while ONR and DARPA fund 6.1, 6.2, and 6.3 work. The NSA does not use this classification, but the 6.1 designation applies to its mathematics grants. Generally the mathematics program officers at the defense agencies act as intermediaries between researchers and the military and have a large role in setting the agenda for what kinds of mathematical sciences research the agencies will fund. For this reason, there is often less reliance on the kind of peer reviewing of proposals one finds, for example, at the NSF and more reliance on the judgment of program officers. In the case of DARPA, proposals are usually refereed only by government employees. The mathematics divisions of the DoD agencies have sometimes been criticized for not doing more peer reviewing of proposals and also for funding the same researchers year after year.

The DoD agencies fund applied mathematics, including such areas as control theory, robotics, dynamics, decision theory, operations research, optimization, discrete mathematics, numerical analysis, probability, and statistics. Signal and image processing, visualization, and computer vision are also important areas. Some of the agencies support parts of analysis that have applications to physical systems in which the military is interested, and all except the NSA support research in computational mathematics and computer science. Because of its interest in cryptography, the NSA concentrates its support in algebra, number theory, discrete mathematics, probability, statistics, and the design and analysis of cryptographic...
systems. Grants from the DoD agencies go primarily to principal investigators at universities and laboratories. There is also some support for conferences, workshops, and a few small centers. In mathematics the DoD grants can be more generous than NSF grants and in some cases provide academic-year salary support.

Why Did the Declines Occur?
When the threat of the Soviet Union disappeared, the entire U.S. military budget shrank, research included. Mathematics research was not singled out for cuts; rather, it took part in the stringent declines felt across the DoD. Overall, the budget of the DoD has declined nearly 30% in constant dollars since the end of the cold war. At the same time, the U.S. military has become more active, and its deployments around the world have increased in number, with the most recent example being the conflict in Kosovo. When these deployments occur, they tend to monopolize the attention of high military officers and to eat into funds intended for other DoD functions. Between 1989 and 1998 DoD funding for research and development declined 23% in constant dollars; in the same period, DoD funding for basic research fell 16% in constant dollars. These declines are less severe than they might have been under the circumstances and in fact seem to indicate a substantial commitment to research on the part of the DoD.

Among the mathematics divisions at the defense agencies, the worst hit was the Mathematical, Computer, and Information Sciences Division at ONR. In fiscal year 1995 its budget for mathematics grants had reached a peak of $21.4 million after several years of increases. By fiscal year 1998 this amount was slashed by nearly one-half, to $11.2 million. At ARO the budget for mathematics within the Mathematical and Computer Sciences Division decreased 26%, from $23.0 million in 1995 to $17.0 million in 1998. The Directorate of Mathematics and Space Sciences at AFOSR fared a little better, as its budget for mathematics rose slightly from $16.4 million in 1994 to $18.0 million in 1998 (though when inflation is taken into account, the increase disappears). One place where the downward trend did not hold is in the Applied and Computational Mathematics Program at DARPA, which has become the DoD leader in funding mathematics; its budget rose from $18.4 million in 1994 to $22.5 million in 1998. Ten years ago DARPA accounted for about 20% of DoD funding for mathematics, and by fiscal 1998 that figure had risen to around 30%. The Mathematical Sciences Program at NSA is quite a bit smaller than the others, hovering around $2 million to $2.5 million for the last several years. The declines at AFOSR,

ARO, and ONR can be contrasted with the growth in the budget for the NSF's Division of Mathematical Sciences, which rose from $78.0 million in 1994 to $93.6 million in 1998.

How did the mathematics divisions in these three agencies deal with the cuts? Inevitably, the process was painful. At ONR, where the cuts ran deepest, the director of the Mathematical, Computer, and Information Sciences Division, Andre van Tilborg, followed the ONR's general policy for handling such decreases, which calls for cutting whole grants rather than shrinking grant size. In addition, he said, "We eliminated entire areas rather than reducing all areas" equally. For example, at one time ONR had a substantial program in discrete mathematics, combinatorics, and graph theory. "We've just about eliminated that program," he said. Figuring out which areas to cut and which to retain was not easy. The decisions were based on judgments about which areas would be of greatest importance to the Navy in a decade or two, said van Tilborg, as well as judgments about which mathematical areas are especially dynamic and innovative. Another factor in the decisions was whether another agency, such as NSF, is funding a particular area. If so, it might be less important that ONR also fund it. Van Tilborg stressed that, as at other agencies, the ONR mathematics budget was not targeted for cuts, but rather decreased in proportion with the decrease in the budget for the agency overall.

At ARO the cuts were spread across all areas. Julian Wu, associate director of the Mathematical and Computer Sciences Division at ARO, said that his division eliminated some grants and reduced the size of others. It also sharpened its focus on grants having the clearest connection to Army needs. For example, ARO can no longer fund theoretical areas of functional analysis, because in the present climate the payoff is less clear and the proposals do not review well among Army scientists. Sometimes the ability of the principal investigator to explain the payoff can be a factor. According to Wu, one well-known mathematician who had an ARO grant was uncomfortable with the additional burden of providing such an explanation and decided to withdraw a renewal proposal. Said Wu ruefully, "When money is tight, we are forced to make these kinds of decisions."

At the AFOSR mathematics several years ago was paired with geosciences when a reduction in senior personnel forced elimination of AFOSR's physics directorate. The Mathematics and Geosciences Directorate, as it was called, has now been renamed the Mathematics and Space Sciences Directorate. Since becoming head of the directorate in October 1998, Clifford E. Rhoades Jr. has had to deal with a 15% budget cut. He decided to eliminate support for a few areas, such as software construction, artificial intelligence, and atmospheric sciences.

\[1\] Budget figures for DARPA come from annual reports on federal funding for mathematical sciences research prepared by the Joint Policy Board for Mathematics.
Cuts to the last of these "drew several expressions of concern," Rhoades said, "particularly with respect to lightning strikes on shuttle launches at Cape Canaveral, where the Air Force retains responsibility for range safety" (to meet this concern, he retained some research on lightning strikes). The reductions in those three areas accounted for about one-half to three-quarters of the necessary cuts. The rest were distributed uniformly across the other areas the directorate supports, in a difficult exercise of determining which grants were most valuable to the Air Force. Although the mathematics divisions at all three agencies have tried to shrink their grants as much as possible, none seems to have instituted blanket measures such as decreeing, say, that all principal investigators get one month of summer support rather than two.

Overall the budget cuts have meant that the mathematics divisions at these agencies have had to focus yet more narrowly on funding research that is of clear and immediate military usefulness. The cuts have reverberated across all of applied mathematics, included among the hardest hit areas are control theory and numerical analysis. Some investigators who have been cut turned to interdisciplinary collaborations, particularly with researchers in areas that have won funding increases in the last few years, such as materials science and biology. Many have also tried to migrate to the NSF, and this has increased pressure on the NSF's Division of Mathematical Sciences, particularly its programs in applied mathematics and computational mathematics.

The Difference at DARPA

One of the reasons mathematics fared better at DARPA than at the service-branch agencies has to do with the way DARPA operates. Rather than being given a set budget, DARPA program managers come up with a collection of projects they would like to support and then compete against each other for funds for the projects. The budget for a given program therefore depends greatly on the effectiveness of its program managers. Many credit Anna Tsao, who was a manager for DARPA's Applied and Computational Mathematics Program from 1994 until 1998, with working well in the DARPA environment to improve funding for mathematics. Also contributing to this effort is Dennis Healy, who has served as a manager in this program since 1996 (at the time of this writing, DARPA was still searching for a replacement for Tsao). One of the program's achievements was an unprecedented collaboration between DARPA and the NSF's Division of Mathematical Sciences to support interdisciplinary research in materials science.

A perennial difficulty for the DoD research agencies is the possibility that their budgets will be "swept". When the U.S. enters into a military conflict and the DoD needs money immediately, any unobligated funds in the research agencies can be "swept" out of the agencies and put toward supporting U.S. activities in the conflict. Sometimes funds that have already been awarded in a research grant but have not yet been spent by the grantee are vacuumed up. Other forms of "budget raiding" can be a problem in the service-branch agencies, though DARPA is less susceptible because it is not embedded in the kind of bureaucracy one finds in the three branches of the military. Big-ticket military hardware can also siphon funds from DoD research. During budget negotiations for fiscal year 2000 there were battles over the F-22 fighter plane, which many feared could endanger increases for DoD research. At the time of this writing the question of whether the F-22 would be funded in fiscal 2000 was still unresolved.

The budgets for AFOSR, ARO, and ONR are buried within the much larger budgets of the military branches they serve. "When military people make their budgets, research is an afterthought," explained Samuel M. Rankin III, director of the AMS Washington Office. "These people think about troops and materiel, not research, even though they are the recipients of that research when they go to war." There are people within the military who serve as advocates for increased funding for research, Rankin said, but the part of the budget with which they are concerned is relatively small, so they lack influence. The situation is not much better in Congress. What looms large in the mind of a member of Congress concerned with DoD budgets are things like whether a base in his or her home district is going to be closed. There is much more "pork barrel" politics and protectionism surrounding DoD funding than there is surrounding funding for, say, the NSF. "For members of Congress on the Defense Appropriations Committee," Rankin observed, "their sense of what the appropriation is for is very different from those overseeing the NSF."

In efforts to increase funding for the DoD research agencies, Congress is an important pressure point. But, according to van Tilborg, it is not the only one. In the case of ONR, for example, "you have to convince the Navy management to put more money into science," he said. He contrasted this situation with that of the NSF, which is an independent agency with no department between it and the Congress. Therefore, if one wants to influence the NSF budget, one goes directly to the relevant congressional committees. But with ONR, van Tilborg maintained, "we need the support of the management chain inside the Navy to get any budget increases." Understanding and influencing this bureaucracy is no easy task. Mathematics might have an especially hard time getting a hearing, van Tilborg predicted, because "one finds almost no mathematicians or computer scientists anywhere in the executive management structure" of the
DoD. On the other hand, van Tilborg noted that the number two uniformed official in the Navy is a mathematician: Admiral Donald L. Pilling, vice chief of naval operations. Pilling is a member of the AMS and of the Society for Industrial and Applied Mathematics.

**Whither the AMS Referendum?**

It was almost twelve years ago that the AMS membership passed a referendum concerning support for mathematics from the DoD agencies. Motion 2 of the referendum expressed concern about the “tendency to distribute this support through narrowly focused (mission-oriented) programs and to circumvent peer review procedures.” The motion warned that this tendency “may skew and ultimately injure mathematics in the United States,” and ended by saying, “Therefore those representing the AMS are requested to direct their efforts towards increasing the fraction of non-military funding for mathematics research, as well as towards increasing total research support.” The referendum also included motions about the Strategic Defense Initiative and other, less controversial, matters of funding policy. The referendum drew about 7,000 votes, and motion 2 passed by a wide margin, with about 74% in favor and about 19% against (there were some abstentions).

At AMS meetings and in the pages of the *Notices*, passions flowed so hot that it is surprising to see how cool they are today. In retrospect the referendum seems like a quaint reminder of a less practical, more idealistic time that has since passed. The referendum’s main effect seems to have been to alienate, at least temporarily, certain segments of the mathematical community from the AMS. Some mathematicians were deeply offended by the referendum; one was James Crowley, who at the time was the head of the mathematics program at AFOSR and is now the executive director of SIAM. Today AMS representatives do not seem constrained to focus their attention only on “increasing the fraction of non-military funding for mathematics research.” As one observer put it, the AMS referendum is “not on the radar screen” of anyone concerned with funding for mathematics or science.

Indeed, the AMS has been active on a variety of fronts to try to boost funding for science and mathematics by all federal agencies, including those in the DoD. The AMS Committee on Science Policy, chaired by Arthur Jaffe, has invited to its meetings a number of key people from the DoD, including Robert J. Trew, director of research in the office of the secretary of defense. The AMS is active in the CNSR (Coalition for National Security Research), a group of sixteen scientific societies, university groups, and industry representatives who are advocates for increased support for research by the DoD. Perhaps their voices are being heard: The fiscal year 2000 defense appropriations bill, signed into law by President Clinton in October 1999, contains a 7.3% increase for DoD research. Consistent advocacy for all of science and mathematics, bolstered by alliances with other scientific groups, is what is likely to improve the funding picture for mathematics at the DoD agencies. As Rankin put it, “It is in the interest of mathematics to have all agencies that fund science be healthy.”

— Allyn Jackson

### Mathematics Budgets for DoD Agencies, FY 1994-1998

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*Constant dollars are computed using the Consumer Price Index, based on prices during 1982-84.*
The Invention of Infinity: Mathematics and Art in the Renaissance

Reviewed by Anthony Phillips

The Invention of Infinity: Mathematics and Art in the Renaissance
J. V. Field
Oxford University Press, 1997
ISBN 0-196-52394-7
384 pages, $35.00

It seems to be a property of human perception that a two-dimensional graphic pattern must be a picture of something. The earliest graphics we know are representations. The picture may be more or less faithful or schematic, on one or the other side of what Gombrich calls “the great divide which runs through the history of art and sets off the few islands of illusionist styles...from the vast ocean of ‘conceptual’ art” ([3], p. 9). Since our minds perceive reality as three-dimensional, a basic geometrical problem for the illusionistic tradition is how to render three-dimensional objects and the surrounding space on a two-dimensional surface. J. V. Field’s The Invention of Infinity tells the story of how this problem was discovered as an explicit geometric problem by the artist/mathematicians of the Italian Renaissance, how its solution became part of the standard artistic curriculum, and how its purely mathematical aspects were generalized and developed during the next two hundred years into what we now know as projective geometry.

The problem is generally labelled by the term perspective. In its simplest form, “one-point per-
us “stereoscopic” input that, for nearby objects, delivers an immediate sensation of volume and distance. Leonardo da Vinci, as quoted in Gombrich’s Art and Illusion ([3], p. 98), complains about the impossibility of reproducing this sensation graphically and adds: “...it is impossible for a painting to look as rounded as a mirror image...except if you look at both with one eye only.” One-point perspective should be viewed from far away or with one eye at a time.

A camera automatically produces a one-point perspective image of its target. In this age of the photograph it may be difficult to realize that the process had to be invented. It is then useful to think back to childhood. Kids learn the trick of drawing a square and two adjacent parallelograms to get something that “looks like” a cube. They do not “see” the parallelograms any more than the untrained eye sees the gamut of colors it takes to render a faithful image of a yellow ball in the sunlight. The brain automatically rectifies and corrects. There is a striking passage in Piaget and Inhelder’s study of how children think about space ([6], p. 211). A six-year-old has drawn a gate in the distance as large as a gate up close. When asked, “Does it seem smaller or not, at the end, down there?” the child answers, “It is not smaller.” Similarly, since God is greater than man, it was natural for the medieval artist to paint a huge Virgin and Child surrounded by pint-sized prophets and saints, just as it was natural for the Egyptian tomb painter to show the master twice as tall as his peasants (see illustrations in [3]). Far from being natural, perspective is a calculated illusion, giving the brain false clues so it will construct a virtual reality.

The Invention of Infinity describes the defining event, which took place around 1415 just inside the main doorway of the Florence cathedral. Filippo Brunelleschi (1377-1446) set up a demonstration in which his fellow citizens were invited to look out across the way and to compare their view of the Baptistery with the view, through a peephole, of his picture of that view. Presumably the views were similar enough to excite admiration and astonishment; this would have been the first objective, systematic exploration of the illusion of depth. In fact, Brunelleschi did not need any special geometrical knowledge to construct his image: all he had to do was look at the Baptistery through a peephole himself and make an accurate drawing of what he saw. His fundamental innovation was the idea of an illusionistic rendering of space, much in the spirit of Giotto’s revolutionary naturalism in the treatment of figures some hundred years before. Another, perhaps more important one was his discovery of the eye as a point in space from which a picture was seen. This made perspective into a problem in solid geometry. Beyond his “demo” in the cathedral, which is fairly well documented [5] although the picture itself is lost, we have no trace of these discoveries. Nevertheless, the appearance of one-point perspective in the bas-relief of St. George and the Dragon (Orsanmichele, Florence) executed by Brunelleschi’s friend Donatello in 1417 makes it plausible that the method was indeed invented by Brunelleschi before that date.

The first surviving written instructions for the geometric construction of perspective images are due to Alberti (1404-1472), another Florentine polymath. Gadol [2] gives a comprehensive survey of this and the rest of his extraordinarily various activity. His Della Pittura [1], written in 1435–36, contains an algorithm for drawing a one-point perspective image of a checkerboard pavement given the position of the eye relative to the frame. This special case was of great use to painters, because it allowed them to draw a convincing floor on which figures could be placed, with relative positions readable from the checkerboard “coordinates”. Moreover, since the floor can be raised or lowered, the algorithm allows the complete projection of a three-dimensional grid.

At that time there was a recipe in use for drawing checkerboard floors in perspective. By having the columns taper off towards a vanishing point and making each row two thirds of the depth of the row in front of it, one could produce an illusion of depth. Alberti describes this construction and criticizes it as inaccurate because it does not locate the position of the eye or, as he calls it, “the point of the visual pyramid” ([1], p. 57; in fact the decrease in row width with distance is inverse-quadratic, not exponential). Alberti probably refers to the calculation of the correct position of the eye by reversing the construction, which is possible if the perspective has been correctly drawn. More details of this backwards construction are given below.
Alberti’s construction, which is not at all obvious, is shown in Figure 1. The checkerboard is horizontal and abuts the edge of the (vertical) frame. A point $O^*$ is drawn in the picture-plane (to the right in this illustration) on a level with the vanishing-point C and such that the horizontal distance $O^*C$ to the frame is equal to the distance from the eye to C. As seen from $O$, the lines in the checkerboard which are perpendicular to the frame appear as lines through $C$. Each line parallel to the bottom of the frame projects to a horizontal line in the picture. The height of that line is found by intersecting the right-hand edge of the frame with the line from $O^*$ to the foot of the corresponding vertical line (the correspondence is given by a ninety-degree rotation to the left). Why does this work? Alberti does not tell us, and Field’s explanation (on pp. 26–27) is unsatisfactory. The construction depends crucially on the rotational and translational symmetry of a checkerboard. This allows the cone of vision and the entire polygon OCHMOP to be swung around into the plane of the picture and allows a three-dimensional construction to be collapsed to two.

The construction itself may be independently due to Brunelleschi; it appears in the design of the vaulted ceiling in the large fresco The Trinity (Santa Maria Novella, Florence), executed by Masaccio in 1426. Vasari (1511–1574), whose Lives of the Artists [7] is the standard early reference on Italian Renaissance art, tells us (Vol. I, p. 272) that “In particular he [Brunelleschi] taught Masaccio the painter, then a youth and his close friend, who did honour to his instructor, as appears in the buildings which occur in his works.” About The Trinity he says (Vol. I, p. 265): “But the most beautiful thing besides the figures is a barrel vault represented in perspective and divided into squares full of bosses, which gradually diminish so realistically that the building seems hollowed in the wall.” The illusion derives its power from geometry: applying the inverse checkerboard construction to the vault locates the ideal viewing position as the height of the eye of a person looking up from across the aisle.

The next arresting character in the narrative is Piero della Francesca (c. 1412–1492). Piero, one of the greatest painters of the Renaissance, wrote mathematical treatises. Three survive, one of which is De Prospectiva pingendi (On perspective in painting, c. 1480). In a general discussion of Piero’s mathematics, The Invention of Infinity reproduces illustrations from this work showing how he locates points by pairs of “rulers”, one horizontal, one vertical. For example, the position of one corner of a column capital is indicated by a tickmark on one of the horizontal rulers and a similarly labeled tickmark on the corresponding vertical ruler. These pictures are fascinating because they show explicitly how coordinates were used before coordinate systems existed.

In De Prospectiva Piero gives a refinement of Alberti’s construction and a diagrammed proof that it really works (Della Pittura has no figures). The verticals are drawn using the vanishing point as before. Piero constructs the top edge of the perspective floor by Alberti’s method, but then locates the horizontals by intersecting the verticals with a diagonal, as shown in Figure 2. Alberti had already introduced the diagonal as a check on his construction: “If one straight line contains the diagonal of several quadrangles described in the picture, it is an indication to me whether they are drawn correctly or not” ([1], p. 57). This use of the projection-invariance of the relation between diagonal, horizontals, and verticals is the first hint of what we now call projective geometry. A further note: the diagonal, extended upwards, meets the horizon (the horizontal through the vanishing point) at $O^*$. Reasoning with similar triangles shows that $AB/O^*C=BE/H*C=AB/O^*C$, with points labeled as in Figure 2. It follows that $O^*C=O*C$ and therefore equals the distance to the
eye. This is the easiest way to locate the ideal viewing position. On the other hand, one can shortcut the construction by first locating $O^{**}$ using $O^{**} C = OC$ and joining $O^{**}$ to the opposite lower corner of the frame. This further and final simplification of Alberti’s algorithm is traditionally called the “distance point construction”.

The Invention of Infinity’s first five chapters tell the story of perspective in the Italian Renaissance. The second half of the book is denser with mathematics. It follows the geometry of perspective through the sixteenth century and well into the seventeenth, with Commandino (1509-1575), Benedetti (1530-1590), Danti (1536-1586), Guidobaldo del Monte (1545-1607), Kepler (1571-1630), and finally Desargues (1591-1661). Desargues is given the special attention he deserves as the man who brought perspective into pure mathematics by his recognition of the importance of projective invariance: “...Desargues is not looking at what is changed by perspective, as artists were, but at what is not changed.” We are shown how he implemented this principle in his unified study of conics. He is also recognized as “the first mathematician to get the idea of infinity properly under control.” As Field puts it, “He uses the concept in a completely precise mathematical way.” Here is the culmination, in geometry at least, of the invention referred to in the title.

This is a handsome book on a wonderful topic. It covers a period when mathematics seems to have been part of the natural efflorescence of genius, and it links two neighborhoods, fifteenth-century Florence and seventeenth-century France, when an unusual amount of genius walked the earth. This was a singular period in another way: mathematics has traditionally taken its new problems and new material from the physical sciences; The Invention of Infinity tells the story of a significant transfusion where the donor was art. And since the artists involved were among the greatest of their period, we can witness milestones of this transfer in details of artistic masterpieces. For mathematicians it makes an irresistible package. For the nonmathematical audience to which this book is presumably addressed, there is a problem. They can learn that Renaissance mathematics evolved hand in hand with Renaissance art, but if they want to penetrate the details of that mathematics, they will have a hard time. Field concentrates on the what-did-they-know-and-when-did-they-know-it questions, which are certainly significant. But when the original proof is unintelligible, incorrect, or nonexistent, readers are left to their own devices. Today’s mathematicians can fill the gaps without much difficulty; for the general reader the book would have been improved by a complete and careful account, explicitly anachronistic when necessary, of each new piece of mathematics.

Field presents the history of these mathematical ideas in great detail, with many quotations of texts and diagrams by the participants. There is a wealth of excellent illustration going well beyond what is necessary to elucidate the text and helping to give a visual impression of an entire intellectual era; this is especially true of the sections on the Italian Renaissance. There is also a wealth of fascinating and instructive information. We get to compare Piero della Francesca’s sober perspective palazzo with the wildly baroque perspective dome painted by Andrea del Pozzo in 1685, just as we can compare Piero’s humble mathematics—the problems in his Abacus treatise are given in terms of the reckoning of debts, the weight of fish, the worth of bolts of cloth— with Desargues’s confident search for maximum generality.

The Invention of Infinity grew out of a series of lectures and many places has preserved the irreverent tone and breezy, donnish mock-pedantry that must have made those lectures hugely entertaining. "Leonardo of Pisa (c. 1170-c. 1240, sometimes called Fibonacci)"—O.K. But the irreverence can get out of hand. Partway through the Sistine Chapel decoration, some of the scaffolding was taken down. We are told that the view from the floor led Michelangelo (that scorn of mathematical constructions!) to enlarge the scale of the figures after work was resumed, and Field indulges in a bit of fun at the master’s expense (p. 117). The real story is probably not so simple. I refer readers to the “Michelangelo” entry in the Grove Dictionary of Art. The irreverence is pointed up by the publishers’ (probably unwittingly) shameless use of some glorious details of the Sistine Chapel ceiling for the book’s dust jacket.

Sometimes the breeziness can lead to misapprehension. Federico da Montefeltro, Alberti’s
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The Number Devil
Hans Magnus Enzensberger
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Translation by Michael Henry Heim

Engaging A Mathematically Disengaged Public
In 1959 C. P. Snow poignantly described the chasm between the sciences and the humanities in his provocative Rede lecture, The Two Cultures. Straddling this chasm himself, he noted stereotypes which are held by members of each culture and which shape profound misconceptions about the work and endeavors of the other. Forty years later the divide which Snow lamented is as wide as ever. John Allen Paulos’s popular books illustrate ways in which many otherwise well-educated Americans lack fundamental quantitative sensibilities and are alienated from mathematics [1]. The same person who would never dream of saying, “I can barely read,” remarks lightheartedly, “I was never good at math.” The same person who can be fascinated with a linguistic detail or a fine point about sociology or politics or music is frequently uninterested in matters of chance, insensitive to orders of magnitude, and impatient with even a modest use of mathematical terminology or symbolic notation. Mathematical ability is widely believed to be innate, mathematics a pure “hard” science. Other fields are seen as “soft”.

One result of this chasm is that fewer and fewer American students voluntarily enroll in mathematics courses past high school, and the number of American mathematics majors in our colleges and universities has dropped steadily. Another equally serious result is that the public is unengaged with mathematics, and matters that require quantitative reasoning or sense are poorly understood. A natural response to this problem has been widespread and often ambitious efforts to improve mathematics instruction at all levels. One wave after another of reforms has swept over our nation’s schools over the past hundred years, leaving a mixed residue of changes and some improvement. These efforts, usually focused on curricular change, have been the subject of controversy and debate and have confronted reformers with the sprawling nonsystem of American schooling and the independent complexity of creating educational change which permeates practice as intended.

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arid as descriptive prose, sketches of surrealistic landscapes. It is hard to imagine their being highly captivating to children.

In keeping with the fanciful style of the narrative, many mathematical terms and characters are colorfully renamed: Fibonacci numbers are now "Bonacci numbers", primes are "prima donnas", and irrational numbers are "unreasonable". "Hopping" is taking powers of a number, and hopping backwards leads to taking "rutabagas", i.e., square roots. Felix Klein gets the pseudonym "Dr. Happy Little", but we have not figured out why Gauss is called "Professor Horrors". Although there is no table of contents, there is an index, called the "Seek-and-Ye-Shall-Find List", which locates and explains these imaginative terms. A warning there explains that when Robert and the Number Devil talk about mathematics, they use some "unusual expressions." The reader is cautioned to use standard terms when not in the fanciful world explored by the Number Devil and Robert.

We turn next to a closer look at the adventures of Robert and the Number Devil and the mathematical territories of their explorations.

**Devilish Mathematics**

The book opens with Robert, who sleeps fitfully, plagued by strange puzzle-filled dreams. Determined to banish the tricks his mind plays on him in the darkness of night, one night he dreams of a meadow. Suddenly he notices an elderly man the size of a grasshopper perched animatedly on a leaf, staring at him with bright eyes. "I am the Number Devil!" asserts the small creature. Dubious, Robert dismisses him, saying there is no such thing as a Number Devil and, "Besides, I hate everything that has to do with numbers!" When the Number Devil inquires why, Robert replies that he must never have gone to school. "Or perhaps you are a teacher yourself?"

After some tussling back and forth, the Number Devil endeavors to show Robert that what he thinks of as mathematics from what he has seen in school is a far cry from the mathematics that the Number Devil could show him: "The thing that makes numbers so devilish is precisely that they are simple. And you don't need a calculator to prove it." He starts out: $1 + 1, 1 + 1 + 1, 1 + 1 + 1 + 1$. "Any idiot can see that these go on forever, infinitely." "Have you tried it?" asks Robert, curious. "It would be a waste of time," says the Number Devil dismissively. Here begins their characteristic pattern of interaction: the Number Devil triumphantly shows Robert interesting things, but when Robert challenges or asks questions, the Number Devil is derisive. When Robert asks more questions about the infinity of numbers, for example, the Number Devil shouts at him impatiently and proceeds to show there are infinitely small numbers too. Robert does not seem to understand what the Number Devil shows him, which makes the Number Devil impatient again, accusing him of being afraid of numbers. He proposes that he can make all numbers out of ones and excitedly presents Robert with the palindromic pattern, $1 \times 1 = 1, 11 \times 11 = 121, 111 \times 111 = 12321, 1111 \times 1111 = 1234321$, and so on. Robert, following along, becomes skeptical and, suspecting that the Number Devil is bluffing, asks about

$$11,111,111,111 \times 11,111,111,111.$$  

This flusters the Number Devil, who tries it. "You were right. It doesn't work. How did you know?" He is annoyed with Robert for embarrassing him. When Robert admits he was guessing, the Number Devil huffs that "mathematics is an exact science where no guessing is allowed.

Their explorations continue in this vein, spanning a range of mathematical fascinations. On the third night the Number Devil takes up factoring, introduces "prima donnas" (primes), and cautions, more or less dogmatically, that division by zero is strictly forbidden. The sieve of Eratosthenes is illustrated with the numbers 1-50, inviting the reader to complete the task. Then, gladly quelling Robert's initial satisfaction, the Number Devil asks, "What if you have a number like 10,000,019, or 141,421,356,237,307? Is it prima donna or isn't it?" He notes that "even the greatest number devils have come to grief over it." And later, "The more simple-minded number devils use giant computers," a curious characterization.

To Robert's plea, "What's the point of it all?" the Number Devil replies, "You do ask stupid questions! Luckily you've got me to initiate you into some of the secrets." He then asserts (without discussion) that between any number larger than one and twice that number there is a prima donna. And when I say always, I mean always!" Then the Number Devil enthusiastically goes on to announce that any even number larger than 2 is the sum of two prima donnas. Robert tries a few examples and sees what the Number Devil is saying. But when Robert asks why, the Number Devil confesses that "no one knows why [this Goldbach Conjecture is true]."

On the fifth night, after an encounter with the infinity between 0.0 and 1.0, the Number Devil warns of the existence of "unreasonable" (irrational) numbers, which "refuse to play by the rules." By way of motivation he recalls the "hopping" numbers—2, 4, 8, 16, 32, etc.—and proposes the problem of "hopping backwards", which he calls "taking the rutabaga" (square root). This leads to the square root of 2, which the Number Devil asserts is unreasonable. He does give a rare and beautiful geometric proof (sans Pythagoras) that the diagonal of the unit square has length $\sqrt{2}$. On
Another path to changing America's ambivalent relationship with mathematics, less often pursued than educational reform, is to produce mathematical exposition for public consumption. At their best such efforts can make good mathematics accessible to the public and engender fascination with the subject. Consider, for instance, the writings of John Allen Paulos, Reuben Hersh, Philip Davis, Martin Gardner, Keith Devlin, Ian Stewart, and Brian Rotman, among others. Some authors—Lewis Carroll, Anno, Marilyn Burns—have written books for children. In *The Phantom Tollbooth*, for example, Norton Juster tucked fascinating mathematical excursions and lessons in and around the adventures of Milo, a bored young child who has "nothing better to do." [2]. Writing books intended for children can produce an interesting twist, for adults often read such books to children. Parents and teachers, grandparents and babysitters thereby also engage with the mathematics of these books. *Anno's Mysterious Multiplying Jar* offers a glorious visual and textual portrait of the mathematics of factorials. Traveling with Milo (*The Phantom Tollbooth*) to Digitopolis, meeting the Dodecahedron, and tracing his encounters with infinity and precision, readers are drawn into fascination with and understanding of fundamental mathematical ideas.

One common-sense fallacy is that interest is innate: some people are interested in mathematics; others are not. However, interests, as John Dewey argued, are made, not found. A central task of education is to engender interest, to help build connections between a learner’s present and the invitational potential of the subject. One thing then that popular texts involving mathematical ideas can do is to open mathematical worlds to the public, interesting people in ideas of number and space; pattern and relationships; and the language, tools, and ideas that mathematicians use to explore these worlds. A central responsibility of the mathematical writer is to create these texts in ways that can connect with their readers, foreign travelers to these mathematical worlds. If successful, these books should send readers away eager for more and surprised by what they have encountered.

We take a closer look here at one such book recently published: *The Number Devil* by Hans Magnus Enzensberger. We begin by providing a snapshot of the book and then trace its interior, following the adventures of Robert and his new friend, the Number Devil. We stand back then and comment on the book’s efforts to open mathematics to children and their adult companions. Does it engender interest in mathematics? Does it present mathematics as something in which anyone can engage? Are some significant mathematical ideas made accessible? What would it take for a child or a teacher or parent to read and profit from this book?

**The Number Devil: Enzensberger’s Mathematical Proselyte**

Hans Magnus Enzensberger is a well-known and respected European intellectual and author with wide-ranging interests. He gave a speech on mathematics and culture, "Zugbrücke außer Betrieb, oder die Mathematik im Jenseits der Kultur—eine Außenansicht" ("Drawbridge out of order, or mathematics outside of culture—a view from the outside"), in the program for the general public at the International Congress of Mathematicians in Berlin in 1998. The speech was published under joint sponsorship of the AMS and the Deutsche Mathematiker Vereinigung as a pamphlet in German with facing English translation under the title *Drawbridge Up: Mathematics—A Cultural Anathema*, with an introduction by David Mumford. Enzensberger’s knowledge of mathematics is discerning and appreciative; he is an adventurous amateur whose treatment of mathematical topics stays within reach of ordinary language and yet is sure-footed without fundamental confusions or conceptual dissonance. In this book he has created a character called the Number Devil who diabolically hounds a young boy, Robert, taunting and tantalizing him with mathematical mysteries and wonders.

*The Number Devil* is a book for older children. The book jacket announces it as “a gift to readers of all ages: a cross between *Alice in Wonderland* and *Flatland*, in which we discover exciting secrets about math, without ever having to do a single math problem.” In fact, the mathematical ideas are substantial and could easily engage even adult readers. The book’s illustrations by Rotraut Susanne Berner are nicely and simply done and supportive of the narrative. Even the mathematical notation and expressions are rendered as illustrations, in soft thick lines and pleasing colors.

The story unwinds as a narrative of dreams in fantastic settings in which Robert has encounters across twelve nights with the Number Devil. Robert and the Number Devil are the only active characters of the book, though Robert’s mathematics teacher, Mr. Bockel, is often mentioned, usually with derision. The dream environments, one for each of the twelve nights, include such settings as a forest of trees shaped like 1’s, a cave with wall paintings, and an overturned boat on an empty seashore. These environments are incidental to the story, except as colorful conversational props. They take the place for Robert of some nightmarish experiences—being swallowed up by a slimy fish, falling down an endless slide, for instance—which tormented his nights before he met the Number Devil. Avoiding these distinctly unpleasant perils serves to keep Robert engaged with the sometimes taunting and aggravating Number Devil. The descriptions of the dream environments are brief and not particularly gripping. They are somewhat
the diagonal the Number Devil erects another square, which he illustrates is composed of four triangles, two of which can form the unit square (see Figure 1). Thus the larger square has twice the area of the unit square, whence the claim.

Next the Number Devil notes that the unreasonable numbers are not rare, in fact there are "more" of them than there are reasonable numbers. Robert protests, since he already knows well that there are infinitely many reasonable numbers, so how can there be "more than infinity?" No answer is offered.

Robert's dreams continue, with encounters with triangular numbers, Gauss's argument for the sum of the first 100 (or $N$) numbers, Pascal's triangle, Fibonacci numbers, permutations, the golden mean, and more. Never are these ideas named as such. Sometimes they are given fanciful names (e.g., Bonacci numbers) and sometimes left unnamed. Rarely are explanations given. One exception is on the ninth night, which deals with some infinite phenomena. The Number Devil seeks to convince Robert that all sequences (whole numbers, odd numbers, triangular numbers, primes, etc.) have the same number of members. Next he gives a geometric proof that $1/2 + 1/4 + 1/8 + 1/16 + \cdots = 1$, followed by a proof that the harmonic series diverges, by forming groups of terms of length $2^n$ for $n = 2, 3, 4, \ldots$. This is one of the rare instances where some substantial mathematical arguments are executed with a fair degree of completeness.

The eleventh night is particularly interesting, since Robert himself begins to ask the Number Devil why all the things shown to him are true: "You've shown me things, but never proved them." The Number Devil answers, "So you want to know the rules of the game, what a mathematician wants to know." He continues, "Showing is easy and fun, guessing and testing guesses is better, but proof is all." He explains how important, and how hard, proving is for mathematicians, often taking centuries and plagued with mistakes along the way. When Robert asks for an example, the Number Devil chooses a curious one: 

$$10^0, 8^0, 100^0, \text{all } 1,$$

which is a (well-rationalized) convention, not a theorem. The Number Devil says, "I could prove it to you, but you'd go mad in the process." He then goes on metaphorically to describe proving as similar to crossing a stream in which one cannot swim: one must step from one stone to another sufficiently nearby. Previous results established by mathematicians furnish sturdy dry rocks, and the shore is built of axiomatic types of propositions (such as that any (whole) number has a unique successor, or two points determine a unique straight line). The Number Devil explains that even though patterns may persist for very large computations, this does not constitute a proof, and exceptions (which are fatal) may always show up when the computations are further extended. The example from the first night is mentioned. Robert reminds him that he became angry when Robert raised questions about the extension of the pattern. "You had a good nose," admits the Number Devil. "Even though the formula worked well enough for a while, it collapsed in the end, without proof. In other words, even a Number Devil can fall on his face."

**The Devil Is in the Details: How Well Does The Number Devil Work?**

*The Number Devil* is an attractive and imaginative fantasy. Robert and his devilish guide visit some of the loveliest sites of mathematical discovery and achievement. Their banter is entertaining, the ideas attractive. Robert is bright in a common sense way, and gradually over the course of the book he becomes more and more engaged with and expectant of his encounter with his unusual mentor. The Number Devil is sprightly, a bit mischievous, temperamental, and cunningly seductive with Robert. The book is aesthetically appealing, with attractive illustrations and clear and colorful fonts and line drawings. But how well would Enzensberger's book work to attract the mathematically hesitant or uninterested reader? What is the book saying about good mathematics and about who can do it? What is it offering the reader mathematically, and what would it take for readers to profit from it?

We worry on several counts. First, real mathematics is repeatedly said to be different from what goes on in school. Good enough. This could be an encouraging message for those who have been turned off by what they encounter in math classes. Robert's teacher, Mr. Bockel, who never actually appears, is a scapegoat symbolizing oppressive practices (e.g., long, boring arithmetic drills) and backward attitudes (e.g., forbidden use of calculators). School, it appears, is not where one learns real mathematics. It is really not Mr. Bockel's (or other teachers') fault, for he cannot go "rock leaping" whenever he wants, as the Number Devil and Robert do, because he has to correct homework.
The implication is that math teachers do not have the mathematical appetite or experience to engage students in "real mathematics". Mr. Bockel is a caricature, who, beyond his intellectual narrowness, is fat and hungry and secretly wolfs pretzels during class. Implicitly, schoolteachers do not know much mathematics, and school mathematics is trivial. Of a typical word problem, the Number Devil says, "That kind of problem has nothing whatever to do with what I'm interested in. Most genuine mathematicians are bad at sums. They have no time to waste on them. That's what calculators are for."

A second concern is that the book may reinforce an image of mathematics as dependent on inside expertise and restricted to privileged access. Although this may be intended to be funny to those who have endured deadening mathematics classes or to caricature what passes for mathematics in school, an insidious message is that teachers are mathematically incompetent and, worse, that real mathematics is found in an insider's world for a select and privileged few—the world into which the Number Devil entices Robert. The topics explored are interesting, and many are substantial. Appreciating Enzensberger's mathematical adventure depends, however, almost entirely on the reader's own mathematical experience and knowledge. How much a mathematical newcomer might be able to glean is far from clear. Virtually all the mathematical ideas are rendered, with due theatrics, by the Number Devil. Robert rarely raises questions, speculates, or uncovers mathematics on his own. Thus, mathematics appears as something delivered by inside experts to a privileged audience.

A third concern has to do with the images implied by the book's characters—who they are and what that may say about who does mathematics. Robert and the Number Devil, both good at mathematics, are male. Of course, so is Mr. Bockel, an unsavory character. But the fact that neither of the main characters is female is significant. Could a bright young girl not have met up with the Number Devil instead of, or along with, Robert? Or, more boldly, could the Number Devil have been a brilliant and imaginative woman instead of an bright, impatient man? The choices of gender in the book fall unfortunately in line with cultural stereotypes which are unlikely to foster change or to caricature what passes for mathematics in school, an insidious message is that teachers are mathematically incompetent and, worse, that real mathematics is found in an insider's world for a select and privileged few—the world into which the Number Devil entices Robert. The topics explored are interesting, and many are substantial. Appreciating Enzensberger's mathematical adventure depends, however, almost entirely on the reader's own mathematical experience and knowledge. How much a mathematical newcomer might be able to glean is far from clear. Virtually all the mathematical ideas are rendered, with due theatrics, by the Number Devil. Robert rarely raises questions, speculates, or uncovers mathematics on his own. Thus, mathematics appears as something delivered by inside experts to a privileged audience.

A final issue centers on mathematical warrants and what is implied about the basis for learning and knowing mathematics. The mathematical visitor will likely come away from the book aware of certain facts and truths, but still learning mathematics by acceptance rather than by conviction. The mathematics is well and colorfully staged. The scope of the book ranges widely, some fascinating doors are opened, and some surprising connections are made, such as between the multiple incarnations of the Fibonacci sequence and the golden mean. Ironically, however, mathematics is presented a bit like magic—intriguing and slightly mystifying, without explanation or development. Hardly any credible approximations to a proof of anything are offered. The ideas are more like invitations to something to be pursued beyond the book itself, like a preview of a good film, with highlights of dramatic scenes intended to lure the reader into pursuing the full version. The notion of proof is actually one of the topics dealt with in the book, on the eleventh night, but even that is left in metaphorical form rather than offering a substantial example. The book presents only a couple of illustrations of significant reasoning. We found the exposition of the mathematics somewhat frustrating—enticing but never consummated. One could get the feeling that mathematics was akin to a bunch of magic acts, a message surely not desirable to entice broader interest in the subject.

Given these concerns, we hesitate to recommend The Number Devil as a book that could be profitably read by most upper elementary and middle school children without adult guidance—that is, read for acquiring new mathematical interests, curiosities, and understandings. So we ask instead: Could children and their adult companions—teachers, parents, babysitters, grandparents—learn some mathematics from The Number Devil? What would it take for them to come away from their encounters with Robert and his friend with a new appreciation for the subject and their appetites whetted for more? Our answer is, unavoidably, a great deal. One thing it would take is knowledgeable guidance and interpretation. Reading this book aloud to a child or to one's child, one would have to be able to explain ideas on which the book only briefly alights. What, for example, went wrong when the Number Devil tried to multiply

\[11,111,111,111 \times 11,111,111,111,\]

and why? Why does the drawing of the two squares show that the diagonal of the first square is the square root of 2, why is this called "unreasonable", and what is important about the idea of an irrational number? Simply reading the book as is, children will (and should) have questions. A second thing it would take is good sense about how to respond to such questions. Which questions
Solicitation for Applications

Visiting Research Professorship at MSRI

A joint project of
the Mathematical Sciences Research Institute
and the Hewlett-Packard Laboratories

The Mathematical Sciences Research Institute in Berkeley, (MSRI) and Hewlett-Packard Laboratories in Palo Alto, California (HPL) have established the position of HPL/MSRI Visiting Research Professor (VRP). The VRP is housed at MSRI. The VRP has no official duties, except to participate in the mathematical life of, and mentor postdocs at, MSRI, and to interact with the mathematical staff at HPL.

The VRP should be a senior mathematical scientist who is internationally recognized as a leader in the discipline. No particular field of mathematics, pure or applied, is specified for the appointment, but preference will be given to candidates with wide-ranging interests, who can contribute in one or more of the upcoming programs at MSRI and the current areas of interest at HPL.

The upcoming programs planned at MSRI for 2000-2001 are “Algorithmic Number Theory”, “Operator Algebras”, and “Spectral Invariants”. More on these programs can be found at http://www.msri.org. MSRI is also interested in encouraging increased interaction of mathematics with other sciences such as physics and biology.

The current mathematical interests at HPL include information theory, source coding, error correcting codes, cryptography, computational number theory, finite fields and elliptic curves over them, analysis of algorithms and complexity, operations research, mathematical economics, probability theory and statistics, sequential decision problems, quantum chaos, quantum computation, foundations of quantum physics, discrete mathematics, graph partitioning, graph matching, combinatorial optimization, theoretical materials science, random networks and percolation, distance geometry.

A one-year position will be offered this year, with starting date August 14, 2000. Future appointments may be from one to four years. Salary range for this position will be commensurate with the candidate’s previous experience and with the intention to hire a mathematical scientist of the highest standing. Applications should be sent to the Director, MSRI, 1000 Centennial Drive, Berkeley CA 94720-5070. We will begin considering applications on February 15, 2000. Applicants should include a curriculum vita and a statement of how the applicant views the possibilities for interaction with the mathematical programs at MSRI and HPL. Applicants may solicit letters of recommendations to be sent to the Director of MSRI, or may include a list of references. Inquiries may be directed to vrp@msri.org.

References


MSRI and HPL support the principles of equal opportunity and affirmative action.
The Royal Swedish Academy of Sciences has awarded the 1999 Nobel Prize in Physics jointly to GERARDUS 'T HOOFT and MARTINUS J. G. VELTMAN. The two were honored “for elucidating the quantum structure of electroweak interactions in physics.” The prize, which carries a cash award of 7,900,000 Swedish crowns (about $1,000,000), will be presented December 10, 1999, in Stockholm.

The theoretical foundation for the standard model of particle physics was at first incomplete mathematically, and in particular it was unclear whether the theory could be used at all for explicit calculations of physical quantities. 't Hooft and Veltman have been awarded the Nobel Prize for placing this theory on a firmer mathematical foundation. Their work has given researchers a well-functioning theoretical machine which can be used for, among other things, predicting the properties of new particles. In particular, their method was used to calculate the mass of the top quark. This quark was observed directly for the first time in 1995 at Fermilab, and the theoretical predictions agreed with the experimental evidence.

Gerardus 't Hooft was born in 1946 in Den Helder, The Netherlands. He received his doctoral degree in physics in 1972 at the University of Utrecht, and he has been a professor of physics there since 1977. He received the Dannie Heineman Prize of the American Physical Society (1979), the Wolf Prize in Physics (1981), and the Franklin Medal of the Franklin Institute (1995). He was elected as a foreign associate of the U.S. National Academy of Sciences in 1984 and has been a member of the Dutch Academy of Sciences since 1982.

Martinus J. G. Veltman was born in 1931 in the Netherlands. He received his doctoral degree in physics in 1963 at the University of Utrecht and was a professor of physics there from 1966 to 1981. He then moved to the University of Michigan, Ann Arbor, where he is now John D. MacArthur Professor of Physics, emeritus. He resides in Bilthoven, The Netherlands. Veltman received the 1993 High Energy and Particle Physics Prize from the European Physical Society and the 1997 Dirac Medal from the International Center for Theoretical Physics. He has been a member of the Dutch Academy of Sciences since 1981.

—Based on information from the Royal Swedish Academy of Sciences
AMS Participation in World Mathematical Year 2000

It warrants a celebration: The International Mathematical Union (IMU) has declared the coming year “World Mathematical Year 2000”. Organizations all over the world have planned a variety of special events to celebrate WMY 2000, as it is called, and the AMS is no exception.

In 1992 the IMU passed its official resolution declaring 2000 as the World Mathematical Year. The purposes of WMY 2000, as stated by the IMU, are: “the determination of great mathematical challenges of the 21st century; the promulgation of mathematics, both pure and applied, as one of the main keys for development; and the recognition of the systematic presence of mathematics in the information society (the image of mathematics).”

The idea of WMY 2000 harks back to the legendary lecture given by David Hilbert in 1900 at the International Congress of Mathematicians in Paris. In that lecture Hilbert set forth his famed list of twenty-three problems, which he believed to be the most important in mathematics. Some of those problems have had a deep influence on the field.

The AMS events for WMY 2000 kick off with the Annual Meeting, to be held January 19-22, 2000, in the nation’s capital, Washington, DC. The meeting will begin with a special WMY 2000 banquet featuring a special champagne toast. The master of ceremonies for the banquet will be David P. Roselle, president of the University of Delaware. Plans also call for a speech by Rita Colwell, director of the National Science Foundation. Joining in the festivities will be representatives from about twenty-five mathematics-related organizations. During the meeting there will be a full program of invited addresses, special sessions, and other activities.

The main AMS event for WMY 2000 is a special summer meeting entitled “Mathematical Challenges of the 21st Century”, to be held on the campus of the University of California, Los Angeles, August 7-12, 2000. This meeting has a larger and more ambitious purpose than other AMS meetings, for it seeks to focus attention on the impact of mathematics across the broad landscape of human endeavor. The stellar array of about thirty speakers representing all major areas of the field will together provide a panorama of today’s research in the mathematical sciences, as well as glimpses of the most important future challenges. The meeting will also feature several social and cultural events and will end with a celebratory banquet.

Another way in which the AMS is participating in WMY 2000 is through its support of the mathematical activities at the annual meeting of the American Association for the Advancement of Science, called “Science in an Uncertain Millennium” and scheduled for February 17-22, 2000, in Washington, DC. A two-part symposium entitled “The Reasonable Effectiveness of Mathematics: Mathematics in Hollywood, Industry, and Daily Life” will feature ten speakers addressing a range of topics, from computer animation to quantum computing.

One of the key themes of WMY 2000 is the international character of mathematics. It is therefore fitting that in 2000 the AMS will hold two international meetings. The first AMS-Scandinavian International Mathematics Meeting will be held June 13-16, 2000, at Odense University in Denmark. It is jointly sponsored by the AMS and the mathematical societies of Denmark, Finland, Iceland, Norway, and Sweden. The other meeting is the First International Meeting of the AMS and the Hong Kong Mathematical Society and will be held December 13-17, 2000, in Hong Kong.


—Allyn Jackson
Come celebrate the achievements of mathematics and contemplate what the future might bring!

MATHEMATICAL CHALLENGES OF THE 21ST CENTURY

UNIVERSITY OF CALIFORNIA LOS ANGELES
AUGUST 7-12, 2000

The purpose of the meeting is to demonstrate, not just to the mathematical community, but to the world at large, the power of mathematical ideas across the landscape of the sciences and practical affairs, while still maintaining a close link to ongoing developments. These leaders in their fields have agreed to give plenary talks. There will be 30 in all who will provide broad perspectives on mathematics in science and practical applications. Ronald L. Graham will give the AMS-MAA President’s Lecture.

James G. Arthur    Sergiu Klainerman    Richard P. Stanley
Alexander A. Beilinson     Maxim Kontsevich
Sir Michael V. Berry   Peter D. Lax
Haim Brezis            Simon A. Levin
Alain Connes           László Lovász
David L. Donoho        David Mumford
Charles L. Fefferman   Peter Sarnak
Michael H. Freedman    Saharon Shelah
Helmut H. W. Hofer     Peter W. Shor
Richard M. Karp        Yakov G. Sinai

For continually updated information on the speakers and events included in this meeting, visit http://www.ams.org/amsmtgs/mathchall.html regularly.

Program Committee: Richard Askey, Spencer Bloch, Felix Browder (chair), Charles Fefferman, Peter Lax, Robert MacPherson, David Mumford, Gian-Carlo Rota (deceased), Peter Sarnak, Audrey Terras, and S. R. S. Varadhan.

Part of World Math Year 2000
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Lusztig Receives Brouwer Medal

GEORGE LUSZTIG of the Massachusetts Institute of Technology has received the 1999 Brouwer Medal of the Dutch Mathematical Society (Wiskundig Genootschap). He received the gold medal and presented a one-hour lecture "A Survey of Group Representations" at the 1999 annual meeting of the Dutch Mathematical Society.

Wilberd van der Kallen, chair of the selection committee for the 1999 Brouwer Medal, presented the laudatio for the prize. The laudatio says that the prize was given for Lusztig's "many deep and influential contributions to representation theory." In particular, the following three achievements were cited:


2. The invention with Kazhdan (Invent. Math., 1979) of what are now called Kazhdan-Lusztig polynomials and the many conjectures and theorems that link them to different parts of representation theory.

3. The construction of quantum groups over the integers and the construction of canonical bases (for classical representations of simple complex Lie groups) and their positivity properties (cf. Lusztig's 1993 book). Lusztig's recent work on totally positive matrices belongs in this context.

The Brouwer Medal was established by the Dutch Mathematical Society and the Royal Netherlands Academy of Sciences in honor of the Dutch mathematician L. E. J. Brouwer (1881-1966). Every three years the society chooses a topic and then selects a Brouwer Lecturer for that area. The area selected for 1999 was algebra (not including number theory or algebraic geometry). The Brouwer Medal is the most prestigious award in mathematics in the Netherlands.


—Allyn Jackson

Cuntz Receives 1999 Leibniz Prize

JOACHIM CUNTZ of Universität Münster has received the 1999 Gottfried Wilhelm Leibniz Prize. The Leibniz Prize is one of Germany's most prestigious awards for outstanding scientists. The prize provides a five-year research grant of 1.5 million DM (about $800,000).

The work of Joachim Cuntz has its roots in functional analysis, more precisely, the theory of $C^*$-algebras and their $K$-theory. He has made substantial contributions to the structure theory of $C^*$-algebras and to G. G. Kasparov's $KK$-theory. Together with Daniel Quillen, Cuntz has been a driving force in the development of cyclic cohomology, a fundamental homological-algebraic structure underpinning $K$-theory and Alain Connes's non-commutative geometry.

Joachim Cuntz was born in 1948 in Mannheim, Germany. He studied mathematics and physics in Heidelberg and Paris and obtained his doctorate from Universität Bielefeld in 1975. He received his habilitation at the Technische Universität Berlin in 1977. He held positions in Berlin and Heidelberg and at the University of Pennsylvania in Philadelphia before taking a position as a full professor at Université de Provence in Marseilles in 1984. In 1988 he became a full professor at Universität Heidelberg. Since 1997 Cuntz has been a full professor at Universität Münster.

The Leibniz Prize was established in 1985 to improve the working conditions of outstanding scientists in Germany, to increase their research opportunities, to reduce their administrative workloads, and to enable them...
to recruit exceptional young scientific researchers. Ten scientists received Leibniz Prizes for 1999. Each prize winner receives a five-year research grant consisting of 3 million DM for those working in experimental areas and 1.5 million DM for those working in theoretical areas. The prize winners have a great deal of freedom in using the prize funds.

The Leibniz Prizes are awarded by the Deutsche Forschungsgemeinschaft (the counterpart in Germany of the U.S. National Science Foundation) and are financed by special funds provided by federal and state governments in Germany. For the 1999 competition about 180 proposals were submitted by higher education institutions, Germany's Max Planck Society, and previous Leibniz Prize winners.

—Allyn Jackson

1999 Prize for Achievement in Information-Based Complexity

The first winner of the Prize for Achievement in Information-Based Complexity is ERICH NOVAK of the University of Erlangen-Nürnberg. He was cited for “numerous outstanding contributions to information-based complexity.” The award, consisting of $3,000 and a plaque, was presented at an awards ceremony during the Foundations of Computational Mathematics Conference in Oxford, England, in July 1999.

—Joseph F. Traub

Presidential Awards for Mentoring

Two programs involved with the mathematical sciences have been chosen as recipients of the 1999 Presidential Awards for Excellence in Science, Mathematics, and Engineering Mentoring. They are the Science and Mathematics Investigative Learning Experience (SMILE) at Oregon State University, directed by Susan J. Borden, and the Douglass Project for Women in Mathematics, Science, and Engineering at Rutgers University, directed by Joseph J. Seneca.

The Presidential Awards for Excellence are administered and funded through the National Science Foundation (NSF). The awards recognize outstanding individual efforts and organizational programs designed to increase the participation of underrepresented groups in mathematics, engineering, and science from kindergarten through twelfth grade and on through the graduate level. Up to ten individuals and ten institutions annually may qualify for the award, which includes a $10,000 grant and a commemorative presidential certificate.

—From an NSF announcement

Pi Mu Epsilon Awards Student Prize

The AMS sponsors an annual prize that is awarded by Pi Mu Epsilon, the national honorary mathematics society. The prize was initiated in 1989 in honor of PME's seventy-fifth anniversary. PME administers the prize and uses it to recognize the best student papers presented at a PME student paper session. Each recipient of the AMS Award for Out-
standing Pi Mu Epsilon Student Paper Presentation receives a check for $150. Following is a list of the recipients of the awards that were made at the joint Mathematical Association of America-PME Student Conference in Providence, Rhode Island, July 31-August 2, 1999.

The winning speakers were ROBIN DRIESNER, Southern Illinois University; JEFFREY DUMONT, Lafayette College; SANJAY KUMAR GUPTA, University of North Carolina, Chapel Hill; BEN JANTSON, Youngstown State University; SARA LA LUMIA, Youngstown State University; TERESA SELEE, Youngstown State University; LIBBY WIEBEL, St. Norbert College.

—From a Pi Mu Epsilon announcement

Visiting Mathematicians

(Supplementary List)

Mathematicians visiting other institutions internationally during the 1999-2000 academic years were listed in the August 1999 issue of the Notices, pp. 807-809. The following is an update (home country is listed in parentheses).

V. Barbu (Romania), Ohio University, Partial Differential Equations and Optimal Control, 3/00-6/00.
Boris Bekker (Russia), Central Michigan University, Combinatorics, 9/99-5/00.
J. Brennan (U.S.A.), Centre de Recerca Matematica, Spain, Analysis, 4/00-5/00.
R. Brunner (U.S.A.), Centre de Recerca Matematica, Spain, Algebraic Topology, 1/00-3/00.
C. Burdzy (U.S.A.), Centre de Recerca Matematica, Spain, Stochastic Analysis, 6/00-7/00.
Junesang Choi (Korea), University of Victoria, British Columbia, Analytic Number Theory, Special Functions, 9/99-8/00.
Y. Hu (U.S.A.), Centre de Recerca Matematica, Spain, Stochastic Analysis, 6/00-7/00.
G. W. Mackey (U.S.A.), Centre de Recerca Matematica, Spain, Algebra, 3/00.
Margaret Readdy (U.S.A.), Stockholm University, Sweden, Algebraic Combinatorics, 9/99-5/00.
D. Schommer (Canada), Centre de Recerca Matematica, Spain, Dynamical Systems, 1/00-4/00.
S. Sehgal (Canada), Centre de Recerca Matematica, Spain, Algebraic Topology, 2/00-3/00.
Hongguo Xu (China), Case Western Reserve University, Numerical Methods and Numerical Analysis, 8/99-5/00.

Deaths

Norman G. Gunderson, professor emeritus at the University of Rochester, NY, died on September 5, 1999. Born on May 29, 1917, he was a member of the Society for 58 years.

William M. Lambert, of Montes de Oca, Costa Rica, died on August 8, 1999. Born on April 6, 1936, he was a member of the Society for 38 years.

Nicholas C. Metropolis, Senior Fellow Emeritus at Los Alamos National Laboratory, died on October 17, 1999. Born on June 11, 1915, he was a member of the Society for 37 years.

Gottfried T. Ruttmann, professor at the University of Bern, Switzerland, died on October 11, 1999. Born on April 20, 1941, he was a member of the Society for 24 years.

Karm Seddighi, professor at Shiraz University, Iran, died on May 11, 1999. Born on April 4, 1930, he was a member of the Society for 21 years.

Dietrich H. Voelker, professor emeritus at Clarkson University, Potsdam, NY, died on August 31, 1999. Born on November 8, 1911, he was a member of the Society for 34 years.

ANNOUNCING THE THIRD EDITION OF
A COMPREHENSIVE INTRODUCTION
TO DIFFERENTIAL GEOMETRY
by Michael Spivak

The main difference in the third edition is that the books are now typeset, rather than reproduced from typewritten copy, and the figures have all been redrawn. The actual content is practically the same, except for the correction of many errors and some rearrangement of material, and also the inclusion of a translation of Gauss' paper in Vol. 2.

Prices for the third edition:

- Volume 1 $35.00 (ISBN 0-914098-70-5)
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- Volume 3 $35.00 (ISBN 0-914098-72-1)
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Mathematics Opportunities

NSF Research Equipment Programs

The National Science Foundation (NSF) has announced two solicitations for funding of equipment for research: SCREMS (Scientific Computing Research Environments for the Mathematical Sciences) and MRI (Major Research Instrumentation). Both programs have the same deadline date, January 18, 2000.

The SCREMS program plans to make a limited number of grants for the purchase and support of computing equipment dedicated to research in the mathematical sciences. The total discounted cost of the equipment portion should be at least $40,000. Some awards may be as high as $200,000, provided a case is made for substantial impact and cost-effectiveness. The Division of Mathematical Sciences (DMS) expects to provide about $1 million for this activity in fiscal year 2000, pending availability of funds. In fiscal year 1999, 14 awards were made, totaling about $800,000.

The MRI program is designed to improve the condition of scientific and engineering equipment for research and research training in academic institutions. Proposals submitted in response to this program solicitation will be competing for about $50 million in fiscal year 2000. MRI is an NSF-wide program, whereas SCREMS is restricted to proposals from mathematical sciences departments. An institution may submit only two proposals for instrument acquisition in response to the MRI solicitation, plus a third for instrument development. Accordingly, groups of mathematical scientists might find it useful to communicate with related groups in their institutions for preparation and submission of such joint proposals or proposals in which mathematical scientists might participate.

Proposers and institutions are urged to apply through MRI if possible; the DMS will have all equipment proposals (SCREMS and MRI) reviewed together, and there will be no disadvantage to proposals that apply through the MRI. Identical proposals may not be sent to both programs. Nevertheless, proposals that do not receive MRI funding may still receive SCREMS funding in the current competition.


—From DMS announcement

News from the IMA

The Institute for Mathematics and its Applications (IMA) announces a workshop for graduate students on the topic Mathematical Modeling in Industry, to be held July 19-28, 2000. Thirty-six students will be selected to participate in the workshop. They will work in teams on real-world industrial problems under the guidance of tutors from industry. Graduate students and advanced undergraduates are invited to apply. Selection criteria will be based on background and statement of interest as well as geographic and institutional diversity. Women and minorities are especially encouraged to apply. Local living expenses will be covered by the IMA.

Details on the project topics and application procedure are available at the IMA's Web site, http://www.ima.umn.edu/modeling/ or by contacting ima-staff@ima.umn.edu. The postal address is: Institute for Mathematics and its Applications, University of Minnesota, 400 Lind Hall, 207 Church Street, SE, Minneapolis, MN 55455. The deadline for applications is April 15, 2000.

—From an IMA announcement
AMS-AAAS Mass Media Fellowships

The American Association for the Advancement of Science sponsors the Mass Media Science and Engineering Fellows Program, through which graduate students work during the summer in major media outlets. The AMS provides support each year for one or two graduate students in the mathematical sciences to participate in the program. In the past three years, the AMS-sponsored fellows have held positions at Business Week, National Geographic Television, and Time magazine.

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

Mathematical sciences faculty are urged to make their graduate students aware of this program. The deadline to apply for fellowships for the summer of 2000 is January 15, 2000. The fellowship application is available online at http://ehri.aas.org/ehri/ (click the “Projects” link). For more information contact Katrina Malloy, AAAS Mass Media Fellows Program, 1200 New York Ave, NW, Washington DC 20005; telephone 202-326-6670; fax 202-371-9849; or the AMS Washington Office, 1527 Eighteenth Street, NW, Washington DC 20036; telephone 202-588-1100; fax 202-588-1853; e-mail: amscd@ams.org.

—Allyn Jackson

2000 Prize for Achievement in Information-Based Complexity

The second annual Prize for Achievement in Information-Based Complexity consists of $3,000 and a plaque to be awarded at a suitable location. The prize committee will consist of Erich Novak, Joseph F. Traub, and Henryk Woźniakowski. Anyone other than current members of the prize committee is eligible. The members of the prize committee would appreciate nominations for the prize. However, a person does not have to be nominated to win the award.

The deadline for nominations for the award is March 31, 2000. The achievement can be based on work done in a single year, over a number of years, or over a lifetime. It can be published in any journal, number of journals, or monographs.

Nominations for the prize may be sent to Joseph Traub, traub@cs.columbia.edu.

—Joseph F. Traub

News from the Institut Mittag-Leffler

The board of the Mittag-Leffler Institute invites tentative proposals and inquiries for the scientific programs of the academic years 2002-03, 2003-04, and beyond. The Institute runs programs in specialized areas of mathematics to which leading scientists in the area are invited. In a concurrent junior visiting program postdocs and advanced graduate students are invited to participate. The programs can run for the whole year, or be of semester length. Around ten senior visitors are in residence at any given time. The minimum length of stay is one month, and it is expected that two or three leading mathematicians will stay for at least a semester each.

The selection criteria for proposals are scientific strength and timeliness and the degree to which the program would benefit mathematical research in Scandinavia, including Finland and Iceland. Recent and planned future programs can be found at http://www.ml.kva.se/history.html.

The scientific programs are led by a steering committee of two to four persons which will work closely with the director and which will suggest invitees to the board. It is expected that at all times during the period of the program at least one member of the committee be present.

The two semesters of the academic year are September 1 to December 31, and January 15 to June 15. The Institute is housed in a patrician nineteenth century villa in a suburb of Stockholm. Visitors are housed on the grounds.

Tentative proposals should contain: 1) a description of the intended area of specialization, 2) the proposed time and duration of the program, 3) the names of the proposed committee, 4) a list of possible invitees, and 5) a description of the Scandinavian connection.

Tentative proposals should be sent to the director, Kjell-Ove Widman, e-mail: widman@ml.kva.se, or to the chairman of the board, Christer O. Kiselman, e-mail kiselman@math.uu.se, not later than February 15, 2000.

The executive committee of the Institute, together with the advisors to the board, will select a small number of the tentative proposals and invite the proposers to submit a complete application, the deadline for which will be April 15, 2000. The board of the institute will then make a decision in May 2000.

Potential proposers are asked to note that the board may select and decide on programs for more than one year, whence tentative proposals, or even informal ideas, for the years 2003-04 and 2004-05 are encouraged.

For further information, consult the Institute's home page, http://www.ml.kva.se/, or contact the director, Kjell-Ove Widman, e-mail: widman@ml.kva.se. The postal address is Institut Mittag-Leffler, Auravågen 17, S-182 62 Djursholm, Sweden.

—Institut Mittag-Leffler announcement
United States to Host International Mathematical Olympiad

The United States will be the host country for the 2001 International Mathematical Olympiad. Six-member teams of mathematicians from high schools in 80 to 100 nations are expected to compete in the Olympiad.

Hosted by the National Science Foundation, the Department of Education, and the National Security Agency, the two-day final competition will be held in July 2001 in Washington, DC. This is the first time in twenty years that the United States will host the International Mathematical Olympiad. Preliminary competitions leading to the selections of the national teams will be held in students’ home countries.

—From an NSF announcement

Final Version of Data Disclosure Regulation Issued

The Office of Management and Budget (OMB) has issued the final revision of a regulation pertaining to public access to data produced through grants by federal agencies. Last year this regulation caused a great deal of concern in the scientific community and generated 12,000 comments sent to OMB.

The final version of the regulation may be found in the October 8, 1999, issue of the Federal Register. It is available on the Web at http://www.access.gpo.gov/su_docs/fedreg/a991008c.html (look for the heading “Management and Budget Office”). Further information about the regulation may be found in the Notices, June/July 1999, pages 690-691; and November 1999, page 1244.

—Allyn Jackson

Departments Coordinate Job Offer Deadlines

A group of mathematical sciences departments is again this year coordinating their deadlines for acceptance of postdoctoral job offers. The purpose is to ensure that applicants do not have to make decisions about job offers before the results of the National Science Foundation postdoctoral fellowship competition are announced.

The departments have agreed not to require applicants who are less than two years past the Ph.D. to decide on a job offer before Monday, February 7, 2000. This is aimed at postdoctoral positions, not tenure-track offers. The list of participating departments, together with additional information, may be found on the Web site http://www.ams.org/employment/postdoc-offers.html.

—Allyn Jackson

Sunley Appointed Interim Head of NSF Education

The National Science Foundation (NSF) has named Judith Sunley as interim assistant director of the Education and Human Resources Directorate, replacing Luther Williams. Sunley’s appointment became effective August 15, 1999.
Since joining NSF, Sunley has served as assistant to the director for Science Policy and Planning, executive officer for Mathematical and Physical Sciences, division director for Mathematical Sciences, and deputy division director and program director in the Division of Mathematical Sciences. Sunley has been the recipient of both the Presidential Rank Award for Meritorious Service and for Distinguished Service. She received her Ph.D. in mathematics from the University of Maryland (1971) and her M.S. (1968) and B.S. (1967) from the University of Michigan.

—Allyn Jackson

Congressional Lunch Briefing

The AMS Washington Office held its annual lunch briefing on mathematics for members of Congress and staff on September 29, 1999, in the Rayburn House Office Building on Capitol Hill.

Despite the frantic pressures of appropriations deadlines in the last week of the government’s fiscal year, a satisfyingly large crowd of around sixty, including two members of Congress and many congressional staff, turned up to hear De Witt Sumners of Florida State University speak on “Calculating the Secrets of Life: Mathematics and Medicine”. Congressman Allen Boyd, R-FL, introduced Sumners, and AMS president Felix Browder acted as master of ceremonies. Also present was Congressman Vernon J. Ehlers, member of the House Committee on Science and, since the death of Congressman George Brown, the current “champion of science” in the House of Representatives.

Presidents of several scientific societies also attended: the American Chemical Society, the American Physical Society, the American Astronomical Society, the Materials Research Society, the Society for Industrial and Applied Mathematics, and the Federation of American Societies for Experimental Biology. The AMS, working with the other societies, had arranged for them to be in town for a day of meetings with National Science Foundation director Rita Colwell and members of Congress with responsibility for overseeing science funding and policy, including House Science Committee chairman James Sensenbrenner; Ralph M. Hall, ranking Democrat on the Science Committee; and legislative assistants for the important appropriations subcommittee on VA/HUD/Independent Agencies.

Sumners held the crowd’s attention with a lively illustrated discussion of a few areas of medical research, indicating how mathematics plays a role in this research. Noting that the human body is an extremely complicated biological system that generates extraordinary data, he pointed out that mathematics is needed to build models and navigation tools in order to turn this huge amount of data into useful knowledge. Mathematics is used to compute the structure and function of life-sustaining enzymes that operate on DNA. These same enzymes that sustain life are also involved in life-threatening diseases, such as cancer; understanding structure and function opens the door to therapy. Geometry is used to build sophisticated heart models so that better heart defibrillators can be designed. Mathematics is also critical in relating brain architecture, as revealed by high-resolution MRI scans, to brain function, as revealed by positron emission tomography and functional magnetic resonance imaging scans.

—Monica Foulkes, AMS Washington Office

Priceless Archimedes Manuscript on Display

Nearly destroyed many times and more than a thousand years old, The Archimedes Palimpsest is one of the most valuable books in the world. Sold at Christie’s auction house for $2 million, this priceless manuscript now belongs to an anonymous collector. Through January 3, 2000, Chicago’s Field Museum will display this unique manuscript in the exhibition “Eureka! The Archimedes Palimpsest”. The book contains a compendium of mathematical treatises by Archimedes of Syracuse, the famous Greek mathematician born in 287 B.C. This will be the last showing to the public before the volume enters a five-year conservation program. This exhibition was organized by The Walters Art Gallery, Baltimore.

The Archimedes Palimpsest contains the only copy of the Method of Mechanical Theorems to survive into the twentieth century. When Danish philologist Johan Ludvig Heiberg discovered that the palimpsest contained this missing treatise, hidden under a religious text, it made front-page news in the New York Times on July 16, 1907. Containing the roots of modern calculus, the Method of Mechanical Theorems reveals a genius that parallels that of Einstein and Galileo. More than ninety years after its discovery, scholars and mathematicians still cannot explain how Archimedes arrived at the Method.

The Archimedes manuscript was written in the ancient city of Constantinople, now Istanbul, during the tenth century, over a thousand years after the great mathematician’s death. About two hundred years later, something remarkable happened: the book was cut up and covered over with another text. During the time of the crusades, religious books were in high demand, and parchment for these books was in short supply. The pages were cut in half, and a religious text was written sideways across the original manuscript. Because the Archimedes treatises were rubbed off and overwritten, it has been difficult until now to see their full contents. The hidden text can be seen clearly in the exhibition through computer-aided digital enhancement and interactive ultraviolet light displays.

The Field Museum is located at 1400 South Lake Shore Drive in Chicago. For general museum information, call 312-922-9410, or 312-665-7009 TDD for the hearing impaired. The museum’s Web site may be found at http://www.fieldmuseum.org/.

—From Field Museum news release
CBMS2000 Survey Announced

The National Science Foundation (NSF) has announced funding of the Fall 2000 Conference Board on Mathematical Sciences (CBMS) survey (CBMS2000), the eighth in a series of quinquennial surveys and reports on undergraduate mathematical sciences education in the United States. In September of the year 2000, survey forms will be mailed to a stratified random sample of about 600 of the country's 2,400 mathematics departments in two- and four-year colleges and universities. Following the pattern of the previous CBMS surveys, publication of the CBMS2000 report is planned for early in 2002. (The report on the 1995 CBMS survey appeared as the second volume in the MAA Reports series).

CBMS2000 will collect longitudinal data on the national mathematical sciences faculty and on detailed enrollment patterns in a wide spectrum of undergraduate mathematical sciences courses. In addition, there will be questions about certain "topics of opportunity", chosen after consultation with many professional society committees. These topics include further study of the outcomes of calculus reform, a study of how undergraduate statistics is taught (and by whom), and an investigation of how K-8 teachers are prepared in mathematics during their college years.

To make suggestions about other topics of opportunity that should be studied by the CBMS2000 survey, please contact David Lutzer (Lutzer@math.wm.edu) or James Maxwell (jwm@ams.org), the codirectors of the CBMS2000 project; or Stephen Rodi (rodi@tenet.edu), the associate director for two-year colleges. Other members of the project steering committee are: Ray Collings, John Fulton, Carolyn Mahoney, Emily Puckette, Richard Scheaffer, and Elizabeth Stasny.

---David Lutzer and James Maxwell

DMS Employment Opportunities

Several of the technical staff of the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF) serve in one- or two-year visiting scientist or Inter-governmental Personnel Act appointments as program directors while on leave from universities, colleges, industry, or national laboratories. Since the timing of these positions is staggered, the division continually seeks talented applicants. In 2000 the division will be seeking to make appointments in all areas. Permanent program director appointments will also be considered.

The positions involve responsibility for the planning, coordination, and management of support programs for research (including multidisciplinary projects), infrastructure, and human resource development for the mathematical sciences. Normally this support is provided through merit-reviewed grants and contracts that are awarded to academic institutions and nonprofit, nonacademic research institutions.

Applicants should have a Ph.D. or equivalent training in a field of the mathematical sciences, a broad knowledge of one of the relevant disciplinary areas of the DMS, some administrative experience, a knowledge of the general scientific community, skill in written communication and preparation of technical reports, an ability to communicate orally, and several years of successful independent research normally expected of the academic rank of associate professor or higher. Skills in multidisciplinary research are highly desirable. Qualified women, ethnic/racial minorities, and/or persons with disabilities are strongly urged to apply. No person shall be discriminated against on the basis of race, color, religion, sex, national origin, age, or disability in hiring by the NSF.

Applicants should send a letter of interest and a vita to Bernard R. McDonald, Executive Officer, Division of Mathematical Sciences, National Science Foundation, 4201 Wilson Boulevard, Suite 1025, Arlington, Virginia 22230; telephone 703-306-1870; fax 703-306-0555.

---NSF announcement
Reference and Book List

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

Contacting the Notices
The preferred method for contacting the Notices is electronic mail. The editor is the person to whom to send articles and letters for consideration. Articles include feature articles, memorial articles, book reviews and other communications, columns for “Another Opinion”, and “Forum” pieces. The editor is also the person to whom to send news of unusual interest about mathematics research.

The managing editor is the person to whom to send items for “Mathematics People”, “Mathematics Opportunities”, “For Your Information”, “Reference and Book List”, and “Mathematics Calendar”. Requests for permissions, as well as all other inquiries, go to the managing editor.

The electronic-mail addresses are notices@math.sunysb.edu in the case of the editor and notices@ams.org in the case of the managing editor. The fax numbers are 631-751-5730 for the editor and 401-331-3842 for the managing editor (please indicate “Notices managing editor” on the fax cover sheet). Postal addresses may be found in the masthead.

Information for Notices Authors
The Notices welcomes unsolicited articles for consideration for publication, as well as proposals for such articles. The following provides general guidelines for writing Notices articles and preparing them for submission.

Notices readership. The Notices goes to about 30,000 subscribers worldwide, of whom about 20,000 are in North America. Approximately 8,000 of the 20,000 in North America are graduate students who have completed at least one year of graduate school. All readers may be assumed to be interested in mathematics research, but they are not all active researchers.

Notices feature articles. Feature articles may address mathematics, mathematical news and developments, mathematics history, issues affecting the profession, mathematics education at any level, the AMS and its activities, and other such topics of interest to Notices readers. Each article is expected to have a large target audience of readers, perhaps 5,000 of the 30,000 subscribers. Authors must therefore write their articles for non-experts, rather than experts or would-be experts. In particular the

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

AMS e-mail addresses
November 1999, p. 1267

AMS Ethical Guidelines
June 1995, p. 694

AMS officers and committee members
November 1999, p. 1269

Board on Mathematical Sciences and Staff
April 1999, p. 479; June/July 1999, p. 696

Bylaws of the American Mathematical Society
November 1999, p. 1250

Information for Notices authors
January 2000, p. 69

Mathematics Research Institutes contact information
May 1999, p. 580; August 1999, p. 804

National Science Board
January 2000, p. 71

NSF Mathematical and Physical Sciences Advisory Committee
March 1999, p. 362

Officers of the Society 1998 and 1999 (Council, Executive Committee, Publications Committees, Board of Trustees)
May 1999, p. 583

Program officers for federal funding agencies (DoD, DoE, NSF)
October 1999, p. 1075; November 1999, p. 1247
Reference and Book List

Mathematics articles in the Notices are expository. The language of the Notices is English. Most feature articles, including those on mathematics, are expected to be of long-term value and should be written as such. Ideally each article is expository. The language of the Notices puts its topic in a context, providing some history and other orientation for the reader and, as necessary, relating the subject matter to things that readers are likely to understand. In most cases, articles should progress to dealing with contemporary matters, not giving only historical material. The articles that are received the best by readers tend in part to relate different areas of mathematics to each other.

By design the Notices is partly magazine and partly journal, and authors’ expository styles should take this into account. For example, many readers want to understand the mathematics articles without undue effort and without consulting other sources.

Mathematics feature articles in the Notices are normally six to nine pages, sometimes a little longer. Shorter articles are more likely to be read fully than are longer articles. The first page is 400 or 500 words, and subsequent pages are about 800 words. From this one should subtract an allowance for figures, photos, and other illustrations, and an appropriate allowance for any displayed equations and any bibliography.

Form of articles. Except with very short articles, authors are encouraged to use section headings and subsection headings to help orient readers. Normally there is no section heading at the beginning of an article. Despite the encouraged use of internal headings, the assigning of numbers to sections and subsections is not permitted in any article.

The bibliography should be kept short. In the case of mathematics articles, bibliographies are normally limited to about ten items and should consist primarily of entries like books in which one may do further reading. To help readers who might want lists of recent literature, an author might include a small number of recent publications with good bibliographies.

Editing process. Most articles that are destined to be accepted undergo an intensive editing process. The purposes of this process are to ensure that the target audience is as large as practicable, that the content of the article is clear and unambiguous, and that the article is relatively easy to read. Usually it is the members of the editorial board who are involved in this process. Sometimes outside referees are consulted.

Preparation of articles for submission. The preferred form for submitted articles is as electronic files. Authors who cannot send articles electronically may send the articles by fax or by postal mail.

Articles with a significant number of mathematical symbols are best prepared in TeX. For TeX files, there is no special style file because the TeX gets converted to something else during the production process. AMS-TeX with the style file amsppt.sty works best with this production process, and plain TeX is a close second. LaTeX and AMSLTEx files are acceptable but require extra processing. In any case the use of nonstandard supplementary files and complex sequences of TeX definitions is discouraged. Authors are advised to keep lines of mathematical displays relatively short so that they will fit within Notices columns and not have to be adjusted in the production process. For the handling of figures and other illustrations, please consult the editor.

Articles without a significant number of mathematical symbols may be prepared as text files or in Microsoft Word. In the case of files prepared in Microsoft Word, it is advisable to send both the file and a fax of a printout.

Upcoming Deadlines

January 1, 2000: Deadline for applications for the Fulbright Scholar Program NATO advanced research fellowships and institutional grants. For more information, contact the USIA Fulbright Scholar Program, Council for International Exchange of Scholars, 3007 Tilden Street, NW, Suite 5L, Box GNEWS, Washington, DC 20008-3009; telephone 202-686-7877; World Wide Web http://www.cies.org/.


January 14, 2000: Deadline for applications for the 2000-01 “Mathematics in Multimedia” program of the IMA. For details, see the IMA’s Web site at http://www.ima.umn.edu/programs.html, or contact the Institute for Mathematics and its Applications, University of Minnesota, 400 Lind Hall, 207 Church Street, Minneapolis, MN 55455; telephone 612-624-6066; e-mail to Fred Dullies, Associate Program Director, at dullies@ima.umn.edu.

January 15, 2000: Deadline for the first competition for NRC Research Associateships. For details, see the NRC Web site at http://www.national-academies.org/rap/, or contact the National Research Council, Associateship Programs (TJ 2114/D3), 2101 Constitution Avenue, NW, Washington, D.C. 20418; telephone 202-334-2760; fax 202-334-2759; e-mail: rap@nas.edu.


January 18, 2000: Deadline for the NSF SCREMS and MRI research equipment programs. For details, see “Mathematics Opportunities” in this issue.

February 1, 2000: Deadline for applications for NSF/AWM Mentoring Travel Grants for Women. Further information may be obtained by telephone at 301-405-7892 or by e-mail at awm@math.umd.edu.

February 1, May 1, October 1, 2000: Deadlines for applications for NSF/AWM Travel Grants for Women. For further information and details on applying, see the AWM Web site.
National Science Board

The National Science Board is the policymaking body of the National Science Foundation. The names and affiliations of the board members follow.

John A. Armstrong
Vice President for Science & Technology (Retired) International Business Machines (IBM)

Pamela A. Ferguson
Professor of Mathematics
Grinnell College
Grinnell, IA

Mary K. Gailliard
Professor of Physics
University of California Berkeley, CA

Sanford D. Greenberg
Chairman & CEO
TEI Industries, Inc.
Washington, DC

M. R. C. Greenwood
Chancellor
University of California Santa Cruz, CA

Stanley V. Jaskolski
Vice President
Eaton Corporation
Cleveland, OH

Anita K. Jones
University Professor
Department of Computer Science
University of Virginia
Charlottesville, VA

Eamon M. Kelly (NSB Chair)
President Emeritus and Professor
Paxon Center for International Development and Technology Transfer
Tulane University
New Orleans, Louisiana

George M. Langford
Professor
Department of Biological Science
Dartmouth College
Hanover, NH

Jane Lubchenko
Wayne and Gladys Valley
Professor of Marine Biology and
Distinguished Professor of Zoology
Oregon State University
Corvallis, OR

Eve L. Menger
Director, Characterization Science & Services (retired)
Corning Incorporated
Corning, NY

Joseph A. Miller Jr.
Senior Vice President for R&D
Chief Technology Officer
E. I. du Pont de Nemours & Co.
Wilmington, DE

Claudia I. Mitchell-Kernan
Vice Chancellor, Academic Affairs and Dean, Graduate Division
University of California
Los Angeles, CA

Diana S. Natalicio
(NSB Vice Chairman)
President
University of Texas
El Paso, TX

Robert C. Richardson
Vice Provost for Research
Professor of Physics
Cornell University
Ithaca, NY

Vera C. Rubin
Staff Member
Department of Terrestrial Magnetism
Carnegie Institution of Washington, DC

Maxine Savitz
General Manager
Allied Signal Inc., Ceramic Components
Torrance, CA

Luís Sequeira
J. C. Walker Professor Emeritus
Department of Bacteriology and Plant Pathology
University of Wisconsin
Madison, WI

Robert M. Solow
Institute Professor Emeritus
Massachusetts Institute of Technology
Cambridge, MA
Bob H. Suzuki
President
California State Polytechnic
University
Pomona, CA

Richard Tapia
Professor
Department of Computational
& Applied Mathematics
Rice University
Houston, TX

Chang-Lin Tien
Distinguished Professor of Engineering
Department of Mechanical Engineering
University of California
Berkeley, CA

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Senior Scientist and Head
Climate Change Research Section
National Center for Atmospheric Research
Boulder, CO

John A. White Jr.
Chancellor
University of Arkansas
Fayetteville, AR

Ex-officio Members
Rita R. Colwell (Chairman, Executive Committee)
Director
National Science Foundation
Arlington, VA

Marta Cehelsky
Executive Officer
National Science Board
National Science Foundation,
Arlington, VA


Book List
The Book List highlights books that have mathematical themes and hold appeal for a wide audience, including mathematicians, students, and a significant portion of the general public.

When a book has been reviewed in the Notices, a reference is given to the review. Generally the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers’ attention to older books. Suggestions for books to include on the list may be sent to the Managing Editor, e-mail: notices@ams.org.


The Language of Mathematics: Making the Invisible Visible, by Keith...


2000 AMS Election

Nominations by Petition

Vice President or Member at Large

One position of vice president and member of the Council ex officio for a term of three years is to be filled in the election of 2000. The Council intends to nominate at least two candidates, among whom may be candidates nominated by petition as described in the rules and procedures.

Five positions of member at large of the Council for a term of three years are to be filled in the same election. The Council intends to nominate at least ten candidates, among whom may be candidates nominated by petition in the manner described in the rules and procedures.

Petitions are presented to the Council, which, according to Section 2 of Article VII of the bylaws, makes the nominations. The Council of 23 January 1979 stated the intent of the Council of nominating all persons on whose behalf there were valid petitions.

Prior to presentation to the Council, petitions in support of a candidate for the position of vice president or of member at large of the Council must have at least fifty valid signatures and must conform to several rules and operational considerations, which are described below.

Editorial Boards Committee

Two places on the Editorial Boards Committee will be filled by election. There will be four continuing members of the Editorial Boards Committee.

The President will name at least four candidates for these two places, among whom may be candidates nominated by petition in the manner described in the rules and procedures.

The candidate’s assent and petitions bearing at least 100 valid signatures are required for a name to be placed on the ballot. In addition, several other rules and operational considerations, described below, should be followed.

Nominating Committee

Three places on the Nominating Committee will be filled by election. There will be six continuing members of the Nominating Committee.

The President will name at least six candidates for these three places, among whom may be candidates nominated by petition in the manner described in the rules and procedures.

Rules and Procedures

Use separate copies of the form for each candidate for vice president, member at large, or member of the Nominating and Editorial Boards Committees.

1. To be considered, petitions must be addressed to Robert J. Daverman, Secretary, American Mathematical Society, 312 Ayres Hall, University of Tennessee, Knoxville, TN 37996-1330, and must arrive by 28 February 2000.

2. The name of the candidate must be given as it appears in the Combined Membership List (CML). If the name does not appear in the list, as in the case of a new member or by error, it must be as it appears in the mailing lists, for example on the mailing label of the Notices.

3. The petition for a single candidate may consist of several sheets each bearing the statement of the petition, including the name of the position, and signatures. The name of the candidate must be exactly the same on all sheets.

4. On the next page is a sample form for petitions. Copies may be obtained from the secretary; however, petitioners may make and use photocopies or reasonable facsimiles.

5. A signature is valid when it is clearly that of the member whose name and address is given in the left-hand column.

6. The signature may be in the style chosen by the signer. However, the printed name and address will be checked against the Combined Membership List and the mailing lists. No attempt will be made to match variants of names with the form of name in the CML. A name neither in the CML nor on the mailing lists is not that of a member. (Example: The name Robert J. Daverman is that of a member. The name R. Daverman appears not to be.)

7. When a petition meeting these various requirements appears, the secretary will ask the candidate to indicate willingness to be included on the ballot. Petitioners can facilitate the procedure by accompanying the petitions with a signed statement from the candidate giving consent.
The undersigned members of the American Mathematical Society propose the name of

as a candidate for the position of (check one):

☐ Vice President
☐ Member at Large of the Council
☐ Member of the Nominating Committee
☐ Member of the Editorial Boards Committee


Name and address (printed or typed)

__________________________________________  Signature

__________________________________________  Signature

__________________________________________  Signature

__________________________________________  Signature

__________________________________________  Signature
How to use this form

1. Using the facing page or a photocopy, (or a TeX version which can be downloaded from the e-math "Employment Information" menu, http://www.ams.org/employment/), fill in the answers which apply to all of your academic applications. Make photocopies.

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

Add this Cover Sheet to all of your Academic Job Applications

The Joint Committee on Employment Opportunities has adopted the cover sheet on the facing page as an aid to job applicants and prospective employers. The form is now available on e-math in a TeX format which can be downloaded and edited. The purpose of the cover form is to aid department staff in tracking and responding to each application.

Mathematics Departments in Bachelor's, Master's and Doctorate granting institutions have been contacted and are expecting to receive the form from each applicant, along with any other application materials they require. Obviously, not all departments will utilize the cover form information in the same manner. Please direct all general questions and comments about the form to:
emp-info@ams.org or call the Professional Programs and Services Department, AMS, at 800-321-4267 extension 4105.

JCEO Recommendations for Professional Standards in Hiring Practices

The JCEO believes that every applicant is entitled to the courtesy of a prompt and accurate response that provides timely information about his/her status. Specifically, the JCEO urges all institutions to do the following after receiving an application:

(1) Acknowledge receipt of the application—immediately; and
(2) Provide information as to the current status of the application, as soon as possible.

The JCEO recommends a triage-based response, informing the applicant that he/she
(a) is not being considered further;
(b) is not among the top candidates; or
(c) is a strong match for the position.
This form is provided courtesy of the American Mathematical Society.

This cover sheet is provided as an aid to departments in processing job applications. It should be included with your application material.

Please print or type. Do not send this form to the AMS.

| Academic Employment in Mathematics |

| AMS STANDARD COVER SHEET |

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<th>Indicate the position for which you are applying and position posting code, if applicable</th>
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<th>If unsuccessful for this position, would you like to be considered for a temporary position?</th>
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<td>□ Yes  □ No  If yes, please check the appropriate boxes.</td>
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<td>Postdoctoral Position  2+ Year Position  1 Year Position</td>
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<th>List the names, affiliations, and e-mail addresses of up to four individuals who will provide letters of recommendation if asked. Mark the box provided for each individual whom you have already asked to send a letter.</th>
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1991
Mathematics
Subject
Classification

| 00 | General          | 52 | Convex and discrete geometry |
| 01 | History and biography | 53 | Differential geometry |
| 03 | Logic and foundations | 54 | General topology |
| 04 | Set theory          | 55 | Algebraic topology |
| 05 | Combinatorics        | 57 | Manifolds and cell complexes |
| 06 | Order, lattices, ordered algebraic structures | 58 | Global analysis, analysis on manifolds |
| 08 | General mathematical systems | 60 | Probability theory and stochastic processes |
| 11 | Number theory        | 62 | Statistics |
| 12 | Field theory and polynomials | 65 | Numerical analysis |
| 13 | Commutative rings and algebras | 68 | Computer science |
| 14 | Algebraic geometry   | 70 | Mechanics of particles and systems |
| 15 | Linear and multilinear algebra, matrix theory | 73 | Mechanics of solids |
| 16 | Associative rings and algebras | 76 | Fluid mechanics |
| 17 | Nonassociative rings and algebras | 78 | Optics, electromagnetic theory |
| 18 | Category theory, homological algebra | 80 | Classical thermodynamics, heat transfer |
| 19 | K-theory             | 81 | Quantum theory |
| 20 | Group theory and generalizations | 82 | Statistical mechanics, structure of matter |
| 22 | Topological groups, Lie groups | 83 | Relativity and gravitational theory |
| 26 | Real functions       | 85 | Astronomy and astrophysics |
| 28 | Measure and integration | 86 | Geophysics |
| 30 | Functions of a complex variable | 90 | Economics, operations research, programming, games |
| 31 | Potential theory     | 92 | Biology and other natural sciences, behavioral sciences |
| 32 | Several complex variables and analytic spaces | 93 | Systems theory, control |
| 33 | Special functions    | 94 | Information and communication, circuits |
| 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, optimal control |
| 51 | Geometry             |
Volume 5, 1999 (up to date)

D. Novikov and S. Yakovenko, Tangential Hilbert problem for perturbations of hyperelliptic Hamiltonian systems

Gaven J. Martin, The Hilbert-Smith conjecture for quasiconformal actions

Steffen König and Changchang Xi, Cellular algebras and quasi-hereditary algebras—a comparison

Robert Brooks and Eran Makover, The first eigenvalue of a Riemann surface

Elon Lindenstrauss, Pointwise theorems for amenable groups

Brian Marcus and Selim Tuncel, Powers of positive polynomials and codings of Markov chains onto Bernoulli shifts

Harsh Pittie and Arun Ram, A Pieri-Chevalley formula in the K-theory of a G/B - bundle

Marcus du Sautoy, Zeta functions and counting finite p-groups

Imre Csiszar, Consistency of the BIC order estimator

Gennady Bachman, Exponential sums with multiplicative coefficients


ERA-AMS publishes high-quality research announcements of significant advances in all branches of mathematics. Authors may submit manuscripts to any editor. All papers are reviewed, and the entire Editorial Board must approve the acceptance of any paper. Papers are posted as soon as they are accepted and processed by the AMS.

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For more information, contact: cust-serv@ams.org
1-800-321-4267, 1-401-455-4000,
fax 1-401-455-4046
Mathematics Calendar

The most comprehensive and up-to-date Mathematics Calendar information is available on e-MATH at http://www.ams.org/mathcal/.

January 2000

27-29 Congresso RSME2000 de la Real Sociedad Matematica Espanola, Universidad Complutense de Madrid, Madrid, Spain.

Speakers: F. Chamizo (Univ. Autonoma de Madrid), O. Garcia-Prada (Univ. Autonoma Madrid), J. J. Velazquez (Univ. Complutense de Madrid), R. de la Llave (Univ. of Texas-Austin), M. Melnikov (Univ. Autonoma de Barcelona), S. Montiel (Univ. de Granada), M. Sanz (Univ. de Barcelona), L. Caffarelli (Univ. of Texas-Austin), J. H. Conway (Princeton Univ).

Information: http://www.mat.ucm.es/rse2000/Carlos_andradas@mat.ucm.es.

February 2000

1-5 Harmonic Maps and Minimal Immersions, Caparide, Lisbon, Portugal.

Speakers: F. Burstall (Bath), J. Eschenburg (Augsburg), B. Fuglede (Copenhagen), A. Gestel (Dusseldorf), S. Gudmundsson (Lund), P. Romon (Marne-la-Vallee), B. Lackey (Hull), H. Rosenberg (Paris), M. Struwe (Zurich), G. Vavil (Pavia), M. Weber (Bon), J. Wood (Leeds).

Application Dates: People wishing to participate in the workshop should apply by 5 December 1999. We are planning a limited number of 20-minute talks. If you wish to present such a talk please send the title and the abstract by 5 December 1999 so that it can be submitted to the Scientific Committee.

Information: If you wish to receive the application form and details on hotel reservations please send an email message to h2s2000@mat.ucm.es or send a letter to M. A. Machado, CMAF, Universidade de Lisboa, Av. Prof. Gama Pinto 2, 1649-003, Lisboa Portugal; http://www.cmaf.ucp.pt/Matem/Events/Workshops/2000/h2s2000/ Includes the application and hotel reservation forms.

12-13 Workshop on Nonlinear Dispersive Equations, Stanford University, Palo Alto, California.

Focus: The goal of this meeting is to summarize classical and recent results on dispersive differential equations and to present some open problems in the area. Graduate students and postdocs are encouraged to attend.

Speakers: J. Bourgain (IAS), C. Kenig (Univ. of Chicago), and F. Merle (Univ. de Cergy-Pontoise) will each give two lectures. These lectures will be followed by presentations by J. Benson (Stanford Univ.), M. Keel (Caltech), K. Nakamura (Kobe Univ.), H. Takaoka (Tokyo Univ.), T. Tao (UCLA), and N. Tzvetkov (Univ. de Paris-Sud).


March 2000

13-16 Geometry and Applications, Sobolev Institute of Mathematics, Novosibirsk, Russia.

Topics: The conference is devoted to the 70th anniversary of the birthday of Victor Toponogov. The main subjects of the conference are: geometry (Riemannian, algebraic, and discrete geometry), geometrical questions of analysis (including differential equations), topology, applications (mathematical methods of chemistry in particular).

Organized by: Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences and Novosibirsk State Univ.

Program Committee: Yu. G. Reshetnyak (chair, Novosibirsk, Russia), A. A. Borisenko (Khar'kov, Ukraine), Yu. D. Burago (St. Petersburg, Russia), V. M. Gol'dshtein (Beer-Sheva, Israel), M. L. Gromov (Paris, France), I. G. Nikolaev (Urbana-Champaign, USA), S. P. Novikov (Maryland, USA; Moscow, Russia), A. V. Pogorelov (Khar'kov, Ukraine).

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

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

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

In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the Notices prior to the meeting in question. To achieve this, listings should be received in Providence six months prior to the scheduled date of the meeting. The complete listing of the Mathematics Calendar will be published only in the September issue of the Notices. The March, June, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.

The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through e-MATH on the World Wide Web. To access e-MATH, use the URL: http://e-math.ams.org/ (or http://www.ams.org/). For those with VT100-type terminals or for those without WWW browsing software, connect to e-MATH via Telnet (telnet e-math.ams.org; login and password e-math) and use the Lynx option from the main menu.)
Kh. Sabitov (Moscow, Russia).

Local Organizing Committee: V. V. Ver- 
shin (chair), V. A. Alexandrov, S. I. Fadeev, 
A. S. Romanov, V. A. Sharafutdinov, I. A. 
Taimanov, S. A. Treskov, E. P. Volokitin.

Information: See http://math.nsc.ru/ 
conference/geomap, or send e-mail to 
Geomap@math.nsc.ru.

* 16 Marvin Rosenblum Day, University of 
Virginia, Charlottesville, Virginia.

Speakers: J. Agler (San Diego), D. Z. Aror 
(Odessa), J. A. Ball (Blackburn), H. Widom 
(Santa Cruz).

Information: This one-day conference on 
March 16 will be run in conjunction with the 
Southeastern Analysis Meeting on March 17 
edu/seea16/ for information concerning 
both meetings.

* 17-18 Southeastern Analysis Meeting, 
University of Virginia, Charlottesville, 
Virginia.

Information: The Southeastern Analysis 
Meeting on March 17-18 will be preceded 
by a one-day conference on March 16 to 
 honor Marvin Rosenblum on the 
ocasion of his retirement. See http:// 
www.math.virginia.edu/seea16/ for 
information concerning both meetings.

* 31-April 2 Combinatorics: The South- 
Central Regional Combinatorics Confe- 
rence, Texas A&M University, College Sta-

tion, Texas.

Speakers (preliminary): M. Bayer (Univ. 
of Kansas), J. Kung (U. of North Texas), 
J. Oxley (Louisiana State Univ.), W. Trotter 
(Arizona State Univ.), D. Welsh (Oxford), 
C. Yan (Texas A&M Univ.), and G. Ziegler 
(Technische Univ., Berlin).

Organizers: L. Anderson and J. McCam-
mond, Texas A&M Univ.

edu/~jon.mccamond/combinatexa/.

April 2000

* 15 50th Algebra Day, Carleton University, 
Ottawa, Canada.

Organizer: Ottawa- Carleton Institute for 
Mathematics and Statistics.

Speakers: P. Gabriel (Zurich), G. Luszti 
(MIT), R. Moody (Alberta), E. Zelmanov (Yale).

Information: V. Drab, Carleton Univ.; 
fax: (613) 520-2166; e-mail: vdlab@math. 
carleton.ca.

* 23-29 Spring School on Functional 
Analysis, Paseky nad Jizerou, Czech Republic.

Organizer: Faculty of Mathematics and 
Physics of Charles University.

Program: A series of lectures on nonlinear 
analysis in Banach spaces will be delivered 
by A. Jaffe (Technion - Israel Inst. of Tech., 
Haifa), T. Rockafellar (Univ. of Washington, 
Seattle), P. Loewen (Univ. of British Colum 
bia, Vancouver), and R. Deville (Univ. de 
Bordeaux, France).

Information: See the Web site http://www. 
karlin.mff.cuni.cz/katedra/kma/.

* 28-30 Riviere-Fabes Symposium on Analy-
sis and PDE, University of Minnesota, 
Minneapolis, Minnesota.

Speakers: L. A. Caffarelli (Univ. of Texas-
Austin), L. C. Evans (Univ. of Calif.-Berkeley), 
F. L. Nazarov (Michigan State Univ.-East Lon-
ingen), S. Salsa (Politecnico di Milano), G. 
Staffilani (Stanford Univ.), C. Thiele (Univ. of 
Calif.-Los Angeles).

Contact: M. Saflonov, Chair, Organizing 
Committee, School of Mathematics, Univ. 
of Minnesota, 127 Vincent Hall, 206 Church 
St. NE, Minneapolis, MN 55455; saflonov@ 
math.umn.edu; tel: 612-625-8571.

May 2000

* 28-June 3 Spring School on Analysis, 
Paseky nad Jizerou, Czech Republic.

Program: The program will consist of 
series of lectures on some recent tech-
niques in harmonic analysis. The lectures 
will be given by P. Tchernov (Michigan State 
Univ.).

Information: For more information see the 
cz/katedra/kma/.

June 2000

* 7-11 Ph.D. Euroconference on Complex 
Analysis and Holomorphic Dynamics, 
Platja d'Aro (Costa Brava), Catalonia, Spain.

Organizing Committee: N. Fagella (Univ. 
Barcelona), X. Jarque (Univ. Autonoma Bar-
celona), X. Massaneda (Univ. Barcelona), 
J. Ortega-Cerdá (Univ. Barcelona).

Organizer: Centre de Recerca Matemàtica 
(CRM).

Main Speakers: J. Buff (Toulouse, France), 
G. Buzzard (Cornell, USA), M. Jonsson 
(Michigan, USA), R. R. Marco (UCLA, USA 
& Paris VI, France), and S. Rohde (Seattle, 
USA).

Focus: Complex analysis and holomorphic 
dynamics are classical domains of the math-
ematical sciences which are going through 
an exciting phase of fruitful interaction. The 
Ph.D. Euroconference is intended to bring 
together young researchers in order to 
exchange and discuss work in progress and 
recent advances in these fields. This aim, 
the lectures given by the main speakers 
will be complemented with shorter talks 
and one session of exposition and discussion 
of open problems.

Information: The Ph.D. Euroconference 
is restricted to young researchers. According 
to the European Commission these are "re-
searchers up to an age limit of 35 at the 
time of the conference." More detailed infor-
mation about the "age criterion", financial 
support, short talks, etc., can be found on 
the conference Web page (available from 
escad2000/cad2000/). Alternatively, e-mail to 
cad2000@crm.es.

* 19-30 Probabilistic Combinatorics, 
University of Wyoming, Laramie, Wyoming.

Description: Probabilistic methods have 
recently become a powerful tool in 
combinatorics. The methods are useful in 
proving the existence of combinatorial structures 
satisfying certain properties. The lectures 
of J. H. Kim will treat the theory and 
applications of probabilistic methods with 
many examples. The sequence of lectures 
will be discussed by A. Sinclair will discuss 
the state-of-the-art random sampling algorithms 
and the tools necessary to analyze these algo-
rithms. The lectures of P. Tetali will focus 
on random walks on graphs, with particular 
emphasis on topics that have contributed 
significantly to the design and analysis of 
randomized algorithms. The intended 
attendees are graduate students and faculty in 
mathematics, computer science, statistics, 
and physics.

Speakers: J. H. Kim (Microsoft Research), 
A. Sinclair (UC-Berkeley), and P. Tetali (Georgia 
Inst. of Tech).

Sponsors: Rocky Mountain Mathematics 
Consorium and the Univ. of Wyoming.

Deadline: For applications/abstracts of talks: 
April 1, 2000.

Information: A. D. Porter or B. L. Shader, 
Math. Dept., Univ. of Wyoming, Laramie, 
WY 82071; e-mail: bsahder@uwyo.edu.

* 27-July 1 The 18th International Confer-
ence on Operator Theory, University of 
the West, Timisoara, Romania.

Program: The conference is organized jointly 
in Timisoara by the Institute of Mathematics 
of the Romanian Academy and the University 
of the West in Timisoara. It is devoted to 
operator theory, operator algebras and 
their applications (differential operators, 
complex functions, mathematical physics, 
matrix analysis, system theory, etc.)

Steering Committee: W. B. Arveson, N. 
K. Korovin, B. L. Shader, F. H. 
Vasilescu.

Information: About the conference, including 
registration forms, can be obtained at 
http://www.theota/cr/ or by contacting 
OTI8, Institute of Mathematics P.O. Box 1-764, 
70700 Bucharest, Romania; e-mail: 
ot18@inmar.ro.

* 30-July 2 2000 Centennial Vranceanu, 
Romanian Academy, Bucharest University, 
Romania.

Organizers: Romanian Academy, Section of 
Mathematics; and Bucharest University, 
Faculty of Mathematics.

Topics: Riemannian and pseudo-Riemann-
ian geometry, submanifold theory, Chen 
invariants, affine differential geometry, rel-

Mathematics Calendar

NOTICES OF THE AMS

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JANUARY 2000

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Mathematics Calendar

NOTICES OF THE AMS

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JANUARY 2000
**Mathematics Calendar**

**July 2000**

*13-17 International Conference on Foundations of Computational Mathematics in honor of Professor Steve Smale's 70th Birthday*, City University of Hong Kong, Kowloon, Hong Kong.

**Plenary Speakers:** V. I. Arnold, Univ. of Paris; K. C. Chang, Peking Univ.; L. Blum, Carnegie Mellon; M. Blum, Carnegie Mellon; F. Cucker, City Univ. of Hong Kong; I. Daubechies, Princeton; R. Graham, AT&T Labs Research; M. Gromov, IHES; H. W. Lenstra, Berkeley; J. Palis, IMPA, Rio de Janeiro; J. Renegar, Cornell; D. Ruelle, IHES; P. Sarnak, Princeton; M. Shub, IBM Yorktown Heights; J. Xia, Northwestern Univ.

**Organizing Committee:** F. Cucker, J. Palis, J. M. Rojas, M. Shub, R. Wong (chair).

**Information:** C. Lam, Conference Secretary, Liu Bie Ju Centre for Mathematical Sciences, City Univ. of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong, tel: (852) 2788 9816, fax: (852) 2788 7446, maininfo@cityu.edu.hk.

**19-26 Conference on Algebra and Algebraic Geometry with Applications**, Purdue University, West Lafayette, Indiana.

**Program:** Celebration of the seventieth birthday of Shreeram S. Abhyankar, Marshall Distinguished Professor of Mathematics, professor of computer science, professor of industrial engineering, Purdue University.

**Organizers:** C. Bajaj, C. Christensen, C. Cowen, P. Eakin, and A. Sathaye.

**Speakers:** Include 2 Fields Medalists, 5 Cole Prize winners, and 3 Steele Prize winners. Also, 17 of Abhyankar's 24 Ph.D. students are included.

**Information:** All interested people are most welcome to attend. In particular, student participation is encouraged. Some small amounts of support might be available for student participants. More information can be obtained from C. Christensen, Dept. of Math. and Computer Science, Northern Kentucky University, Highland Heights, KY 41099, christensen@nku.edu; or from the conference Web site, http://www.nku.edu/math/AlgGeoConf/.

**31-August 4 Numerical Modelling in Continuum Mechanics**, Prague, Czech Republic.

**Invited Plenary Speakers:** I. Babuška (USA), J. W. Barrett (Great Britain), D. Braess (Germany), L. Demkowicz (USA), P. Frauńi (France), R. Glowinski (USA), T. Hou (USA), K. Kunisch (Austria), Yu. Kuznetsov (USA/Russia), M. A. Leschziner (Great Britain).

**Topics:** Fluid dynamics; structural mechanics; material, structures and optimization; environmental problems.

**Call for Papers:** The program of the conference will include invited 50-minute lectures and 20-minute communications. All invited lectures and communications can be published in the conference proceedings after a reviewing process.

**Contact Address:** Prof. Dr. Miloslav Feistauer, Charles University Prague, Faculty of Mathematics and Physics, Institute of Numerical Mathematics, Sokolovská 83, 186 00 Praha 8, Czech Republic; e-mail: mfeista@karlin.mff.cuni.cz. Phone: +420 2 21911111, +420 2 21914223; fax: +420 2 535229, +420 2 23239994; http://www.karlin.mff.cuni.cz/ katedry/kma/ mfeista2000/.

**August 2000**

*21-24 International Conference on Geometry, Analysis, and Applications (In Honor of Late Professor V. K. Patodi), Banaras Hindu University, Varanasi, India.*

**Conference Themes:** Recent developments in differential geometry, classical and modern analysis, generalized functions, partial differential equations and applications. Symposia on (i) Atiyah-Patodi-Singer Index Theorem, (ii) Wavelets and applications.

**Invites Speakers:** Sir Michael Atiyah (Cambridge), J. M. Singer (MIT), R. Bott (Harvard), R. B. Melrose (MIT), M. S. Narsimhan (ICTP), S. Ramanan (TFIR, Bombay), Adimurthi (TFIR, Bangalore), K. B. Sinha (ISI, Delhi), S. Bhar­ gava (Mysore), R. Bhatia (ISI, Delhi), R. D. Carmichael (Winston-Salem, NC), H. P. Dith­ sch (Bhopal), S. Deshmukh (Riyadh), K. L. Duggal (Windsor), K. Fukaya (Kyoto), P. A. Gaste­ si (Chennai), H. J. Graeske (Jena, FRG), M. J. M. Hiemen­ mans (Amsterdam), R. F. Hoskins (Bedford), P. K. Jain (Delhi), S. L. Kalla (Kuwait), T. Kawaguchi (Japan), K. S. Kazarin (London), O. Liess (Bologna), A. Miy­achi (Tokyo), M. Naga­ se (Osaka), M. Ober­ gegenberger (Innsbruck, Austria), H. Pedersen (Odense, Denmark), J. N. Pandey (Ottawa), L. Rodino (Torino), S. Saioh (Japan), S. Deo (Rewa), J. Schneel­ (Virginia), R. Sharma (New Haven), D. Singh (Delhi), R. K. Singh (Jammu), S. P. Singh (Portsmouth), M. Sitaramayya (Hyderabad), H. M. Srivastava (Victoria), V. S. Sunder (ISI, Bangalore), U. B. Tewari (Khar­ man), K. Trimeche (Tunisia), A. W. Wong (York, Canada), S. L. Yadava (TIFR, Bangalore).

**Call for Papers:** Abstracts of contributed papers should be sent by March 31, 2000. Proceedings of the conference will be published.

**Information:** R. S. Pathak, Dept. of Math., Banaras Hindu Univ., Varanasi-221005, India; tel: 091-5042-307435 (O), 091-5042-312158 (R), fax: 091-5042-317074, e-mail: rspathak@banaras.ernet.in.

**September 2000**

*5-16 Advanced Course on Algebraic Quantum Groups*, Centre de Recerca Matemati­ ca, Campus of the Universitat Autonoma de Barcelona, Bellaterra, Spain.

**Speakers:** K. Brown (Univ. of Glasgow) and K. Goodearl (Univ. of California, Santa Bar­ bara).

**Further Information:** http://crm.es/ quantum/, or e-mail: quantum@crm.es.

**October 2000**

*7-10 International Conference on the Mathematical Modeling and Computational Experiments (ICMMCE), Dushanbe, Tajikistan.*

**Organizers:** Tajik State National University, Tajik Academy of Sciences, Council Young Scientists of Tajikistan, Tajik Military Strategic Centre.

**Conference Themes:** Modeling (nonlinear, economical, ecological, physical, social and other processes); Computing systems and technology; Information security and business.

**Information:** Rudaki str.17, Dushanbe, 734025, Tajikistan, e-mail: admin@tajjun. td.silk.org, tguu@tajnet.com; http:// www.tajnet.com/, tel: (7-377-2) 214209, 212043, or 217711.

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**NOTICES OF THE AMS** VOLUME 47, NUMBER 1
New Publications Offered by the AMS

Algebra and Algebraic Geometry

Extension Theory
Hermann Grassmann

The Ausdehnungslehre of 1862 is Grassmann's most mature presentation of his "extension theory". The work was unique in capturing the full sweep of his mathematical achievements.

Compared to Grassmann's first book, Lineale Ausdehnungslehre, this book contains an enormous amount of new material, including a detailed development of the inner product and its relation to the concept of angle, the "theory of functions" from the point of view of extension theory, and Grassmann's contribution to the Pfaff problem. In many ways, this book is the version of Grassmann's system most accessible to contemporary readers.

This translation is based on the material in Grassmann's "Gesammelte Werke", published by B. G. Teubner (Stuttgart and Leipzig, Germany). It includes nearly all the Editorial Notes from that edition, but the "improved" proofs are relocated, and Grassmann's original proofs are restored to their proper places. The original Editorial Notes are augmented by Supplemental Notes, elucidating Grassmann's achievement in modern terms.

This item will also be of interest to those working in general and interdisciplinary areas.

Co-published with the London Mathematical Society. Members of the LMS may order directly from the AMS at the AMS member price. The LMS is registered with the Charity Commissioners.

Contents: The elementary conjunctions of extensive magnitudes; Addition, subtraction, multiples and fractions of extensive magnitudes; The product structure in general; Combinatorial product; Inner product; Applications to geometry; The theory of functions: Functions in general; Differential calculus; Infinite series; Integral calculus; Index of technical terms; Editorial notes; Supplementary notes; Subject index.

History of Mathematics

Categories of Operator Modules (Morita Equivalence and Projective Modules)
David P. Blecher, University of Houston, TX, Paul S. Muhly, University of Iowa, Iowa City, and Vern I. Paulsen, University of Houston, TX

Contents: Introduction; Preliminaries; Morita contexts; Duals and projective modules; Representations of the linking algebra; C*-algebras and Morita contexts; Stable isomorphisms; Examples; Appendix—More recent developments; Bibliography.
Memos of the American Mathematical Society, Volume 143, Number 681


Analysis

Inverses of Disjointness Preserving Operators
Y. A. Abramovich, Indiana University-Purdue University, Indianapolis, and A. K. Kitover, Community College of Philadelphia, PA

Contents: Setting forth the problems; Some history; Synopsis of the main results; Preliminaries; The McFollin-Wickstead and Huijsmans-de Pagter-Koldunov Theorems revisited; d-bases; Band preserving operators and band-projections; Central operators and Problems A and B; Range-domain exchange in the Huijsmans-de Pagter-Koldunov Theorem; d-splitting number of
disjointness preserving operators; Essentially one-dimensional and discrete vector lattices; Essentially constant functions and operators on $C[0,1]$; Counterexamples; Dedekind complete vector lattices and Problems A and B; Generalizations to $(\mathbb{Q}_p)$-complete vector lattices; Open problems; References; Index.

**Memoirs of the American Mathematical Society**, Volume 143, Number 679


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**Dynamics in One Complex Variable**  
John Milnor, *State University of New York at Stony Brook, NY*

*A publication of Vieweg Verlag.*

The text studies the dynamics of iterated holomorphic mappings from a Riemann surface to itself, concentrating on the classical case of rational maps of the Riemann sphere. It is based on introductory lectures given by the author at SUNY, Stony Brook (NY), over the past 10 years.

The subject is large and rapidly growing. These lecture notes are intended to introduce readers to some key ideas in the field and to form a basis for further study. Readers are assumed to be familiar with the basics of complex variable theory and of two-dimensional differential geometry, as well as some basic topics from topology. The exposition is clear and enriched by many beautiful illustrations.

The AMS is exclusive distributor in North America, and non-exclusive distributor worldwide except in Germany, Switzerland, Austria, and Japan.

**Contents:** Chronological Table; Riemann Surfaces; Iterated Holomorphic Maps; Local Fixed Points; Periodic Points; Global Theory; Structure of the Fatou Set; Using the Fatou Set to Study the Julia Set; Appendix A: Theorems from Classical Analysis; Appendix B: Length-Area-Modulus Inequalities; Appendix C: Rotations, Continued Fractions, and Rational Approximation; Appendix D: Remarks on Two Complex Variables; Appendix E: Branched Coverings and Orbifolds; Appendix F: No Wandering Fatou Components; Appendix G: Parameter Space; Appendix H: Remarks on Computer Graphics; References; Index.

*Vieweg Monographs*

August 1999, 257 pages, Softcover, ISBN 3-528-03130-1, 2000 Mathematics Subject Classification: 37Fxx, All AMS members $26, List $29, Order code VW/9N

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**Continuous Tensor Products and Arveson’s Spectral $C^*$-Algebras**  
Joachim Zacharias, *University d’Orléans, France*

*Memoirs of the American Mathematical Society*, Volume 143, Number 680


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**Applications**

**Introduction to Mathematical Finance**  

The foundation for the subject of mathematical finance was laid nearly a hundred years ago by Bachelier in his fundamental work, *Théorie de la spéculation*. In this work, he provided the first treatment of Brownian motion. Since then, the research of Markowitz, and then of Black, Merton, Scholes, and Samuelson brought remarkable and important strides in the field. A few years later, Harrison and Kreps demonstrated the fundamental role of martingales and stochastic analysis in constructing and understanding models for financial markets. The connection opened the door for a flood of mathematical developments and growth.

Concurrently with these mathematical advances, markets have grown, and developments in both academia and industry continue to expand. This lively activity inspired an AMS Short Course at the Joint Mathematics Meetings in San Diego (CA).

The present volume includes the written results of that course. Articles are featured by an impressive list of recognized researchers and practitioners. Their contributions present deep results, pose challenging questions, and suggest directions for future research. This collection offers compelling introductory articles on this new, exciting, and rapidly growing field.

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

**Contents:** S. E. Shreve, Quantitative methods for portfolio management; M. Avellaneda, An introduction to option pricing and the mathematical theory of risk; F. Delbaen and W. Schachermayer, Non-arbitrage and the fundamental theorem of asset pricing; Summary of main results; D. Heath,
(i) Representations $\pi \in \Pi(G)$ are typically infinite dimensional.
(ii) Decompositions of general representations $R$ typically have both a discrete part (like Fourier series) and a continuous part (like Fourier transforms).

**Problem of the Plancherel Formula**

Against the prevailing opinion of the time, Harish-Chandra realized early in his career that a rich theory would require the study of a more restricted class of nonabelian groups. From the very beginning, he confined his attention to the class of semisimple Lie groups, or slightly more generally, reductive Lie groups. These include the general linear groups $GL(n, \mathbb{R})$, the special orthogonal groups $SO(p, q; \mathbb{R})$, the symplectic groups $Sp(2n, \mathbb{R})$, and the unitary groups $U(p, q; \mathbb{C})$. For the purposes of the present article, the reader can in fact take $G$ to be one of these familiar matrix groups.

Harish-Chandra’s long-term goal became that of finding an explicit Plancherel formula for any such $G$. As in the two examples above, one takes $V_R = L^2(G)$, with respect to a fixed Haar measure on $G$. One can then take $R$ to be the 2-sided regular representation

$$ (R(g_1, g_2)f)(x) = f(g_1^{-1}x^{-1}g_2), $$

$g_1, g_2 \in G$, $f \in V_R$,

of $G \times G$ on $V$. The regular representation is special among arbitrary representations in that it already comes with a candidate for an isomorphism with a direct integral. This is provided by the general Fourier transform

$$ f \rightarrow \hat{f}(\pi) = \int_G f(x)\pi(x) dx, $$

$f \in C_c^\infty(G)$, $\pi \in \Pi(G)$,

which is defined on a dense subspace $C_c^\infty(G)$ of $L^2(G)$, and takes values in the vector space of families of operators on the spaces $\{V_\pi\}$.

The problem of the Plancherel formula is to compute the measure $d\pi$ on $\Pi(G)$ such that the norm

$$ \|f\|_2^2 = \int_G |f(x)|^2 dx $$

equals the dual norm

$$ \|\hat{f}\|_2^2 = \int_{\Pi(G)} \|\hat{f}(\pi)\|_2^2 d\pi, $$

for any function $f \in C_c^\infty(G)$. In the second integrand, $\|\hat{f}(\pi)\|_2$ denotes the Hilbert-Schmidt norm of the operator $\hat{f}(\pi)$. The norm $\|\hat{f}\|_2$ then defines a Hilbert space $\hat{V}$ on which $G \times G$ acts pointwise by left and right translation on the spaces of Hilbert-Schmidt operators on $\{V_\pi\}$. The problem was known to be well posed. A general theorem of I. Segal from 1950, together with Harish-Chandra’s proof in 1953 that $G$ is of “type I”, ensures that the Plancherel measure $d\pi$ exists and is unique. The point is to calculate $d\pi$ explicitly. This includes the problem of giving a parametrization of $\Pi(G)$, at least up to a set of Plancherel measure zero.

The first person to consider the problem and to make significant progress was I. M. Gelfand. He established Plancherel formulas for a number of matrix groups, and laid foundations for much of the later work in representation theory and automorphic forms. However, some of the most severe difficulties arose in groups that he did not consider. Harish-Chandra worked in the category of general semisimple (or reductive) groups. His eventual proof of the Plancherel formula for these groups was the culmination of twenty-five years of work. It includes many beautiful papers, and many ideas and constructions that are of great importance in their own right. I shall describe, in briefest terms, a few of the main points of Harish-Chandra’s overall strategy, as it applies to the example $G = GL(n, \mathbb{R})$.

**Geometric Objects**

In Harish-Chandra’s theory of the Plancherel formula, the geometric objects are parametrized by the regular, semisimple conjugacy classes in $G$. In the example $G = GL(n, \mathbb{R})$ we are considering, these conjugacy classes are the ones that lie in the open dense subset

$$ G_{\text{reg}} = \left\{ g \in G : \text{the eigenvalues } y_i \in \mathbb{C} \text{ of } g \text{ are distinct} \right\}. $$

of $G$. They are classified by the characteristic polynomial as a disjoint union of orbits

$$ \bigsqcup_P \left( T_{\text{reg}} \backslash W_P \right), $$

where $P$ ranges over certain partitions

$$ \left\{ P = (1, \ldots, 1, 2, \ldots, 2) : r_1 + 2r_2 = n \right\}. $$
Number Theory 1
Fermat's Dream
Kazuya Kato, University of Tokyo, Japan,
Norishige Kurokawa, Tokyo Institute of Technology, Japan,
and Tatsuki Saito, University of Tokyo, Japan

This is the English translation of the original Japanese book. In this volume, "Fermat's Dream", core theories in modern number theory are introduced. Developments are given in elliptic curves, $p$-adic numbers, the $\zeta$-function, and the number fields. This work presents an elegant perspective on the wonder of numbers.

Translations of Mathematical Monographs (Iwanami Series in Modern Mathematics), Volume 186

Algebra, K-Theory, Groups, and Education
On the Occasion of Hyman Bass's 65th Birthday
T. Y. Lam, University of California, Berkeley, CA, and A. R. Magid, University of Oklahoma, Norman, OK, Editors

This volume includes expositions of key developments over the past four decades in commutative and non-commutative algebra, algebraic K-theory, infinite group theory, and applications of algebra to topology. Many of the articles are based on lectures given at a conference at Columbia University honoring the 65th birthday of Hyman Bass. Important topics related to Bass's mathematical interests are surveyed by leading experts in the field. Of particular note is a professional autobiography of Professor Bass, and an article by Deborah Ball on mathematical education. The range of subjects covered in the book offers a convenient single source for topics in the field.


Contemporary Mathematics, Volume 243

Spectral Theory of Non-Self-Adjoint Two-Point Differential Operators
John Locker, Colorado State University, Fort Collins

This monograph develops the spectral theory of an $n$th order non-self-adjoint two-point differential operator $L$ in the Hilbert space $L^2[0,1]$. The mathematical foundation is laid in the first part, where the spectral theory is developed for closed linear operators and Fredholm operators. An important completeness theorem is established for the Hilbert-Schmidt discrete operators. The operational calculus plays a major role in this general theory.

In the second part, the spectral theory of the differential operator $L$ is developed by expressing $L$ in the form $L = T + S$, where $T$ is the principal part determined by the $n$th order derivative of $S$ is the part determined by the lower-order derivatives. The spectral theory of $T$ is developed first using operator theory, and then the spectral theory of $L$ is developed by treating $L$ as a perturbation of $T$. Regular and irregular boundary values are allowed for $T$, and regular boundary values are considered for $L$. Special features of the spectral theory for $L$ and $T$ include the following: calculation of the eigenvalues, algebraic multiplicities and ascents; calculation of the associated family of projections which project onto the generalized eigenspaces; completeness of the generalized eigenfunctions; uniform bounds on the family of all finite sums of the associated projections; and expansions of functions in series of generalized eigenfunctions of $L$ and $T$.

Mathematical Surveys and Monographs, Volume 73

Lectures on Hilbert Schemes of Points on Surfaces
Hiraku Nakajima, Kyoto University, Japan

The Hilbert scheme $\text{Hilb}^n(X)$ of a surface $X$ describes collections of $n$ (not necessarily distinct) points on $X$. More precisely, it is the moduli space for 0-dimensional subschemes of $X$ of length $n$. Recently it was realized that Hilbert schemes originally studied in algebraic geometry are closely related to several branches of mathematics, such as singularities, symplectic geometry, representation theory—even theoretical physics. The discussion in the book reflects this feature of Hilbert schemes.

For example, a construction of the representation of the infinite dimensional Hessenberg algebra (i.e., Fock space) is presented. This representation has been studied extensively in the literature in connection with affine Lie algebras, conformal field theory, etc. However, the construction presented in this volume is completely unique and provides the unexplored link between geometry and representation theory.

The book offers a nice survey of current developments in this rapidly growing subject. It is suitable as a text at the advanced graduate level.

University Lecture Series, Volume 18
The Lives of Renowned Mathematicians

S. S. Chern: A Great Geometer of the Twentieth Century
Expanded Edition
S.-T. Yau, Harvard University, Cambridge, MA, Editor
A publication of International Press.
International Press publications are distributed worldwide, except in Japan, by the American Mathematical Society.
All AMS members $34, List $45, Order Code INPY914CT001

The Man Who Loved Only Numbers
The Story of Paul Erdős and the Search for Mathematical Truth
Paul Hoffman
A publication of Hyperion Press.
It is interesting that Hoffman, Erdős and others in the book remember the mathematical tidbit that first intrigued them and bound them to this world. Possibly a future scientist or mathematician, or future scientific writer, will remember something in this book that way.
—New York Times Book Review
Published by Hyperion Press. Distributed worldwide by the American Mathematical Society.
1998; ISBN 0-7868-0362-5; 302 pages; Hardcover; All AMS members $16, List $23, Order Code MLNC01CT001

Pioneers of Representation Theory: Frobenius, Burnside, Schur, and Brauer
Charles W. Curtis, University of Oregon, Eugene
Co-published with the London Mathematical Society. Members of the LMS may order directly from the AMS at the AMS member price. The LMS is registered with the Charity Commissioners.

Jacques Hadamard, A Universal Mathematician
Vladimir Maz'ya and Tatjana Shaposhnikova, Linköping University, Sweden
Maz'ya and Shaposhnikova have created an authoritative source for biographical information on Jacques Hadamard.
—MAA Online
The reviewer recommends the book highly for both enjoyment and information. The authors have a masterful grasp of both the mathematics and the biography, and they tell the story in a very interesting way.
—Mathematical Reviews
Co-published with the London Mathematical Society. Members of the LMS may order directly from the AMS at the AMS member price. The LMS is registered with the Charity Commissioners.
History of Mathematics, Volume 14; 1998; ISBN 0-8218-1923-2; 574 pages; Softcover; All AMS members $39, List $49, Order Code HMATH14SCT001

Quest: An Autobiography
Second Edition
Leopold Infeld
Indeed, this reviewer knows of no account that does such ample justice to the great mind and spirit of Einstein.
—Saturday Review of Literature
A fascinating book ... remarkable ... convincingly held together by the skill and scrupulous truthfulness of the autobiographer ... The narrative flows so well that one hates to be interrupted in the reading of the book.
—The New York Times
AMS Chelsea Publishing; 1980; ISBN 0-8284-0309-2; 361 pages; Hardcover; All AMS members $18, List $23, Order Code CHEL/30CT001

John von Neumann
The Scientific Genius Who Pioneered the Modern Computer, Game Theory, Nuclear Deterrence, and Much More
Norman Macrae
I always thought [von Neumann's] brain indicated that he belonged to a new species, an evolution beyond man. Macrae shows us in a lively way how this brain was nurtured and then left its great imprint on the world.
—Hans A. Bethe, Cornell University
A lively portrait of the hugely consequential mathematician-physicist-ETF-al., whose genius has left an enduring impress on our thought, technology, society, and culture.
—Robert K. Merton, Columbia University
The AMS is licensed to produce and distribute this book in English throughout the world except in the British Commonwealth of Nations, Republic of Ireland and South Africa, Burma, Iraq, and Jordan.
1992; ISBN 0-8218-2046-4; 406 pages; Hardcover; All AMS members $28, List $35, Order Code JVN01CT001

The Way I Remember It
Walter Rudin, University of Wisconsin, Madison
It is a real pleasure to read this book and to admire the charming personal style we have come to know from Rudin's textbooks, monographs and articles.
—European Mathematical Society Newsletter
Co-published with the London Mathematical Society. Members of the LMS may order directly from the AMS at the AMS member price. The LMS is registered with the Charity Commissioners.
History of Mathematics, Volume 12; 1997; ISBN 0-8218-0309-4; 191 pages; Softcover; All AMS members $23, List $29, Order Code HMATH12CT001

Stephen Smale: The mathematician who broke the dimension barrier
Steve Batterson, Emory University, Atlanta, GA
2000; ISBN 0-8218-2045-1; approximately 265 pages; Hardcover; All AMS members $26, List $35, Order Code SMALL/1CT001
**American Mathematical Society**

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**Geometric Nonlinear Functional Analysis**  
Volume I  
Yoav Benyamin, Technion—Israel Institute of Technology, Haifa, and Joram Lindenstrauss, Hebrew University, Jerusalem, Israel

The book presents a systematic and unified study of geometric nonlinear functional analysis. The main theme is the study of uniformly continuous and Lipschitz functions between Banach spaces (e.g., differentiability, stability, approximation, existence of extrema, fixed points, etc.). This study leads naturally also to the classification of Banach spaces and of their important subspace categories in the uniform and Lipschitz categories.

Many recent results and delicate examples are included with complete and detailed proofs. Challenging open problems are described and explained, and promising new research directions are indicated.

Volume 48; 2000; 488 pages; Hardcover; ISBN 0-8218-0836-4; List $65; All AMS members $52; Order code COL/48

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**Random Matrices, Frobenius Eigenvalues, and Monodromy**  
Nicholas M. Katz and Peter Sarnak, Princeton University, NJ

The main topic of this book is the deep relation between the spacings between zeros of zeta and L-functions and spacings between eigenvalues of random elements of large compact classical groups. This relation, the Montgomery-Odlyzko law, is shown to hold for wide classes of zeta and L-functions over finite fields. The book draws on and gives accessible accounts of many disparate areas of mathematics, from algebraic geometry, moduli spaces, monodromy, equidistribution, and the Weil conjectures, to probability theory on the compact classical groups in the limit as their dimension grows to infinity and related techniques from orthogonal polynomials and Fredholm determinants.

Volume 45; 1999; 413 pages; Hardcover; ISBN 0-8218-1917-0; List $66; Individual member $41; Order code COL/45

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**The Book of Involutions**  
Max-Albert Knus, Eidgenössische Technische Hochschule, Zürich, Switzerland, Alexander Merkurjev, University of California, Los Angeles, Markus Rost, Universität Regensburg, Germany, and Jean-Pierre Tignol, Université Catholique de Louvain, Louvain-la-Neuve, Belgium

This monograph is an exposition of the theory of central simple algebras with involution, in relation to linear algebraic groups. It provides the algebra-theoretic foundations for much of the recent work on linear algebraic groups over arbitrary fields. Involutions are viewed as twisted forms of (hermitian) quadratics, leading to new developments on the model of the algebraic theory of quadratic forms. In addition to classical groups, phenomena related to triality are also discussed, as well as groups of type F_4 or G_2 arising from exceptional Jordan or composition algebras. Several results and notions appear here for the first time, notably the discriminant algebra of an algebra with unitary involution and the algebraic-theoretic counterpart to linear groups of type D_4.

Volume 44; 1998; 583 pages; Hardcover; ISBN 0-8218-0904-0; List $89; All AMS members $71; Order code COL/44

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**Fully Nonlinear Elliptic Equations**  
Luis A. Caffarelli and Xavier Cabré, Institute for Advanced Study, Princeton, NJ

The book marks an important stage in the theory of fully nonlinear elliptic equations. Its timely appearance will surely stimulate fresh attacks on the many difficult and interesting questions which remain.

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**Frobenius Manifolds, Quantum Cohomology, and Moduli Spaces**  
Yuri I. Manin, Director, Max-Planck-Institut für Mathematik, Bonn, Germany

This is the first monograph dedicated to the systematic exposition of the whole variety of topics related to quantum cohomology. The subject first originated in theoretical physics (quantum string theory) and has continued to develop extensively over the last decades. The author’s approach to quantum cohomology is based on the notion of the Frobenius manifold. The first part of the book is devoted to this notion and its extensive interconnections with algebraic formalism of operads, differential equations, perturbations, and geometry. In the second part of the book, the author describes the construction of quantum cohomology and reviews the algebraic geometry mechanisms involved in this construction (intersection and deformation theory of Deligne-Artin and Mumford stacks).

Yuri Manin has authored and coauthored 10 monographs and almost 200 research articles in algebraic geometry, number theory, mathematical physics, history of culture, and psycholinguistics. Manin’s books have secured for him solid recognition as an excellent expositor. Undoubtedly the present book will serve mathematicians for many years to come.

Volume 47; 1999; 303 pages; Hardcover; ISBN 0-8218-1917-0; List $55; All AMS members $44; Order code COL/47

All prices subject to change. Charges for delivery are $3.00 per order. For optional air delivery outside of the continental U.S., please include $6.50 per item. Prepayment required. Order from: American Mathematical Society, P.O. Box 667, Providence, RI 02940, USA. For credit card orders, fax 1-401-455-4046 or call toll free 1-800-321-AMS (4267) in the U.S. and Canada, 1-401-455-4000 worldwide. Or place your order through the AMS bookstore at www.ams.org/bookstore/. Residents of Canada, please include 7% GST.
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Department of Mathematics and Computer Science

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Department of Mathematics

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Applicants should submit a curriculum vitae, a description of their current research program; and three letters of recommendation to the Department of Mathematics, Claremont McKenna College, 850 Columbia Street, Claremont, CA 91711-6400; Claremont is an Equal Opportunity Employer.

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Department of Mathematics
Assistant Professor of Mathematics

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Claremont is situated approximately thirty-five miles east of downtown Los Angeles in the San Gabriel mountains. The community is known for its tree-lined streets and village charm. It is an easy drive from Claremont to the cultural attractions of the greater Los Angeles area, as well as the ocean, mountains, and deserts of Southern California.

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EOE. Saint Mary's College is a Catholic, liberal arts, co-educational college operated by the Christian Brothers.

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Department of Mathematics

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Candidates should send a letter of application and a curriculum vitae, including a list of publications, and a cover letter clearly stating the following: name, area of specialization, institution, (expected) date of Ph.D., and Ph.D. advisor. Also, the candidate should arrange to have three letters of recommendation and some evidence of commitment to excellence in teaching sent to Professor Leon Simon, Department of Mathematics, Stanford University, Stanford, CA 94305, by January 15, 2000.

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Search Committee
Department of Computing and Mathematics
C/o Stacey Wilkins
Embry-Riddle Aeronautical University
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Daytona Beach, FL 32114-3900
email: wilkinss@cts.db.er au.edu
fax: 904-226-6678
Embry-Riddle Aeronautical University is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

FLORIDA ATLANTIC UNIVERSITY
The Department of Mathematical Sciences invites applications for one or more tenure-track faculty positions in applied mathematics beginning in the fall of 2000. Applicants must have a Ph.D. in mathematics or a related discipline. We are especially interested in a senior mathematician to lead our planned new master's program in applied mathematics and statistics. Candidates at the assistant professor level are also encouraged to apply. Applicants should send a curriculum vitae, including a list of publications, a statement of research and teaching interests, and three letters of recommendation to: Hiring Committee, Department of Mathematical Sciences, Florida Atlantic University, Boca Raton, FL 33431. Applications received before December 31, 1999, will receive full consideration. For more information visit http://www.math.fau.edu/. Women and minorities are strongly encouraged to apply. As an agency of the State of Florida, FAU will make application materials and selection procedures available for review, in accordance with the State Sunshine Law. Florida Atlantic University is an Equal Opportunity/Access/Affirmative Action Institution.

UNIVERSITY OF MIAMI
The University of Miami, Department of Mathematics and Computer Science, seeks applications for two tenure-track assistant professor positions starting August 2000. The positions require excellence in both research and teaching. The department is interested in candidates with research specialization in algebra (commutative algebra, representation theory, Lie theory, or number theory) or in geometric analysis (gauge theory, string theory, pseudo-Riemannian geometry, symplectic geometry, mathematical physics, or analysis on manifolds). To apply, please send your vita and three letters of recommendation to: Professor Alan M. Zame, Chairperson, Department of Mathematics, P.O. Box 249085, University of Miami, Coral Gables, FL 33124-4250. Review of applications will begin immediately and will continue until the positions are filled. The University of Miami is an Equal Opportunity/Affirmative Action Employer and smoke/drug-free workplace. Women and minorities are encouraged to apply.

ILLINOIS

ILLINOIS INSTITUTE OF TECHNOLOGY
The Department of Applied Mathematics at IIT seeks applicants for one or more tenure-track assistant professor positions to begin in August of 2000. The successful candidate will have already demonstrated excellent teaching skills and the capability of establishing a fundable research program in applied mathematics. The general area of interest is in modern applied mathematics, including discrete applied mathematics. Interdisciplinary research is strongly encouraged. Applications should include a vita, description of research and future plans, documentation as to how the candidate would be able to interact with a specific field within science or engineering, statement of teaching experience, and four letters of reference (one addressing teaching effectiveness). Review of applications will begin on January 15, 2000, and will continue until the position(s) is filled. Information about IIT and the Department of Applied Mathematics can be found at http://www.iit.edu/math. Send material to:
F. R. McMorris, Chair
Department of Applied Mathematics
Illinois Institute of Technology
10 West 32nd Street, Room 208, E1
Chicago, IL 60616-3793
IIT is an AA/EO Employer.

NORTHERN ILLINOIS UNIVERSITY
Department of Mathematics
2033 Sheridan Rd.
Evanston, IL 60208-2730
Lecturer
Coordinator of calculus teaching. Northwestern University plans to fill a non-tenure-track, two-year renewable lectureship starting September 2000. Responsibilities: teach and improve the teaching of calculus; coordinate calculus sections offered by the mathematics department; develop and implement new programs to improve undergraduate learning of calculus. Requirements include Ph.D. in mathematics, record of excellent teaching, experience in varied approaches to teaching calculus, dedication to teaching excellence and to enhancement of learning. Candidates should send AMS Standard Cover Sheet for Academic Employment, curriculum vitae, and letters assessing their qualifications for this position by four referees to: Professor Paul Goerss, Department of Mathematics, Northwestern University, Evanston, IL 60208-2730. Direct inquiries to hiring@math.nwu.edu. Full consideration will be given to applicants whose materials have all been received by January 31, 2000.

SOUTHERN ILLINOIS UNIVERSITY
AT CARBONDALE
Department of Mathematics
Analysis Position
Tenure-track position in analysis at the assistant professor level beginning on August 16, 2000. Applicants from all areas of analysis (e.g., classical, geometric, modern, stochastic, as well as probability) will be considered. However, applicant must have a broad background in mathematical analysis and must demonstrate evidence of, or potential for, excellence both in research and in teaching at all university levels. Ph.D. in mathematics required by August 15, 2000. Postdoctoral experience preferred. Send letter of application, C.V., and three letters of recommendation to: Analysis Position, Department of Mathematics, Southern Illinois University, Carbondale, IL 62901-4408. Review of applications will begin December 6, 1999, and will continue until position is filled. Southern Illinois University Carbondale is an Equal Opportunity/Affirmative Action Employer. Women and minorities are particularly encouraged to apply.

INDIANA

INDIANA UNIVERSITY SOUTH BEND
Department of Mathematics and Computer Science
Visiting Assistant Professor of Mathematics
The Department of Mathematics and Computer Science invites applications for a two-year visiting position in mathematics at the assistant professor level starting August 2000. Applicants must have completed all requirements for a doctoral degree in mathematics, mathematics education, or a closely related field by August 2000. The responsibilities of this position include: teaching up to 12 hours per semester and service to the department. Salaries and benefits are competitive. The department currently has 17 full-time faculty and about 35 associate faculty. IUSB is an Equal Opportunity/Affirmative Action Employer; women and minority candidates are encouraged to apply. Send a curriculum vitae, a statement on teaching, and three letters of recommendation,
at least two of which address teaching, to: Mathematics Hiring Committee, Department of Mathematics and Computer Science, Indiana University South Bend, South Bend, IN 46634. Completed applications received by February 18, 2000, will be given full consideration. Visit us at http://www.iusb.edu/~mcsi/.

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**KANSAS**

**KANSAS STATE UNIVERSITY**
Department of Mathematics

Subject to budgetary approval, applications are invited for an instructorship commencing between January 15 and August 15, 2000, and lasting through July 2002. The instructor will participate in the design and implementation of a collaborative program to improve teacher preparation and will teach in the undergraduate program. The instructor will have time to pursue research in the department along with these duties.

Applicants must have a commitment to excellence in teaching. A Ph.D. in mathematics or a Ph.D. dissertation accepted with only formalities to be completed is required. Experience in mathematics education and/or teaching with technology is preferred. Letter of application, current vita, three letters of reference, and a statement of teaching philosophy should be sent to:

Louis Pigno  
Department of Mathematics  
Cardwell Hall 138  
Kansas State University  
Manhattan, KS 66506

Offers may begin by January 2000, but applications for the position will be reviewed until the position is closed. AA/EOE.

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**UNIVERSITY OF KANSAS**
Department of Mathematics

Applications are invited for two tenure-track positions at the assistant professor level beginning August 18, 2000, or as negotiated. (These positions are contingent on final budgetary approval.) First preference will be given to candidates in commutative algebra, the second in numerical partial differential equations, and otherwise to candidates whose research interests mesh well with those of our faculty. Candidates must have a Ph.D. or its requirements completed by August 18, 2000.

Letter of application, detailed résumé with description of research, completed AMS Standard Cover Sheet, and three letters of recommendation should be sent to: Jack Porter, Chair, Department of Mathematics, 405 Snow Hall, University of Kansas, Lawrence, KS 66045-2142.

Deadlines: Review of applications will begin on January 1, 2000, and will continue until the positions are filled.

EO/AA Employer.

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**LOUISIANA**

**LOUISIANA STATE UNIVERSITY**
Department of Mathematics
Associate Professor or Professor (Applied Mathematics)

Applications are invited for an associate professor or full professor in applied mathematics. The department, in conjunction with the university administration, is seeking to build a program in this field with an interdisciplinary component. The individual hired will be expected to assume a leadership role in the development of this program.

Duties include dedicated and effective teaching at the undergraduate and graduate levels and commitment to, and maintenance of, a strong research program. A Ph.D. in mathematics or related field, or a degree equivalent to the U.S. doctoral degree is required. An applicant is expected to have a history of obtaining research grants and interacting with other disciplines. Areas with which the department is seeking to establish links include material science, mathematical biology and health care sciences, environmental science and oceanography.

Salary and rank will be commensurate with qualifications and experience. Review of applications will begin December 1, 1999, and will continue until the position is filled. To apply, use the AMS Standard Cover Sheet, and enclose a full résumé, including a statement on research and teaching, and four or more letters of recommendation. Submit to: Ron Rutherford, Chair, Department of Mathematics, Louisiana State University, Ref: #000558, Baton Rouge, LA 70803-4918; e-mail: dept@math.lsu.edu.

Louisiana State University is an Equal Opportunity/Equal Access Employer.

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**MAINE**

**UNIVERSITY OF MAINE**
Department of Mathematics and Statistics

The Department of Mathematics and Statistics is seeking to fill four positions beginning September 2000 as follows:

- A tenure-track position in computational mathematics at the rank of assistant professor. Workload for the position consists of teaching eight credit hours of mathematics courses per semester (three courses) of research in computational mathematics with interdisciplinary expectation, and departmental/college/university service. Requirements for the position are: Ph.D. in mathematics specializing in one of computational mathematics linked to departmental research interests, completed Ph.D. thesis by September 2000, proven research ability, and demonstrated excellence in teaching. Preference given to candidates interested in developing collaborative extramurally funded research programs.

- Two ongoing lecturer positions. Workload consists of teaching 12 credit hours per semester (three courses) of mathematics or statistics courses and an expectation of department/college service. Requirements for the positions are: demonstrated excellence in teaching, including outstanding student evaluations and other evidence and knowledge of classroom technology use. Master's degree in mathematics or statistics required, Ph.D. preferred.

- One ongoing SET lecturer position. Workload for this position consists of teaching 12 credit hours of applied mathematics courses (three or four courses) per semester for engineering technology students and an expectation of department/college service. Requirements for the position: demonstrated excellence in teaching, including outstanding student evaluations and other evidence. A master's degree in mathematics is required.

Interested individuals should send a letter of application, a curriculum vitae, a statement of teaching philosophy, evidence of teaching excellence, three letters of recommendation, and for the computational mathematics position an overview of research program to the respective search committee, prefaced by one of the following: Computational Math, Lecturer, or SET Lecturer; Department of Mathematics & Statistics, Room 333, 5752

NOTICES OF THE AMS  
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Neville Hall, University of Maine, Orono, ME 04469-5752. Review of applications will begin on December 1, 1999. Further information about the Department of Mathematics & Statistics can be found at http://www.umemat.maine.edu. The University of Maine is an Equal Opportunity/Affirmative Action Employer. Women and minorities are especially encouraged to apply.

MARYLAND

TOWSON UNIVERSITY
Department of Mathematics
Entry-level tenure-track assistant professor, pure mathematics, starting fall 2000. Ph.D. is required. Faculty are expected to be productive scholars and excellent teachers. Commitment to innovative instruction. Teaching assignment is nine contact hours per semester. The salary is commensurate with that of an entry-level position. The mathematics department (http://www.towson.edu/sath/) offers bachelor's programs in various concentrations, a master's program in applied and industrial mathematics, and mathematics education. Submit letter of interest, vita, and transcripts; and arrange for three letters of recommendation. Applications must be received by February 1, 2000. Direct correspondence to: Leonid Stern, Chair, Search Committee, Mathematics Department, Towson University, 8000 York Road, Baltimore, MD 21252-0001; Fax: 410-830-4149. Applications or materials sent by email will not be considered. Towson University is an Equal Opportunity/Affirmative Action Employer with a strong institutional commitment to diversity. Women, minorities, persons with disabilities, and veterans are encouraged to apply.

UNIVERSITY OF MARYLAND
UNIVERSITY COLLEGE
Teach in Asia or Europe
University of Maryland University College continually seeks experienced faculty for undergraduate courses on U.S. military bases overseas. Appointments begin January or August 2000. Requirements include the Ph.D. or ABD in mathematics/physics, Ph.D., recent U.S. university teaching experience, and U.S. citizenship. Clear competence to teach in another discipline desirable. Benefits include transportation, health insurance, military base privileges, and TIAA/CREF. Frequent relocation and the cost of schooling make these positions difficult for those with children. Further information can be found at http://www.umuc.edu/ under "Faculty/Staff". Send résumé to Dr. Rosemary Hoffmann, University of Maryland University College, Overseas Programs, College Park, MD 20742-1642, or e-mail to overseas-programs@umuc.ed.UA/EOE.

BOSTON UNIVERSITY
The Center for BioDynamics (CBD) at Boston University will have postdoctoral positions available starting September 2000. The CBD is a multidisciplinary center devoted to research and training at the interfaces among dynamical systems, biology, and engineering. Current research themes include computational neurobiology, genetic regulatory networks, fluid and solid mechanics, and applied biodynamics. We seek candidates interested in working across disciplinary boundaries with multiple members of the CBD.

The CBD is highly connected to many departments and other research centers at Boston University, providing a very stimulating research environment. For further information about the CBD, including the associated faculty and current research interests, please see our Web page at http://www.cbd.bu.edu/.

To apply, please send (1) a statement that includes your background, career goals, how this position satisfies those goals, and why you think you are a good candidate; (2) your C.V.; and (3) three letters of recommendation to:

Nancy Kopell, Co-Director
Center for BioDynamics
Department of Mathematics
111 Cummington Street
Boston University
Boston, MA 02215

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics
Applied Mathematics
Applications are invited for a limited number of positions in applied mathematics, starting fall 2000. Available positions include instructorships, lecturerships, assistant professorships, and possibly higher levels. Applicants will be evaluated on the basis of demonstrated research accomplishments and potential. Complete applications must be received by January 3. To apply, please send a vita with a description of your recent research and research plans, and arrange to have three letters of reference sent. Address: Committee on Applied Mathematics, Room 2-345, Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA 02139-4307. MIT is an Equal Opportunity/Affirmative Action Employer.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics
The Department of Mathematics may make a few appointments at the assistant professor and higher levels in pure mathematics for the year 2000-01. The teaching load will be nine hours for the academic year (eight hours for assistant professor appointments). Open to mathematicians with doctorates who show definite promise in research. Applications should be completed by January 15. Applicants should send (1) a vita, three letters of reference, (2) a description of your most recent research, and (3) a research plan for the immediate future to: Pure Mathematics Committee, Massachusetts Institute of Technology, Room 2-263, Cambridge, MA 02139-4307. MIT is an Equal Opportunity/Affirmative Action Employer.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics
C.L.E. Moore Instructorships in Mathematics
Open to mathematicians with doctorates who show definite promise in research. Teaching load is six hours per week during one semester and three hours per week during the other. Applications should be completed by January 1, 2000. Please arrange to have sent (1) a vita, (2) three letters of reference, (3) a description of the research in your thesis, and (4) a research plan for the next year to: C.L.E. Moore Instructorship Committee, Massachusetts Institute of Technology, Room 2-263, Cambridge, MA 02139-4307. MIT is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF MASSACHUSETTS, AMHERST
Mathematics and Statistics
The Department of Mathematics & Statistics (http://www.math.umass.edu/) invites applications for tenure-track positions at the assistant professor level. In addition, two-year, non-tenure-track positions will be available. The search will focus within the following areas: algebraic geometry, applied analysis, geometric analysis, harmonic analysis, Lie theory, number theory, probability, scientific computation, and statistics. Exceptional promise in research and teaching (at all levels of the curriculum) is required. Although this search focuses on junior-level appointments, candidates for more senior-level appointments will be considered. Applicants should send a curriculum vitae and direct at least three letters of recommendation to: Search Committee, Department of Mathematics & Statistics, University of Massachusetts, Amherst, MA 01003-4515. Review of applications will begin on November 15. Applications will continue to be accepted until all positions are filled. Please include the AMS Standard Cover Sheet. Women and members of minority groups are encouraged to apply. Equal Opportunity/Affirmative Action Employer.

Classified Advertisements
UNIVERSITY OF MASSACHUSETTS, AMHERST  
Mathematics and Statistics

The Department of Mathematics & Statistics (http://www.math.umass.edu) invites applications for tenure-track positions at the assistant professor level. In addition, two-year, non-tenure track positions will be available. Applicants should have a background in theoretical statistics and have an interest in applications, interdisciplinary research, and computation. Exceptional promise in research and teaching (at all levels of the curriculum) is required. Although this search focuses on junior-level appointments, candidates for more senior-level positions will be considered. Applicants should send a curriculum vitae and at least three letters of recommendation to: Search Committee, Department of Mathematics & Statistics, University of Massachusetts, Amherst, MA 01003-4515. Review of applications will begin on November 15. Applications will continue to be accepted until all positions are filled. Please include the AMS Standard Cover Sheet. Women and members of minority groups are encouraged to apply. Equal Opportunity/Affirmative Action Employer.

WILLIAMS COLLEGE  
Department of Mathematics  
Williamstown, MA 01267

Tentative full-time visiting position in mathematics for the 2000-01 year, probably at the rank of assistant professor; in exceptional cases, however, more advanced appointments may be considered. Excellence in teaching and research, and Ph.D. required.

Please have a vita and three letters of recommendation on teaching and research sent to Visitor Hiring Committee. Evaluation of applications will begin on or after January 15 and will continue until the position is filled. As an EEO/AA Employer, Williams especially welcomes applications from women and minority candidates.

WORCESTER POLYTECHNIC INSTITUTE  
Mathematical Sciences Department  
Faculty Positions

The WPI Mathematical Sciences Department invites applications for two faculty positions to begin in the fall of 2000. An earned Ph.D. or equivalent degree is required. Successful candidates must be able to contribute strongly to both the department's research activities and its innovative, project-based educational programs. The first position will probably be at the assistant professor level, but exceptionally well-qualified candidates may be considered for appointments at higher rank. Cryptography and applied discrete mathematics are of particular interest. Other areas of interest include, but are not limited to, operations research, optimization, and financial mathematics.

Appointments will be made for two years, contingent on satisfactory teaching, with possible renewal for a third year at the discretion of WPI and the appointee. WPI's academic year is divided into four seven-week terms. The teaching load for these positions is five courses over the four terms, i.e., one course in each of three terms and two courses in the remaining term.

WPI is a private and highly selective technological university with an enrollment of 2,700 undergraduates and about 1,000 full- and part-time graduate students. Worcester, New England's second largest city, offers ready access to the diverse cultural and recreational resources of the region, together with opportunities for urban, suburban, or rural lifestyles.

The Mathematical Sciences Department has 24 full-time faculty and supports a Ph.D. program and M.S. programs in applied mathematics and applied statistics, as well as a full undergraduate program. For additional information see http://www.wpi.edu/maht.

Qualified applicants should send a detailed curriculum vitae, a brief statement of their specific teaching and research objectives, and three letters of recommendation, at least one of which addresses teaching potential, to: Visitor Search Committee, Mathematical Sciences Department, WPI, 100 Institute Road, Worcester, MA 01609-2280.

Applicants will be considered on a continuing basis beginning January 1, 2000, until the positions are filled.

WPI offers a smoke-free environment. To enrich education through diversity, WPI is an Affirmative Action/Equal Opportunity Employer.

WORCESTER POLYTECHNIC INSTITUTE  
Mathematical Sciences Department  
Visiting Assistant Professorships

The WPI Mathematical Sciences Department invites applications for two visiting assistant professorships to begin in the fall of 2000. An earned Ph.D. or equivalent degree is required. Successful candidates must demonstrate strong research potential and evidence of quality teaching and will be expected to contribute to the department's research activities and to its innovative, project-based educational programs. Preferred research interests are areas of applied and computational mathematics compatible with those represented in the department: partial differential equations with applications in fluid and continuum mechanics, composite materials, computational modeling and simulation, numerical analysis, optimization, control theory, applied probability, and discrete mathematics.

Applications for tenure-track positions at WPI are encouraged. Women and members of minority groups are encouraged to apply. Equal Opportunity/Affirmative Action Employer.

MICHIGAN  
MICHIGAN TECHNOLOGICAL UNIVERSITY  
Department of Mathematical Sciences  
Tenure-Track Assistant Professor Positions

The Department of Mathematical Sciences is searching for one, possibly more (pending budget approval), tenure-track assistant professor in one of the areas of applied combinatorics and statistics. At least one of the positions will be filled in the area of applied combinatorics. We are especially interested in the area of combinatorial optimization, cryptography, data compression, and graph theory, as well as individuals who will be able to interact with faculty in the areas of coding theory, combinatorial designs, and combinatorial algorithms. Candidates must have completed their Ph.D. by August 7, 2000, and must have demonstrated evidence of excellence in teaching and outstanding research potential.
Send vita and three letters of reference to:
Search Committee
Department of Mathematical Sciences
Michigan Technological University
1400 Townsend Drive
Houghton, MI 49931-1295

Review process will begin January 17, 2000, and will continue until the position is filled. Michigan Technological University is an Equal Opportunity Educational Institution/Equal Opportunity Employer. We especially encourage applications from women, minorities, and underrepresented groups.

OAKLAND UNIVERSITY
Rochester, MI
Mathematics and Statistics

We invite applications for a tenure-track position at the rank of assistant professor in the area of applied continuous mathematics. Candidates must have a Ph.D. in mathematics or in a closely related field by August 15, 2000. Preference will be given to applicants with strong research potential in applied continuous mathematics and operations research. Of particular interest is a specialty in continuous optimization (deterministic or stochastic). Candidates should arrange for a curriculum vitae, transcripts, and three letters of recommendation to be sent to Prof. I. E. Schochetman (schochetman@oakland.edu). Completed applications should be received by January 31, 2000, to ensure full consideration. Further information about the department can be obtained from its Web site, http://www.math.oakland.edu. Oakland University is an Affirmative Action/Equal Opportunity Employer and encourages applications from women and minorities.

MINNESOTA
UNIVERSITY OF MINNESOTA-DULUTH

Tenure-track asst. professor in the applied mathematical sciences starting 8/28/00. Expertise required in applied analysis, including mathematical modeling, dynamical systems, control theory, scientific visualization, and high-performance computation. Teach two courses per semester at graduate and undergraduate level, assist in master’s programs, direct student research, conduct active research program, perform usual service responsibilities. Ph.D. in mathematics or related field required by 8/28/00. Competitive salary. For more information contact Dr. Bruce Peichham, Search Committee Chair, Dept. of Math & Stat., University of Minnesota-Duluth, Duluth, MN 55812. Review of completed applications will start 1/24/00 and will continue until position is filled. Full position description and application procedures at http://www.d.umn.edu/math/ or e-mail address mathed.umn.edu. The University of Minnesota is an Equal Opportunity Educator and Employer.

MISSISSIPPI
THE UNIVERSITY OF SOUTHERN MISSISSIPPI
Department of Mathematics
Hattiesburg, MS 39406-5045

Applications are invited for a tenure-track mathematics position at the assistant professor level beginning August 2000. A doctorate in pure or applied mathematics or a closely related discipline is required. The research area is open, but preference will be given to those candidates who have the potential to attract external funding. The application is further enhanced if the applicant is able to contribute to the doctoral program in scientific computing. Closing date is open, but selection will begin as early as February 2000. Send letter of application, research summary, transcripts, curriculum vitae, brief statement of professional goals, and the names of three references to Search Committee Chair, Box 50435, at the address above.

AA/EEO/ADA.

NEVADA
THE UNIVERSITY OF NEVADA
Professor and Chair
Department of Mathematical Sciences

The University of Nevada, Las Vegas, invites applications for the position of professor and chair of the department of mathematical sciences. The department is seeking a dynamic leader with proven administrative abilities, a record of scholarship, excellence in teaching, and a commitment to undergraduate and graduate education. Candidates in all areas of mathematics and statistics are encouraged to apply; we seek an individual with a wide appreciation and respect for the full array of disciplines represented by the mathematical sciences. Candidates should hold a Ph.D. in mathematics, statistics, or a related field. Please consult the UNLV World Wide Web site at http://www.unlv.edu/. Position is contingent upon funding. Submit a C.V., an application statement (see Web site), and the names and addresses (including e-mail) of five references to: Prof. Peter L. Starkweather, Associate Dean, Department of Mathematical Sciences, University of Nevada, Las Vegas, NV 89154-4020; (702) 895-1406; or starkweather@ccmail.nevada.edu. Review of applications received, continuing until the position is filled.

UNLV is an Equal Opportunity/Affirmative Action Employer. Persons are selected on the basis of ability without regard to race, color, sex, age, national origin, sexual orientation, religion, disability, or veteran status.

NEW HAMPSHIRE
DARTMOUTH COLLEGE
Dept. of Mathematics
6188 Bradley Hall
Hanover, NH 03755-3551

Dartmouth College is the recent recipient of an NSF award to establish a National MRI Data Center. This is a joint effort of Dartmouth's Department of Mathematics, Center for Cognitive Neuroscience, and Department of Computer Science. In conjunction with the Center, the Department of Mathematics is now accepting applications for a two-year postdoctoral fellow in applied mathematics, initial appointment in the 2000-01 academic year. Fellows will be expected to teach one graduate seminar each year (in their specialty) and to help in the implementation and development of novel postprocessing tools for the Center. Fellows will interact with all of the cooperating departments. The ideal applicant will have strong interdisciplinary interests and a background in informatics, image or signal processing, or medical imaging, but applicants with strong mathematical backgrounds who are looking to become more applied and learn about data mining, medical imaging, or image processing may also be excellent candidates.

Send letters of application, résumé, graduate transcript, thesis abstract (and description of other research activities and interests if appropriate), and three or preferably four letters of recommendation (at least one should discuss teaching) to Betty Harrington at the address above. Applications received by February 15 receive first consideration. Dartmouth College is committed to Affirmative Action and strongly encourages applications from minorities and women.

UNIVERSITY OF NEW HAMPSHIRE
Department of Mathematics
Assistant Professor

The Department of Mathematics invites applications for at least one tenure-track assistant professor position in applied mathematics with a possibility of a second appointment pending college approval. Preference will be given to candidates whose interests are aligned with existing strengths in the applied mathematics program, which include but are not limited to the areas of nonlinear dynamics, time-series analysis, computational fluid dynamics, and numerical analysis. Candidates are expected to have a Ph.D. in mathematics by August 2000 and demonstrated research ability. Strong commitment to teaching is expected. The position will begin in the fall semester of 2000. Review of applications will begin on
January 1, 2000, and there is an internal candidate for one of the positions. All applications will be considered until the position is filled. Please submit résumé, e-mail address if possible, and three letters of recommendation to Kenneth Appel, Chair, Department of Mathematics, University of New Hampshire, Durham, NH 03824 (kia@unh.edu). UNH is committed to enhancing the diversity of its faculty and staff and encourages applications from women, persons of color, persons with disabilities, and veterans.

NEW JERSEY

THE COLLEGE OF NEW JERSEY
Department of Mathematics and Statistics

Applications are invited for two anticipated tenure-track positions starting September 2000. The positions require doctorate, demonstrated record of teaching effectiveness, and strong indications of research potential. Responsibilities include undergraduate teaching, advising, and committee service. Preference given to candidates with postdoctoral experience in teaching and research. Position preferences will be given in one to two statistics/applied math and in the other to mathematics education. Send vita and three letters of recommendation addressing teaching and research to: Search Committee, Department of Mathematics and Statistics, The College of New Jersey, P.O. Box 7718, Ewing, NJ 08628-0718. Application deadline: February 1, 2000. To enrich education through diversity, TCNJ is an AA/EOE.

RUTGERS UNIVERSITY, NEWARK
Assistant Professor of Mathematics

The Department of Mathematics and Computer Science invites applications for a tenure-track assistant professor position in mathematics to begin September 2000. Candidates must have a Ph.D. and a strong research record, show outstanding promise for future work, and demonstrate a commitment to effective teaching. Preference will be given to research areas compatible with those of our department, which include geometry, number theory, representation theory, Teichmüller theory, and topology. In addition to participating in our undergraduate and Ph.D. math programs, candidates must be prepared to teach courses and advise students in our department's undergraduate computer science program. Preference will be given to candidates with a willingness to take a leadership role in this area.

Applicants should arrange for (1) an AMS Standard Cover Sheet; (2) a curriculum vitae; (3) a research statement; and (4) at least four letters of recommendation, one of which addresses teaching, to be sent to:
Personnel Committee
Department of Mathematics
and Computer Science
Rutgers University
Newark, NJ 07102

The review process will begin January 15, 2000. Applications may be accepted until the position is filled.
Rutgers University is an Equal Opportunity/Affirmative Action Employer.

NEW YORK

BINGHAMTON UNIVERSITY

The Department of Mathematical Sciences at Binghamton University (The State University of New York at Binghamton) invites applications for a senior position in topology/differential geometry or a related area of mathematics which would strengthen the department's already strong group. Qualifications: A very substantial international research reputation, a record of successful supervision of Ph.D. students, research grants, and a strong teaching record. Screening begins January 15, 2000. Send C.V. and evidence of research and teaching credentials to: Erik Pedersen, Chair, Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902-6000. Also arrange for three letters of recommendation to be sent. Phone: 607-777-2148; fax: 607-777-2450; e-mail: senior@math.binghamton.edu. The department URL is http://math.binghamton.edu/. Binghamton University is an Equal Opportunity/Affirmative Action Employer.

COLUMBIA UNIVERSITY
Department of Computer Science

The Department of Computer Science anticipates one or more non-tenure-track openings for a lecturer. We invite applications from outstanding classroom instructors with strong activity in research in computer science or in a computer-related mathematical discipline. Our department of twenty tenure-track faculty and four lecturers emphasizes excellence in research and teaching and attracts excellent undergraduate and graduate students. The number of faculty is expected to increase.

Departmental facilities include numerous Sun 4 servers; Sun, IBM, and SGI workstations; Macs and PCs; plus state-of-the-art experimental equipment. The department is in the third year of an NSF CISE research infrastructure grant. We are within an hour’s drive of the research laboratories of AT&T, Bellcore, IBM, Lucent, Matsushita, NEC, Nynex, Philips, Siemens, and other leading industrial companies.

Columbia University is one of the leading research universities in the United States, and New York City is one of the cultural, financial, and communications capitals of the world. Columbia’s enclosed campus of tree-lined walks is located in Morningside Heights on the Upper West Side. The department has its own building plus additional space and facilities in the new interdisciplinary Schapiro Center for Engineering and Physical Science Research. University subsidized housing and parking are available.

Please submit a summary of research interests, C.V., e-mail address, and the names of at least three references by filing an online application using the form at http://www.cs.columbia.edu/recruit/. A confirmation of receipt will be sent by e-mail.

Columbia University is an Equal Opportunity/Affirmative Action Employer. We encourage applications from women and minorities.

LEHMAN COLLEGE (CUNY)
Department of Mathematics and Computer Science

Positions are available starting September 1, 2000, for an assistant/associate/full professor in the department of mathematics and computer science. Professorial positions require an earned doctorate, outstanding research record or potential, and commitment to excellence in teaching and departmental and college-wide service. Appointment rank and salary commensurate with qualifications and experience. Application deadline is February 5, 2000. Application procedure: Send curriculum vitae with a cover letter and arrange for at least three letters of recommendation to be sent to: Professor Robert Feinerman, Chair, Department of Mathematics and Computer Science, Lehman College,
RENSESLEA POLYTECHNIC INSTITUTE
Tenured Positions
Applications are invited for one or more tenured positions in applied mathematics, to begin in August 2000. Applicants are expected to possess an outstanding record in research and a strong interest and ability in teaching. Of particular interest are candidates with a commitment to interdisciplinary research who are knowledgeable in scientific computation. When applying, applicants should indicate whether they are applying for an associate professor or full professor position. Applicants should submit a letter of application, a curriculum vitae, a description of research interests, and direct three letters of recommendation to: Search Committee Chair, Department of Mathematical Sciences, Rensselaer Polytechnic Institute, Troy, NY 12180. Evaluation of applications will begin January 15, 2000, and will continue until a candidate is selected. Rensselaer is an Equal Opportunity/Affirmative Action Employer and strongly encourages applications from women and underrepresented minorities.

RENSESLEA POLYTECHNIC INSTITUTE
Tenure-Track Positions
Applications are invited for one or more tenure-track assistant professor positions in applied mathematics, to begin in August 2000. Applicants are expected to have demonstrated outstanding research potential and to have a strong interest and ability in teaching. Of particular interest are candidates with a commitment to interdisciplinary research who are knowledgeable in scientific computation. Applicants should submit a letter of application, a curriculum vitae, a description of research interests, and direct three letters of recommendation to: Search Committee Chair, Department of Mathematical Sciences, Rensselaer Polytechnic Institute, Troy, NY 12180. Evaluation of applications will begin January 15, 2000, and will continue until a candidate is selected. Rensselaer is an Equal Opportunity/Affirmative Action Employer and strongly encourages applications from women and underrepresented minorities.

NORTH CAROLINA
UNIVERSITY OF NORTH CAROLINA,
CHARLOTTE
Applications are invited for a tenure-track assistant professorship in mathematics beginning August 2000. Salary is competitive. Applicants must have a doctorate in mathematics and show outstanding promise in both research and teaching. The fields of interest are those represented by MR codes 05, 11, 12, 13, 14: algebraic geometry, commutative rings and algebras, field theory and polynomials, number theory, and combinatorics. Send a letter of application, curriculum vitae, brief statements of your current research and your teaching objectives, and three letters of recommendation to: Prof. Barnet M. Weinstock, Department of Mathematics, UNC Charlotte, Charlotte, NC 28223. The letters of recommendation must be addressed and mailed directly to Prof. Weinstock. Review of applications will begin on January 31 and will continue until the position is filled. If you have any questions, e-mail Dr. Cai at wein@uncw.edu. The University of North Carolina at Charlotte is an AA/EOE Employer.

PENNSYLVANIA
GETTYSBURG COLLEGE
Tenure-Track Assistant Professor Position in Mathematics
Gettysburg College invites applications for a new tenure-track assistant professor position in mathematics beginning August 2000. Applicants must have a Ph.D. in mathematics or applied mathematics or expect to complete all requirements for the degree by September 2000. Promise of excellence in teaching and a commitment to continued research are essential. Preference will be given to an individual who is willing to teach a broad range of undergraduate mathematics courses and who has the desire to involve undergraduate students in research.

Gettysburg College is a highly selective liberal arts college located within 30 minutes of the Baltimore/Washington area. Established in 1832, the college has a rich history and is situated on a 220-acre campus with an enrollment of 2,300 students. The college seeks to promote diversity in its community through its Affirmative Action/Equal Opportunity programs; included in an attractive benefits package is a Partner Assistance Program. A comprehensive program of support is provided for faculty development, including a pre-tenure leave with full pay. Please send a letter of application explaining your interest in our department, a curriculum vitae, a brief description of your teaching methods and objectives, and a summary of your research goals to: Mathematics Search Committee, Department of Mathematics, Gettysburg College, Gettysburg, PA 17325.

Also arrange for the committee to receive three letters of recommendation addressing teaching effectiveness and research potential. Completed applications received by January 14, 2000, will receive full consideration.

SWARTHMORE COLLEGE
Swarthmore, PA 19081
Department of Mathematics and Statistics
The Department of Mathematics and Statistics invites applications for a tenure-track position at the beginning assistant
professor level starting fall 2000. The position is pending administrative approval, which is anticipated in fall 1999.

The department is looking for candidates in areas that support our existing curriculum and complement existing expertise on our faculty. For more information about our department and program, please see http://www.swarthmore.edu/natsci/math/jobs/. Candidates should possess a commitment to undergraduate education and promise in research. A Ph.D. in mathematics by the starting date is also expected. The annual teaching load is three courses in one semester and two courses in the other. Faculty are eligible to apply for sabbatical leave after every three years of teaching.

Please send a cover letter, résumé, research summary, teaching statement, and three letters of recommendation to the Mathematics Search Committee, Department of Mathematics and Statistics, Swarthmore College, 500 College Ave., Swarthmore, PA 19081. The cover letter should include a statement about how the candidate complements the department. All applications should be sent in paper form. No e-mail or fax applications will be considered. E-mail inquiries can be sent to: nstdept@swarthmore.edu.

All applications received by December 10 will receive full consideration. Later applications may be considered until the position is filled. Swarthmore is an Equal Opportunity Employer. Women and minority candidates are encouraged to apply.

SOUTHERN CAROLINA

COLLEGE OF CHARLESTON

Department of Mathematics

Applications are invited for at least one full-time tenure-track position in mathematics at the assistant professor level starting in August 2000. The mathematics department at the College of Charleston has 29 full-time faculty and offers the B.S. and M.S. degrees in mathematics. Candidates must have a Ph.D. in one of the mathematical sciences, a commitment to undergraduate and graduate teaching, and the potential for continuing research. Preference for the first position will be given to applicants with a Ph.D. in one of the mathematical sciences, a commitment to undergraduate teaching, and the potential for continuing research. Preference for the first position will be given to applicants who hold a Ph.D. in one of the mathematical sciences, a commitment to undergraduate teaching, and the potential for continuing research.

The Department of Mathematics expects to have an opening for a tenure-track assistant professor position starting in fall 2000 and invites applications. Applications completed by February 1, 2000, will receive full consideration. While applications in all areas of mathematics will be considered, those whose interests mesh well with the strengths of the department will be given preference. The Ph.D. degree or its equivalent is required. Candidates with some postdoctoral experience are generally preferred, although finishing Ph.D.'s with significant accomplishments in research are also encouraged to apply. This appointment will be consistent with the department's commitment to excellence in research and in teaching at the undergraduate and graduate level. A complete application should include a detailed resume with a summary of research accomplishments and goals, a completed copy of the AMS Standard Cover Sheet (see the Notices), and four letters of recommendation. All material should be sent to:

Robert M. Stephenson, Jr., Chairman
Department of Mathematics
University of South Carolina
Columbia, SC 29208

We encourage applications to the AMS Cover Sheet located on our World Wide Web site, http://www.math.sc.edu/jobs/2000/. The University of South Carolina is an Affirmative Action/Equal Opportunity Employer.

WINTHROP UNIVERSITY

Applicants only in the fields of applied mathematics or operations research are invited to apply for a tenure-track position at the assistant professor level beginning in the fall 2000 semester. Research and scholarly activities must support this level of teaching. Documentation of teaching excellence independent of professional references is required. In addition to this tenure-track position, the department will have one instructor position available.

A completed application, vita, documented evidence of teaching excellence, and three letters of reference are required. This process will close March 1, 2000. Applications should be sent to:

Dr. Gary T. Brooks, Chair
Department of Mathematics

Winthrop University
Rock Hill, SC 29733

Winthrop University is a comprehensive university supported by the State of South Carolina, with an enrollment of 5,200 students. Winthrop is located approximately twenty miles south of Charlotte, North Carolina. EOE/AA.

TENNESSEE

THE UNIVERSITY OF TENNESSEE, KNOXVILLE

Subject to university approval, the mathematics department of the University of Tennessee seeks to fill a tenure-track assistant professorship in algebraic geometry or geometric group theory. A Ph.D. is required. Some postdoctoral experience is preferred but not required. Substantial research promise and dedication to teaching are paramount. Employment begins August 1, 2000.

Interested applicants should arrange to have one vita, three reference letters, a research statement (including abstracts), and evidence of quality teaching sent to: Professor John B. Conway, Geometry Search, Mathematics Department, University of Tennessee, Knoxville, TN 37996-1300. Electronic applications are not acceptable. Use of the AMS application form is appreciated. Review of applications will begin December 1 and will continue until the position is filled. Information about the department can be found at http://www.math.utk.edu/.

UTK Knoxville is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA Institution in the provision of its education and employment programs and services.

THE UNIVERSITY OF TENNESSEE, KNOXVILLE

Subject to university approval, the mathematics department of the University of Tennessee (http://www.math.utk.edu) seeks to fill a tenure-track position with an Outreach Mathematician (OM). The duties of the OM will be to foster close relations between the university and the community colleges and/or high schools across the state, to collaborate with faculty in the College of Education, as well as to teach in the department. The appointment will be at a rank that is commensurate with experience.

A Ph.D. in mathematics or a doctoral degree in another discipline with a Master's of Science degree in mathematics is required, together with a clear commitment to outreach activities. Some postdoctoral experience is preferred but not required. Dedication to teaching is paramount. Employment begins August 1, 2000.

We seek a person who will participate in the education program of the department, actively pursue grants to foster these aims,
involved in statewide mathematics education reform, and work with the appropriate faculty in the College of Education.

Interested applicants should arrange to have a vita, three reference letters, a statement of accomplishments, qualifications, plans for outreach activities, and evidence of quality teaching sent to: Professor John B. Conway, OM Search, Mathematics Department, University of Tennessee, Knoxville, TN 37996-1300. Electronic applications are not accepted. Use of the AMS application form is encouraged. Review of applications will begin December 1 and will continue until the position is filled.

UTK Knoxville is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA Institution in the provision of its education and employment programs and services.

THE UNIVERSITY OF TENNESSEE, KNOXVILLE
Subject to university approval, the mathematics department of the University of Tennessee seeks to fill a tenure-track assistant professorship in probability and stochastic processes with emphasis on stochastic analysis, stochastic differential equations, or nondeterministic modeling. Preference will be shown to candidates working in applied aspects of these areas such as communication networks, mathematical biology and genetics, and mathematical finance. A Ph.D. is required. Some postdoctoral experience is preferred but not required. Substantial research promise and dedication to teaching are paramount. Employment begins August 1, 2000.

Interested applicants should arrange to have a vita, three reference letters, a research statement (including abstracts), and evidence of quality teaching sent to: Professor John B. Conway, Probability Search, Mathematics Department, University of Tennessee, Knoxville, TN 37996-1300. Electronic applications are not acceptable. Use of the AMS application form is appreciated. Review of applications will begin December 1 and will continue until the position is filled. Information about the department can be found at http://www.math.utk.edu/.

UTK Knoxville is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA Institution in the provision of its education and employment programs and services.

VANDERBILT UNIVERSITY
1326 Stevenson Center
Nashville, TN 37240
Department of Mathematics

We invite applications for two non-tenure-track positions in the areas of universal algebra, lattice theory, ordered algebraic structures, mathematical biology, population dynamics, and computational harmonic analysis beginning fall 2000. These are two-year appointments at the assistant professor level, normally renewable for a third year. They are intended for recent Ph.D. recipients with demonstrated research potential and strong commitment to excellence in teaching. To apply, send the following materials in a single mailing to the contact person in your research area: letter of application (including e-mail address and fax number), the AMS Cover Sheet fully completed, curriculum vitae, and research summary. Do not send additional information (including letters of recommendation) unless requested to do so after the initial screening. Evaluation of applications will commence on October 25 and will continue until the positions are filled.

Application deadline: No application deadline.
Vanderbilt University is an Affirmative Action/Equal Opportunity Employer.

VANDERBILT UNIVERSITY
1326 Stevenson Center
Nashville, TN 37240
Department of Mathematics

Applications are invited for at least two tenure-track assistant professor positions beginning fall 2000. All areas of mathematics will be considered, but priority will be given to candidates in (1) computational mathematics, and (2) algebra, geometry, or topology. A successful candidate will show strong promise or accomplishment in research and teaching. Please send a resume, a completed AMS Standard Cover Sheet, and three letters of recommendation to: Alex Wang, Hiring Chair, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409-1042. Review of applications will begin immediately. Additional information is available at http://ttmath.ttu.edu/awang/employ/employ.html. Texas Tech is an AA/EO Employer.

THE UNIVERSITY OF TEXAS AT AUSTIN
Department of Mathematics

Openings for fall 2000 include: (1) instructorships, some of which have R. H. Bing Faculty Fellowships attached to them; and (2) two or more positions at the tenure-track/tenured level.

1. Instructorships at The University of Texas at Austin are postdoctoral appointments, renewable for two additional years. It is assumed that applicants for instructorships will have completed all Ph.D. requirements by August 31, 2000. Other factors being equal, preference will be given to those whose doctorates were conferred in 1999 or 2000. Candidates should show superior research ability and have a strong commitment to teaching. Consideration will be given only to persons whose research interests have some overlap with those of the permanent faculty. Duties consist of teaching undergraduate and graduate courses and conducting independent research. The projected salary is $35,000 for the nine-month academic year.

Each R. H. Bing Fellow holds an instructorship in the mathematics department, with a teaching load of two courses in one semester and one course in the other. The combined instructorship-fellowship stipend for nine months is $38,500, which is supplemented by a travel allowance of $1,000. Pending satisfactory performance of teaching duties, the fellowship can be renewed for two additional years. Applicants must show outstanding promise in research. Bing Fellowship applicants will automatically be considered for other departmental openings at the postdoctoral level, so a separate application for such a position is unnecessary.

Those wishing to apply for instructor positions are asked to send a vita and a brief research summary to the above address c/o Instructor Committee. Transmission of the preceding items via e-mail (address: instructor@math.uta.edu) is encouraged.

2. An applicant for a tenure-track or tenured position must present a record of exceptional achievement in her or his research area and must demonstrate a
proficiency at teaching. In addition to the duties indicated above for instructors, such an appointment will typically entail the supervision of M.A. or Ph.D. students. The salary will be commensurate with the level at which the position is filled and the qualifications of the person who fills it.

Those wishing to apply for tenure-track/tenured positions are asked to send a vita and a brief research summary to the above address, c/o Recruiting Committee. Transmission of the preceding items via e-mail (address: recruit@math.utexas.edu) is encouraged.

All applications must be supported by three or more letters of recommendation, at least one of which speaks to the applicant's teaching credentials. The screening of applications will begin on December 1, 1999.

The University of Texas at Austin is an Equal Opportunity Employer.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Department of Mathematics

Applications are solicited for tenure-track positions in numerical analysis, optimization, or computational mathematics at the assistant or associate professor level. We seek candidates who will augment an existing faculty focus in numerical treatment of partial differential equations, optimization, control, and computational mathematics. For a complete position announcement, please see our Web site at http://www.math.vt.edu/. Candidates must have a Ph.D. in mathematics or equivalent, with a strong record or demonstrated potential in research and teaching.

Virginia Tech is an Equal Opportunity/Affirmative Action Employer and complies with all federal and Commonwealth of Virginia laws, regulations, and executive orders regarding affirmative action requirements in all programs. The College of Arts and Sciences at Virginia Tech is deeply committed to recruiting, selecting, promoting, and retaining women, persons of color, and persons with disabilities. We strongly value diversity in the college community and seek to assure equality in education and employment. Individuals with disabilities desiring accommodations in the application process should contact Pat Ray, Department of Mathematics, 540-231-6536 (IDD/PC 1-800-828-1120, Voice 1-800-828-1140).

Send a letter of application, curriculum vitae, summary of research plans, together with four letters of recommendation (one of which addresses teaching), to:
Numerical Analysis Search Committee
Department of Mathematics
Virginia Tech
Blacksburg, VA 24061-0123

CANADA

THE FIELDS INSTITUTE FOR RESEARCH IN THE MATHEMATICAL SCIENCES

Nominations and applications for the position of director of The Fields Institute for Research in the Mathematical Sciences are invited. The term of office of the current director, Donald A. Dawson, expires as of June 30, 2000.

The director is the chief executive officer of the institute with responsibility for the institute's scientific leadership and overall operation. The term of office is three to five years, renewable once. Candidates should have a strong international stature in the mathematical sciences as well as proven administrative experience. Nominations and applications should be received by January 21, 2000.

Applications, including curriculum vitae, should be made in confidence to:
John Gardner
Chair of the Board of Directors
The Fields Institute
222 College Street, 2nd Floor
Toronto, Ontario M5T 3J1
fax: 416-348-9714
Web site: www.fields.utoronto.ca
The Fields Institute encourages applications from qualified women or men, members of visible minorities, Aboriginal peoples, and persons with disabilities for further information please contact the Director of The Fields Institute at the above address.

UNIVERSITY OF TORONTO
Tenure-Stream Appointment in Analysis or Applied Mathematics

The University of Toronto solicits applications for a tenure-stream appointment in analysis or applied mathematics.

The appointment is at the University of Toronto at Mississauga, Erindale College, at the level of assistant professor to begin July 1, 2000. Candidates are expected to have at least three years' experience in teaching and research after the Ph.D. and to be able to demonstrate excellence in each. In particular, a candidate's research should show clearly the ability to make significant original and independent contributions to mathematics. Salary commensurate with qualifications and experience.

Applicants should send their complete C.V., including a list of publications, a short statement describing their research program, and appropriate material about their teaching. They should also arrange to have at least four letters of reference sent directly to: Professor R.-O. Buchweit, Associate Chair, Department of Mathematics, University of Toronto, Toronto, Canada M5S 3G3. At least one letter should be primarily concerned with

the candidate's teaching. In addition, it is recommended that applicants submit the electronic application form at http://www.math.toronto.edu/jobs/.

To ensure full consideration, this information should be received by January 31, 2000.

In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents of Canada. In accordance with its Employment Equity Policy, the University of Toronto encourages applications from qualified women or men, members of visible minorities, Aboriginal peoples, and persons with disabilities.

THE UNIVERSITY OF TORONTO
Joint Tenure-Stream Appointment in Mathematics, and Electrical and Computer Engineering

The Department of Electrical and Computer Engineering and the Department of Mathematics at the University of Toronto invite applications for a joint tenure-stream assistant professor position to begin July 1, 2000. The successful candidate will have a demonstrated ability as a researcher in mathematics and in the application of mathematics in electrical and computer engineering. Areas of interest include but are not limited to applied probability, stochastic differential equations, and computational partial differential equations, and their application in communications, image and signal processing, network modelling, or real-time systems.

The position involves teaching and research in electrical engineering, computer engineering, and mathematics. Candidates must have a doctoral degree, an outstanding academic record, and effective teaching ability.

Additional information can be found on the Web pages at: http://www.ece.toronto.edu/ and http://www.math.toronto.edu/.

Applicants should send a curriculum vitae, including a statement about teaching and research interests. They should also arrange for at least three reference letters about their research and teaching abilities to be sent to:
Professor Safwat G. Zaky, Chair
Department of Electrical and Computer Engineering
University of Toronto
10 King's College Road, Room 1024
Toronto, Ontario M5S 3G3, Canada

To ensure consideration, please send the application material by January 31, 2000. In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents. The University of Toronto is committed to employment equity and encourages applications from women, visible
minorities, and physically challenged persons.

HONG KONG
THE CHINESE UNIVERSITY
OF HONG KONG
Department of Mathematics
Professor of Mathematics

The department offers undergraduate and postgraduate programs leading to B.Sc., M.Sc., M.Phil., and Ph.D. degrees. Research interests of faculty members include algebra, number theory, topology, geometry, differential equations, functional analysis, harmonic analysis, fractals, and wavelets. By virtue of his/her established scholarship in the discipline, the professor will be expected to provide leadership in teaching and research and play a major role in curriculum planning and development. Applicants should possess excellent academic qualifications, extensive university teaching, and relevant research experience; and should have published scholarly works of originality and merit. Academic administration experience will be an additional asset. Appointment will initially be made on a fixed-term contract basis for up to three years.

Annual Salary and Fringe Benefits: Starting at HK$1,229,280 (approx. exchange rate in November 1999: $1 = HK$12.83; US$1 = HK$7.75). Starting salary will be commensurate with qualifications and experience.

Benefits include leave with full pay; medical and dental care; where applicable, children’s education allowance; housing benefit for eligible appointee (subject to the rules for the prevention of double housing benefits); and a contract-end gratuity (up to 15% of basic salary).

Further information about the university and the general terms of service for teaching appointees is available at our home page, http://www.cuhk.edu.hk.

Application Procedure: Please send full resume, a list of academic credentials, a publication list and/or abstracts of selected published papers, together with names and addresses (fax numbers/e-mail addresses as well, if available) of three referees to the Personnel Office, The Chinese University of Hong Kong, Shatin, New Territories, Hong Kong (fax: 852-2603-6852), before the closing date of January 20, 2000. Please quote the reference number 99/109(047)/2 and mark “Application” on cover. [Note: The University reserves the right not to fill the post or to fill the post by invitation.]

THE HONG KONG UNIVERSITY
OF SCIENCE AND TECHNOLOGY

The Department of Mathematics invites applications for faculty staff at the rank of professor, associate professor, or assistant professor in the area of statistics. Applicants who are specialized in areas other than statistics and have demonstrated outstanding performance and contributions to their own fields of specialization will also be seriously considered. Exceptionally strong research and teaching experience are required. Applicants must demonstrate excellence in teaching and proven ability to teach effectively in English.

Starting rank and salary will depend on qualifications and experience. Benefits, including medical and dental benefits, children’s education allowance, and assistance in housing will be provided wherever applicable. Initial appointment will normally be for a one-year contract; future tenure may be considered for appointment at professorial level. A gratuity will be payable upon successful completion of contract.

Applications should send a curriculum vitae and ask at least three referees to send letters of recommendation, preferably before February 29, 2000, directly to: The Director of Personnel, HKUST, Clear Water Bay, Kowloon, Hong Kong; fax: (852) 2358 0700. More information about the university is available on the university’s home page, http://www.ust.hk.

INDIA
MEHTA RESEARCH INSTITUTE

Mehta Research Institute is an established research institute devoted to research in pure mathematics and theoretical physics. Located on the banks of the river Ganga and overlooking the famous site of confluence of the rivers Ganga and Yamuna, the Mehta Research Institute has a beautiful campus of its own at a distance of about 15 km from the city of Allahabad in northern India. The faculty in mathematics has interests in several areas of pure mathematics, including algebraic geometry, automorphic forms, complex analysis, and number theory. The institute seeks applications for both postdoctoral and more permanent positions.

The postdoctoral fellowship is presently Rs. 8000/- per month plus free accommodations, liberal leave rules, and travel support for attending conferences. If interested for postdoctoral appointments, please write with details to: Professor Dipendra Brahmachari Mehta Research Institute Chhatnag Road, Allahabad - 211 019, India e-mail: dprasad@mri.ernet.in

If interested for regular appointments, please write with details to: Director Mehta Research Institute Chhatnag Road, Allahabad - 211 019, India e-mail: main@mri.ernet.in

MEXICO

UNIVERSIDAD AUTONOMA
Metropolitana Iztapalapa Campus

The Department of Mathematics invites applications for two tenure-track positions in theoretical and applied statistics. These positions are at senior level to start at any time after March 1, 2000. Qualifications: Ph.D. and demonstrated strong research record and teaching experience. It is expected that the candidate will be able to teach in Spanish after one year's residence in Mexico. We offer competitive salaries to suitable qualified applicants. The university will arrange Mexican visas and work permits for those hired.

To apply, send curriculum vitae and at least three letters of reference to: Professor Ernesto Perez Chavela Departamento de Matemáticas Av. México y la Purísima S/N APDO. Postal 55-534 C.P. 09340 Mexico, D.F., Mexico

The Universidad Autonoma Metropolitana Iztapalapa Campus is a publicly funded institution located in the southeast of Mexico City with a student body of 15,000 and a mathematics department of 60 full-time tenured faculty. Normal teaching load is 4 trimester courses per year.
This is the first of two volumes on the qualitative theory of foliations. This volume is divided into three parts. It is extensively illustrated throughout and provides a large number of examples.

Part 1 is intended as a "primer" in foliation theory. A working knowledge of manifold theory and topology is a prerequisite. Fundamental definitions and theorems are explained to prepare the reader for further exploration of the topic. This section places considerable emphasis on the construction of examples, which are accompanied by many illustrations.

Part 2 considers foliations of codimension one. Using very hands-on geometric methods, the path leads to a complete structure theory (the theory of levels), which was established by Conlon along with Cantwell, Hector, Duminin, Nishimori, Tauchiya, et al. Presented here is the first and only full treatment of the theory of levels in a textbook.


This comprehensive volume has something to offer a broad spectrum of readers: from beginners to advanced students to professional researchers. Packed with a wealth of illustrations and copious examples at varying degrees of difficulty, this highly-accessible text offers the first full treatment in the literature of the theory of levels for foliated manifolds of codimension one. It would make an elegant supplementary text for a topics course at the advanced graduate level.

Graduate Studies in Mathematics, Volume 23, 2000; 402 pages; Hardcover; ISBN 0-8218-4699-9; List $54; All AMS members $43; Order code GSM/23.

PORTUGAL

INSTITUTO SUPERIOR TÉCNICO
Center for Mathematical Analysis, Geometry and Dynamical Systems of the Department of Mathematics of Instituto Superior Técnico, Lisbon, Portugal, invites applications for postdoctoral positions for research in mathematics. Positions are for one year, and the possibility of extension for a second year upon mutual agreement. Selected candidates will be able to take up their position between September 1, 2000, and January 1, 2001.

Applicants should have a Ph.D. in mathematics obtained after December 31, 1997. They must show very strong research promise in one of the areas in which the mathematics faculty of the center is currently active. There are no teaching duties associated with these positions.

Applicants should send a curriculum vitae; reprints, preprints, and/or dissertation abstract; description of research project (in no more than 1,000 words); and three letters of reference directly to the director at the above address.

To ensure full consideration, complete application packages should be received by March 15, 2000. Additional information about the center and the positions is available at http://www.math.ist.utl.pt/cam/.

SINGAPORE

NATIONAL UNIVERSITY OF SINGAPORE
Department of Mathematics

The Department of Mathematics at NUS invites applications for several tenure-track and postdoctoral positions, commencing July 1, 2000. Outstanding researchers will be considered in any field. The department has a special interest in building up its OR and financial mathematics research groups.

For further information about this advancing department, its attractive salaries and facilities, and the research interests of its 80 faculty, please see http://www.math.nus.edu.sg/. An application form may be downloaded from the Web site.

Applications should be supported by three letters testifying to research excellence and (for tenure-track applicants) evidence of effectiveness and commitment to teaching. As well as a completed application form, curriculum vitae, and list of publications, applicants should indicate a statement of research achievements and plans. All correspondence should be sent to:

e-mail: search@math.nus.edu.sg
Towards Excellence: Leading a Doctoral Mathematics Department in the 21st Century

John Ewing, Editor

This book is aimed at mathematics departments in research universities and calls on those departments to understand what is of value to their universities. Because undergraduate education is a major focus for many universities, education is important for departments—not to replace research but in order to support it.

The simple message of the report is: To ensure an institution’s commitment to excellence in mathematics research, doctoral departments must pursue excellence in the instructional programs. To help accomplish this goal, this book contains advice and analysis of a number of focus groups involving department chairs, as well as several meetings with groups of deans. It also contains examples of interesting programs studied during site visits to specific departments and a number of other resources.

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Acknowledgments

The American Mathematical Society and The Task Force on Excellence gratefully acknowledge the support for this project by The National Science Foundation and EXXON Education Foundation.

The book may be downloaded at: http://www.ams.org/towardsexcellence/. To order a free copy of Towards Excellence (1999; 261 pages; Softcover; ISBN 0-8218-2033-8), please send email to res@ams.org with subject line “Book Order”, and include your full mailing address in the body of the message.

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MathSciNet

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When links to original articles in online journals have not yet been established, MathSciNet will link to that journal's home page. From the journal's home page, various avenues of access to the original article may be available to subscribers of the journal.

To Journal New links will continue to be added throughout 2000.

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Consortia pricing is available: please contact Lori Sprague, Publications Administrator, by telephone at 1-401-455-4064 or by email at las@ams.org.

* Free trial available for institutions and corporations. For more information, contact the American Mathematical Society, Membership and Customer Services Department at: 1-800-321-4267 or 1-401-455-4000, worldwide; fax 1-401-455-4046; e-mail cust-serv@ams.org.

MathSciNet has an especially powerful system of internal links between reviews and provides direct links to the papers themselves if they are available online. The reviews are classified by subject and are searchable in multiple ways. Thus, it provides an unparalleled method of browsing the literature for serious content (along with accurate bibliographic data).

—Journal of Electronic Publishing,
University of Michigan Press

Reviews posted to MathSciNet nightly:
Reviews in MR now appear 6-10 weeks sooner. Since these reviews do not yet have an MR number assigned, they are noted as "Review" in search results by the CMP issue number.

A simplified Basic Search has been added.
Basic Search provides one pulldown menu of fields and one input box. Boolean operators and parentheses may be used. The standard Full Search, is still available.

Document Delivery:
CISTI (Canada Institute for Scientific and Technical Information) is the new provider of document delivery from MathSciNet.

Nearly 1,400,000 searchable reviews on the Mathematical Reviews electronic database

The entire collection of MathSciNet review now contains searchable reviews of a definitive part of mathematical development over the past 60 years—from 1940 to the present.

The addition of review texts since 1940 allows researchers to see more fully the historical development and applications of mathematics and mathematical ideas. A combination of sophisticated tools—notably the Author Identification resource and the extensive network of links throughout the database—enhances the vitality and usefulness of MathSciNet.

Go to www.ams.org/mathscinet/ for updates and to view a demo.
General Information Regarding Meetings & Conferences of the AMS

Speakers and Organizers: The Council has decreed that no paper, whether invited or contributed, may be listed in the program of a meeting of the Society unless an abstract of the paper has been received in Providence prior to the deadline.

Although an individual may present only one ten-minute contributed paper at a meeting, any combination of joint authorship may be accepted, provided no individual speaks more than once. An author can speak by invitation in more than one Special Session at the same meeting.

Special Sessions: The number of Special Sessions at an Annual Meeting is limited. Special Sessions at Annual Meetings are held under the supervision of the Program Committee for National Meetings and, for Sectional Meetings, under the supervision of each Section Program Committee. They are administered by the associate secretary in charge of that meeting with staff assistance from the Meetings and Conferences Department in Providence. (See the list of associate secretaries on the next page.)

Each person selected to give an Invited Address is also invited to generate a Special Session, either by personally organizing one or by having it organized by others. Proposals to organize a Special Session are sometimes solicited either by a program committee or by the associate secretary. Other proposals should be submitted to the associate secretary in charge of that meeting with staff assistance from the Meetings and Conferences Department in Providence. (See the list of associate secretaries on the next page.)

Talks in Special Sessions are usually limited to twenty minutes; however, organizers who wish to allocate more time to individual speakers may do so within certain limits. A great many of the papers presented in Special Sessions at meetings of the Society are invited papers, but any member of the Society who wishes to do so may submit an abstract for consideration for presentation in a Special Session, provided it is received by the abstracts coordinator in Providence prior to the special early deadline for consideration. Contributors should know that there is a limit to the size of a single Special Session, so sometimes all places are filled by invitation. Papers submitted for consideration for inclusion in Special Sessions but not accepted will receive consideration for a contributed paper session, unless specific instructions to the contrary are given.

The Society reserves the right of first refusal for the publication of proceedings of any Special Session. If published by the AMS, these proceedings appear in the book series Contemporary Mathematics.

Contributed Papers: The Society also accepts abstracts for ten-minute contributed papers. These abstracts will be grouped by related Mathematical Reviews subject classifications into sessions insofar as possible. The title and author of each paper accepted and the time of presentation will be listed in the program of the meeting.

Other Sessions: In accordance with policy established by the AMS Committee on Meetings and Conferences, mathematicians interested in organizing a session at an annual or sectional meeting on employment opportunities inside or outside academia for young mathematicians should contact the associate secretary for the meeting with a proposal by the stated deadline. Also, potential organizers for poster sessions on a topic of choice should contact the associate secretary before the deadline.

Abstracts: Abstracts for all papers must be received by the meeting coordinator in Providence by the stated deadline. Unfortunately, late papers cannot be accommodated.

Electronic submission procedures: Send a message to abs-submit@ams.org and type help as the subject to review your options, or visit the meetings and conferences home page on the Web at http://www.ams.org/committee/meetings/. Completed electronic abstracts must be submitted to abs-submit@ams.org, typing submission as the subject.

Submission by U.S. mail: AMS abstract forms are available at many departments of mathematics or may be requested by contacting the Meeting Coordinator, AMS Meetings and Conferences Department, P. O. Box 6887, Providence, RI 02940; telephone: 401-455-4146; e-mail: abs-misc@ams.org. Your completed abstract should be sent to the same address by the stated deadline. N. B. there is a $20 processing fee for paper abstracts. There is no charge for abstracts submitted electronically.

See the inside front cover of Abstracts of Papers Presented to the American Mathematical Society for information on abstracts published by title and not presented at a meeting.

Site Selection for Sectional Meetings

Sectional meeting sites are recommended by the associate secretary for the section and approved by the Secretariat. Recommendations are usually made eighteen to twenty-four months in advance. Host departments supply local information, ten to twelve rooms with overhead projectors for contributed paper sessions and Special Sessions, an auditorium with twin overhead projectors for Invited Addresses, and registration clerks. The Society partially reimburses for the rental of facilities and equipment and for staffing the registration desk. Most host departments volunteer; to do so, or for more information, contact the associate secretary for the section.
Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the Notices. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on e-MATH. See http://www.ams.org/meetings/. Programs and abstracts will continue to be displayed on e-MATH in the Meetings and Conferences section until about three weeks after the meeting is over. Final programs for Sectional Meetings will be archived on e-MATH in an electronic issue of the Notices as noted below for each meeting.

Washington, District of Columbia
Marriott Wardman Park Hotel and Omni Shoreham Hotel
January 19-22, 2000

Meeting #950
Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM), the annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic.
Associate secretary: Bernard Russo
Announcement issue of Notices: October 1999
Program first available on eMATH: November 1, 1999
Program issue of electronic Notices: January 2000
Issue of Abstracts: Volume 21, Issue 1

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

Joint Session Updates
An invited address sponsored by the AMS, MAA, MSEB, and SIAM will be given by Judith S. Sunley, National Science Foundation, from 4:25 p.m. to 5:15 p.m. on Wednesday, title to be announced.

The title for Brian Greene's joint invited address on Wednesday is Spacetime in string theory.
The AMS Committee on Science Policy and MAA Science Policy Committee Government Speaker has been cancelled.

AMS Session Updates
The Committee on Education Panel Discussion has been cancelled.

MAA Session Updates
Presentations by Teaching Award Recipients on Friday afternoon include Arthur T. Benjamin, Harvey Mudd College, Magical moments in teaching; Donald S. Passman, University of Wisconsin, Madison, The end of calculus; and Gary W. Towsley, SUNY, College at Geneseo, What does mathematics have to do with Dante?

Other Organizations Updates
Invited Addresses on the Association for Symbolic Logic program include:
Manuel Lerman, University of Connecticut, Homomorphisms and quotients of degree structures, Friday, 9:00 a.m.-9:25 a.m.
Willem L. Fouché, University of Pretoria, Symmetry and the Ramsey degree of finite relational structures, Friday 9:30 a.m.-9:55 a.m.
Zachary Robinson, Eastern Carolina University, Title to be announced, Friday, 10:05 a.m.-10:30 a.m.
Meir Buzaglo, Hebrew University of Jerusalem, Forced expansions, Friday 10:35 a.m.-11:00 a.m.
Timothy J. Carlson, Ohio State University, Title to be announced, Friday, 1:00 p.m.-1:45 p.m.
Saul A. Kripke, Princeton University, *The collapse of the Hilbert program: Variations on the Godelian theme*, Friday, 2:00 p.m.-2:45 p.m.

Jeffrey B. Remmel, University of California, San Diego, *Complexity theoretic algebra and model theory*, Friday, 3:00 p.m.-3:45 p.m.

Kevin Wald, University of Connecticut, *Automorphisms and noninvariant properties of the computably enumerable sets*, 10:00 a.m.-10:30 a.m.

James Cummings, Carnegie Mellon University, *Title to be announced*, Saturday, 10:45 a.m.-11:10 a.m.

J. Karel Lambert, University of California, Irvine, *Four solutions in search of a problem*, Saturday, 1:20 p.m.-1:45 p.m.

Brad Hart, McMaster University, *The logic of hyperimaginaries*, Saturday, 2:00 p.m.-2:45 p.m.

Dirk van Dalen, Utrecht University, *L. E. J. Brouwer: How mathematics is rooted in life*, Saturday, 3:00 p.m.-3:45 p.m.

**Registration at the Meetings**

Individuals who registered by November 22 and who so elected will have their badge and the final program mailed to them before the Meetings. All other registrants will receive the final program at the Meetings. The additional information below is to assist those who will register at the Meetings and those who registered in advance but elected not to receive their badges and final programs by mail.

Advance and on-site meeting registration fees only partially cover expenses of holding meetings. All mathematicians who wish to attend sessions are expected to register and should be prepared to show the Meetings badge, if so requested. Badges are required to obtain discounts at the AMS and MAA Book Sales and to cash a check with the Meetings cashier. If advance registrants should arrive too late in the day to pick up their badges, they may show the acknowledgment received from the Mathematics Meetings Service Bureau (MMSB) as proof of registration.

Registration fees may be paid at the Meetings in cash, by personal or traveler's check, or by VISA, MasterCard, American Express, or Discover. Letters verifying attendance at the Meetings may be obtained from the cashier or at the Registration Assistance section of the Registration Desk.

Participants wishing to attend sessions for one day only may take advantage of a one-day fee. These special fees are effective daily, January 19 through 22, and are available at the Meetings to both members and nonmembers. These one-day fees are not applicable to librarians, high school teachers, unemployed or emeritus participants, or high school, undergraduate, or graduate students.

**Joint Mathematics Meetings**

<table>
<thead>
<tr>
<th>Category</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member of AMS, ASL, Canadian Mathematical Society (CMS), MAA, SIAM</td>
<td>$215</td>
</tr>
<tr>
<td>Emeritus Member of AMS, MAA</td>
<td>$45</td>
</tr>
<tr>
<td>Nonmember</td>
<td>$332</td>
</tr>
<tr>
<td>Temporarily Employed</td>
<td>$140</td>
</tr>
<tr>
<td>Graduate Student/Unemployed</td>
<td>$45</td>
</tr>
<tr>
<td>Librarians/High School Teachers</td>
<td>$45</td>
</tr>
<tr>
<td>Developing Country Participant</td>
<td>$45</td>
</tr>
<tr>
<td>Undergraduate Students</td>
<td>$26</td>
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</tbody>
</table>

**Joint Mathematics Meetings One Day**

<table>
<thead>
<tr>
<th>Category</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member of AMS, ASL, CMS, MAA, SIAM</td>
<td>$118</td>
</tr>
<tr>
<td>Nonmember</td>
<td>$183</td>
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</table>

**MAA Minicourses (if openings available)**

<table>
<thead>
<tr>
<th>Minicourses</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>#7-15</td>
<td>$55</td>
</tr>
<tr>
<td>#1-6</td>
<td>$80</td>
</tr>
</tbody>
</table>

**Employment Center**

<table>
<thead>
<tr>
<th>Category</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employer (First Table)</td>
<td>$250</td>
</tr>
<tr>
<td>Employer (Each Additional Table)</td>
<td>$75</td>
</tr>
<tr>
<td>Applicant (all services)</td>
<td>$75</td>
</tr>
<tr>
<td>Applicant (Winter List and Message Ctr. only)</td>
<td>$20</td>
</tr>
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</table>

**AMS Short Course**

<table>
<thead>
<tr>
<th>Category</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student/Unemployed</td>
<td>$45</td>
</tr>
<tr>
<td>Emeritus Member of AMS, MAA</td>
<td>$45</td>
</tr>
<tr>
<td>All Other Participants</td>
<td>$95</td>
</tr>
</tbody>
</table>

**MAA Short Course**

<table>
<thead>
<tr>
<th>Category</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA member</td>
<td>$140</td>
</tr>
<tr>
<td>Nonmember</td>
<td>$190</td>
</tr>
<tr>
<td>Student/Unemployed/Emeritus</td>
<td>$60</td>
</tr>
</tbody>
</table>

**Accommodations and Travel**

Participants who did not reserve a room during advance registration but who would like to obtain a room at one of the hotels listed on pages 1152 and 1153 in the October issue of the *Notices* should call the hotels directly **after December 29**. However, we regret that after that date the MMSB can no longer guarantee availability of rooms or of the special convention rates.

Please see the October issue for special discount fare information on US Airways, as well as driving directions to the Marriott Wardman Park Hotel and the Omni Shoreham Hotel.

**Registration Dates, Times, and Locations**

**AMS Short Courses**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday, January 17</td>
<td>9:00 a.m. to 4:00 p.m.</td>
<td>Outside the Coolidge Room, Marriott Wardman Park</td>
</tr>
</tbody>
</table>

**MAA Short Course**

<table>
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<tbody>
<tr>
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</tr>
</tbody>
</table>

**Joint Mathematics Meetings and MAA Minicourses**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuesday, January 18</td>
<td>3:00 p.m. to 7:00 p.m.</td>
<td>Exhibit Hall C, Marriott Wardman Park Hotel</td>
</tr>
<tr>
<td>Wednesday-Friday,</td>
<td>7:30 a.m. to 4:00 p.m.</td>
<td>Marriott Wardman Park</td>
</tr>
<tr>
<td>January 19-21</td>
<td>7:30 a.m. to 4:00 p.m.</td>
<td>Marriott Wardman Park</td>
</tr>
</tbody>
</table>

**Employment Center**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wednesday, January 19</td>
<td>7:30 a.m. to 5:00 p.m.</td>
<td>(registration for scheduled interviews, Interview Center)</td>
</tr>
<tr>
<td>Thursday, January 20</td>
<td>7:00 a.m. to 7:30 p.m.</td>
<td>(schedule distribution, interviews, Interview Center)</td>
</tr>
<tr>
<td>Friday, January 21</td>
<td>8:15 a.m. to 7:30 p.m.</td>
<td>(scheduled interviews and Interview Center)</td>
</tr>
<tr>
<td>Saturday, January 22</td>
<td>9:00 a.m. to 2:00 p.m.</td>
<td>(Interview Center only)</td>
</tr>
</tbody>
</table>

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Employment Center registrants who are participating in
the computer-scheduled interviews must register and fill out
interview request forms on Wednesday, January 19. There
will be no registration on Thursday and Friday; only in­
terviews will take place on these days.

Santa Barbara,
California
University of California, Santa Barbara
March 11–12, 2000
Meeting #951
Western Section
Associate secretary: Bernard Russo
Announcement issue of Notices: January 2000
Program first available on eMATH: February 1, 2000
Program issue of electronic Notices: May 2000
Issue of Abstracts: Volume 21, Issue 2

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Ses­
tions: Expired
For abstracts: January 18, 2000

Invited Addresses
Dietmar Bisch, University of California, Santa Barbara,
Title to be announced.
Svetlana Jitomirskaya, University of California, Irvine,
Title to be announced.
Yair Minsky, State University of New York at Stony Brook,
Title to be announced.
Ram Murty, Queen’s University, Zeta Functions and Dirich­
let Series.

Special Sessions
Automorphic Forms (Code: AMS SS D1), Ozlem Imamoglu
and Jeffrey Stopple, University of California, Santa Barbara.
Geometric Analysis (Code: AMS SS C1), Xian-Zhe Dai, Doug
Moore, Guofang Wei, and Rick Ye, University of Califor­
nia, Santa Barbara.
Geometric Methods in 3-Manifolds (Code: AMS SS B1), Daryl
Cooper, Darren Long, and Martin Scharlemann, University
of California, Santa Barbara.
History of Mathematics (Code: AMS SS A1), James Tatters­
sall, Providence College.
Representation Theory of Algebras (Code: AMS SS F1), F. W.
Anderson, University of Oregon, K. R. Fuller, University of
Iowa, and B. Huisgen-Zimmermann, University of Califor­
ia, Santa Barbara.
Subfactors and Free Probability Theory (Code: AMS SS E1),
Dietmar Bisch, University of California, Santa Barbara,
Sorin Popa, University of California, Los Angeles, and Dan
Voiculescu, University of California, Berkeley.
Uniformly and Partially Hyperbolic Dynamical Systems
(Code: AMS SS G1), Bjorn B\r\n\r\nir, University of California,
Santa Barbara, and Nicolai T. A. Haydn, University of Southern California.

Accommodations
Participants should make their own arrangements directly
with the hotel of their choice and request the UCSB discount.
The AMS is not responsible for rate changes or for the qual­
ity of the accommodations.
Holiday Inn, 5650 Calle Real, Goleta, CA; 805-964-6241;
$89 single or double.
Motel 6, 5897 Calle Real, Goleta, CA; 805-964-3596; $58
single or double.
Pilot House Motel; 1 Sandspit Road, Goleta, CA;
805-967-2336; weekend rates start at $48.
Ramada Limited, 4770 Calle Real, Goleta, CA; 805-964-
3511; from $85/night.

University of California, Santa Barbara
Food Service
There are a number of restaurants adjacent to the campus. A list of restaurants will be available at the registration desk. Food service will also be available in the University Center and the Arbor located on campus.

Local Information
Please visit the Web site maintained by the Department of Mathematics at http://www.math.ucsb.edu/, Santa Barbara Visitors Bureau site at http://www.santabarbaraca.com/ or the site maintained by the city of Santa Barbara at http://www.ci.santa-barbara.ca.us/.

Other Activities
AMS Book Sale: Examine the newest titles from AMS! Most books will be available at a special 50% discount offered only at meetings. Complimentary coffee will be served, courtesy of AMS Membership Services.

Parking
Campus parking is free on Saturdays and Sundays and virtually unrestricted except in spaces that are marked "R", or "Service Vehicle" or the like. There is no need to obtain a parking permit unless on campus during the work week (M-F 8-5). The kiosks at the East and West gates are open on weekends and are a good check-in point for a campus map and further information.

Registration and Meeting Information
The registration desk will be located in the foyer on the first floor of Givetz Hall, and will be open 8:00 a.m. to 4:30 p.m. on Saturday, and 8:00 a.m. to 1:30 p.m. on Sunday. Talks will take place in Givetz Hall and South Hall.

Registration fees (payable on-site only) $30/AMS or CMS members; $45/nonmembers; $10/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Travel
By Air: You may choose to land at Los Angeles International Airport (LAX) or the Santa Barbara airport (http://www.engineering.ucsb.edu/~guentert/). The following specially negotiated rates on USAirways are available exclusively to mathematicians and their families for the period March 8-15, 2000. Discounts apply only to travel within the continental U.S. Other restrictions may apply and seats are limited. Receive a 5% discount off First or Envoy Class and any published US Airways promotional round-trip fare. By purchasing your ticket 60 days or more prior to departure, you can receive an additional 5% bonus discount. Or, you may receive a 10% discount off unrestricted coach fares with seven-day advance purchase. By purchasing your ticket 60 days or more prior to departure, you can receive an additional 5% bonus discount. For reservations call (or have your travel agent call) US Airways Group and Meeting Reservation Office toll-free at 877-874-7687 between 8:00 a.m. and 9:30 p.m. Eastern Time. Refer to Gold File number 18611161.

The Santa Barbara Airbus offers several daily trips for the 2.5 hour ride from LAX to Santa Barbara. For information call 800-423-1618 (in the U.S. or Canada) or 805-964-7759 (outside the U.S. or Canada). The current fare is $35/one way, $65/round trip; however, the fare decreases with advance reservations, prepayment, and/or multiple passengers on the same trip.

Driving: UCSB is easily accessible from US 101. From the south, take the UCSB/Highway 217 exit. From the north, take Storke Road/UCSB exit and drive south (toward the ocean) to the junction with El Colegio Road. Turn left on to El Colegio Road and proceed to the West Gate kiosk.

Other: Santa Barbara is also served by Amtrak train service and Greyhound bus service.

Weather
Located on the coast of California, Santa Barbara County's climate is mild and sunny all year, with an average daytime temperature between 60° and 70°F (16° and 21°C). Santa Barbara attire is generally California casual.

Temperatures vary from 80°F to 50°F in September.

Lowell, Massachusetts
University of Massachusetts, Lowell
April 1–2, 2000
Meeting #952
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: February 2000
Program first available on eMATH: February 24, 2000
Program issue of electronic Notices: June 2000
Issue of Abstracts: Volume 21, Issue 2

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: December 14, 1999
For abstracts: February 8, 2000

Invited Addresses
Walter Craig, Brown University, Title to be announced.
Erwin Lutwak, Polytechnic University, Title to be announced.
Alexander Nabutovsky, Courant Institute, New York University, Title to be announced.
Mary Beth Ruskai, University of Massachusetts, Lowell, Title to be announced.
Notre Dame, Indiana
University of Notre Dame

April 7–9, 2000

Meeting #953
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: February 2000
Program first available on eMATH: February 24, 2000
Program issue of electronic Notices: June 1999
Issue of Abstracts: Volume 21, Issue 2

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: December 21, 1999
For abstracts: February 15, 2000

Invited Addresses
Peter Bates, Brigham Young University, Title to be announced.

Andras Nemethi, Ohio State University, Title to be announced.
Charles Radin, University of Texas at Austin, Title to be announced.
David Sattinger, Utah State University, Title to be announced.

Special Sessions

Algebraic Coding Theory (Code: AMS SS K1), Judy Walker, University of Nebraska, and Jay Wood, Purdue University.
Algebraic Geometry (Code: AMS SS F1), Karen Chandler and Scott Nollet, University of Notre Dame.
Algebraic Methods in Statistics (Code: AMS SS V1), Marlos Viana, University of Illinois, Chicago.
Applications of Invariant Manifold Theory (Code: AMS SS M1), Peter Bates, Brigham Young University, and Clarence Eugene Wayne, Boston University.
Commutative Algebra (Code: AMS SS A1), Juan Migliore, University of Notre Dame, and Chris Peterson, Colorado State University.
Cooperative Learning in Undergraduate Mathematics Education (Code: AMS SS T1), Nahid Erfan, University of Notre Dame, and Vic Perera, Kent State University.
Differential Geometry and its Applications (Code: AMS SS B1), Jiarong Cao, Brian Smyth, and Frederico Xavier, University of Notre Dame.
Differential Inequalities and Applications (Code: AMS SS N1), Paul W. Eloe, University of Dayton.
Geometry and Analysis in Carnot Carathéodory Spaces (Code: AMS SS W1), Scott Pauls, Rice University.
Homotopy Theory (Code: AMS SS H1), William G. Dwyer, University of Notre Dame, and Michele Intermont, Kalamazoo College.
Index Theory and Topology (Code: AMS SS Q1), John Roe, Pennsylvania State University, and Stephan Stolz and Bruce Williams, University of Notre Dame.
Integrable Systems and Nonlinear Waves (Code: AMS SS E1), Mark S. Alber and Gerard Misiolek, University of Notre Dame.
Microlocal Analysis and Partial Differential Equations (Code: AMS SS D1), Nicholas Hanges, CUNY, Lehman College, and Alex Himonas, University of Notre Dame.
Nonlinear Partial Differential Equations (Code: AMS SS J1), Qing Han and Bei Hu, University of Notre Dame, and Hong-Ming Yin, Washington State University.
Number Theory, Algorithms, and Cryptography (Code: AMS SS R1), Eric Bach, University of Wisconsin, Madison, and Jonathan Sorenson, Butler University.
Optimization and Numerical Analysis (Code: AMS SS C1), Leonid Faybusovich, University of Notre Dame.
Quasigroups and Loops and their Applications (Code: AMS SS P1), Michael K. Kinyon, Indiana University South Bend, and J. D. Phillips, Saint Mary's College of California.
Meetings & Conferences

Representations of Groups and Related Objects (Code: AMS SS S1), Chris Bendel, University of Wisconsin, Stout, and George McNinch, University of Notre Dame.

Several Complex Variables (Code: AMS SS G1), Jeffrey Diller, University of Notre Dame, and Nancy Stanton, University of Notre Dame.

Singularities in Algebraic Geometry (Code: AMS SS L1), Sandor Kovacs, University of Chicago, and Andras Nemethi, Ohio State University.

Symbolic Dynamics (Code: AMS SS U1), William Geller, Indiana University-Purdue University Indianapolis, and Nicholas S. Ormes, University of Texas, Austin.

Lafayette, Louisiana
University of Louisiana at Lafayette
April 14-16, 2000

Meeting #954
Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of Notices: February 2000
Program first available on eMATH: March 2, 2000
Program issue of electronic Notices: June 2000
Issue of Abstracts: Volume 21, Issue 2

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: December 28, 1999
For abstracts: February 22, 2000

Invited Addresses
Paul Aspinwall, Duke University, Title to be announced.
Michael Renardy, Virginia Polytechnic Institute & State University, Title to be announced.
Robin Thomas, Georgia Institute of Technology, Title to be announced.
Fernando Rodriguez Villegas, University of Texas at Austin, Title to be announced.

Special Sessions
Continuum Theory (Code: AMS SS F1), Thelma R. West, University of Louisiana at Lafayette.
Fluid Dynamics (Code: AMS SS H1), Michael Renardy, Virginia Polytechnic Institute & State University.
L-functions, Periods, and Arithmetic (Code: AMS SS J1), Fernando Rodriguez Villegas and Jeff Vaaler, University of Texas at Austin.
Mathematical Models in the Biological and Physical Sciences (Code: AMS SS B1), Azmy S. Ackleh, Lan Ke, and Robert D. Sidman, University of Louisiana at Lafayette.
Nonlinear Differential Equations and Their Applications (Code: AMS SS C1), C. Y. Chan, Keng Deng, and A. S. Vatsala, University of Louisiana at Lafayette.

Quantum Topology (Code: AMS SS E1), Patrick M. Gilmer, Louisiana State University.
Recent Advances in Statistics (Code: AMS SS G1), Calvin Berry, Kalimuthu Krishnamoorthy, and Nabendu Pal, University of Louisiana at Lafayette.
Rings and Their Generalizations (Code: AMS SS A1), Gary F. Birkenmeier and Henry E. Heatherly, University of Louisiana at Lafayette.
Scientific Computing (Code: AMS SS D1), R. Baker Kearfott, Qin Sheng, and Christo Christov, University of Louisiana at Lafayette.

Odense, Denmark
Odense University
June 13-16, 2000

Note: This is a World Math Year 2000 (WMY2000) event.

Meeting #955
First AMS-Scandinavian International Mathematics Meeting.
Sponsored by the AMS, Dansk Matematisk Forening, Suomen matemaattinen yhdistys, Icelandic Mathematical Society, Norsk Matematisk Forening, and Svenska matematikersamfundet.
Associate secretary: Robert M. Fossum
Announcement issue of Notices: To be announced
Program first available on eMATH: N/A
Program issue of electronic Notices: N/A
Issue of Abstracts: N/A

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

Invited Addresses
Tobias Colding, Courant Institute, New York University, Title to be announced.
Johan Håstad, Royal Institute of Technology, Stockholm, Title to be announced.
Nigel J. Hitchin, University of Oxford, Title to be announced.
Elliott Lieb, Princeton University, Title to be announced.
Pertti Mattila, University of Jyväskylä, Title to be announced.
Curtis T. McMullen, Harvard University, Title to be announced.
Alexei N. Rudakov, Norwegian University of Science & Technology, Title to be announced.
Karen Uhlenbeck, University of Texas at Austin, Title to be announced.
Dan Voiculescu, University of California, Berkeley, Title to be announced.

Special Sessions
Algebraic Groups and Representation Theory, Henning Haahr Andersen and Niels Lauritzen, Aarhus University.
Complex Analysis in Higher Dimensions, Finnur Larusson, University of Western Ontario, and Ragnar Sigurdsson, University of Iceland.
Differential Geometry, Claude R. LeBrun, State University of New York at Stony Brook, and Peter Petersen, University of California, Los Angeles.
Discrete Mathematics, Iiro S. Honkala, University of Turku, and Carsten Thomassen, Technical University of Denmark.

Dynamical Systems, Michael Benedicks, Royal Institute of Science, Stockholm, and Carsten Lunde Petersen, Roskilde.
Geometric Analysis/PDE, Gerd Grubb, University of Copenhagen, and Bent Ørsted, Odense University.
Joint EWM and AWM Session, Lisbeth Fajstrup, Aalborg University, Tiinne Hoff Kjeldsen, Roskilde, and Christina Wiis Tonnesen-Friedman, Aarhus University.
K-Theory and Operator Algebras, Søren Eilers, University of Copenhagen, and Nigel D. Higson, Pennsylvania State University.
Linear Spaces of Holomorphic Functions, Peter L. Duren, University of Michigan, Ann Arbor, Michael Stessin, State University of New York at Albany, and Harold S. Shapiro, Royal Institute of Technology, Stockholm.
Mathematical Physics, Bergfinnur Durhuus, University of Copenhagen, and Kurt Johansson, Royal Institute of Technology, Stockholm.
Mathematics Education, Claus Michelsen, Odense, and Martti E. Pesonen, University of Joensuu.
Stochastic DE and Financial Mathematics, Tomas Björk, University of Stockholm, and Bernt Øksendal, University of Oslo.

Deadlines
For organizers: N/A
For consideration of contributed papers in Special Sessions: N/A
For abstracts: May 10, 2000

Invited Addresses
James G. Arthur, University of Toronto, will speak on automorphic forms and the Langlands program.
Alexander A. Beilinson, University of Chicago, will speak on the geometric Langlands conjecture.
Michael V. Berry, University of Bristol, will speak on waves, geometry, and arithmetic.
Haim Brezis, University of Paris XI and Rutgers University, will speak on nonlinear partial differential equations.
Alain Connes, Collège de France, will speak on noncommutative geometry.
David L. Donoho, Stanford University, will speak on interactions among harmonic analysis, statistical analysis, and information theory.
Charles L. Fefferman, Princeton University, will speak on the equations of fluid mechanics.
Michael H. Freedman, Microsoft Research, will speak on the physics of computation.
Ronald L. Graham, University of California at San Diego, title to be announced (AMS and MAA President's Address).
Helmut H. W. Hofer, New York University - Courant Institute, will speak on symplectic geometry/dynamical systems.
Richard M. Karp, University of Washington, will speak on computational molecular biology.
Sergiu Klainerman, Princeton University, will speak on partial differential equations.
Maxim Kontsevich, Institut des Hautes Études Scientifiques, will speak on deformations, supermanifolds, and homotopical algebra.
Peter D. Lax, New York University - Courant Institute, will speak on mathematics and computing.
Simon A. Levin, Princeton University, will speak on complexity of biology.
László Lovász, Yale University, will speak on discrete mathematics and algorithms.
David Mumford, Brown University, will speak on models of perception and inference.
Peter Sarnak, Princeton University, will speak on analysis and number theory.

Los Angeles, California
University of California-Los Angeles
August 7–12, 2000
Meeting #956
Associate secretary: Robert J. Daverman
Announcement issue of Notices: May 2000
Program first available on eMATH: May 24, 2000
Program issue of electronic Notices: October 2000
Issue of Abstracts: Volume 21, Issue 3
Meetings & Conferences

Saharon Shelah, The Hebrew University, will speak on mathematical logic.

Peter W. Shor, AT&T Labs, will speak on quantum computing/quantum information theory.

Yakov G. Sinai, Princeton University, will speak on dynamical systems.

Richard P. Stanley, Massachusetts Institute of Technology, will speak on algebraic combinatorics.

Dennis P. Sullivan, The CUNY Graduate School, will speak on applications of combinatorial topology to geometry.

Clifford Taubes, Harvard University, will speak on geometry and topology of the future.

Jean E. Taylor, Rutgers University, will speak on applications of geometric analysis.

William P. Thurston, University of California - Davis, will speak on three-dimensional topology and geometry.

Karen Uhlenbeck, University of Texas at Austin, will speak on a subject to be announced.

S. R. S. Varadhan, New York University - Courant Institute, will speak on stochastic analysis and applications.

Edward Witten, Institute for Advanced Study, will speak on the mathematical impact of quantum fields and strings.

Boris Tsyagan, Pennsylvania State University, Title to be announced.

Special Sessions

Commutative Algebra and Algebraic Geometry (Code: AMS SS A1), Anthony Geramita, Queens University, and William Traves, United States Naval Academy.

Ergodic Theory and Dynamical Systems (Code: AMS SS B1), Andres del Junco, University of Toronto, and Blair Madore, SUNY Potsdam.

Nonabsolute Integration (Code: AMS SS C1), Patrick Muldowney, University of Ulster, and Erik Talvila, University of Illinois, Urbana.

San Francisco, California

San Francisco State University

October 21-22, 2000

Meeting #958

Western Section

Associate secretary: Bernard Russo

Announcement issue of Notices: August 2000

Program first available on eMATH: September 11, 2000

Program issue of electronic Notices: November 2000

Issue of Abstracts: Volume 21, Issue 4

Deadlines

For organizers: March 21, 2000

For consideration of contributed papers in Special Sessions: June 21, 2000

For abstracts: August 29, 2000

Special Sessions

Algebraic and Geometric Combinatorics (Code: AMS SS A1), Jesus De Loera, University of California, Davis, and Frank Sottile, University of Wisconsin.

New York, New York

Columbia University

November 3-5, 2000

Meeting #959

Eastern Section

Associate secretary: Lesley M. Sibner

Announcement issue of Notices: September 2000

Program first available on eMATH: September 28, 2000

Program issue of electronic Notices: To be announced

Issue of Abstracts: Volume 21, Issue 4

Deadlines

For organizers: April 3, 2000

Invited Addresses

George Elliott, University of Toronto, Title to be announced.

Benson Farb, University of Chicago, Title to be announced.

Yongbin Ruan, University of Wisconsin, Title to be announced.
Hong Kong, People’s Republic of China

December 13–17, 2000

Meeting #961
First Joint International Meeting between the AMS and the Hong Kong Mathematical Society.
Associate secretary: Bernard Russo
Announcement issue of Notices: To be announced
Program first available on eMATH: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

New Orleans, Louisiana

New Orleans Marriott and Sheraton New Orleans Hotel

January 10–13, 2001
Joint Mathematics Meetings, including the 107th Annual Meeting of the AMS, 84th Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: October 2000
Program first available on eMATH: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: Volume 22, Issue 1

Deadlines
For organizers: April 11, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Birmingham, Alabama

University of Alabama-Birmingham

November 10–12, 2000

Meeting #960
Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of Notices: September 2000
Program first available on eMATH: October 5, 2000
Program issue of electronic Notices: To be announced
Issue of Abstracts: Volume 21, Issue 4

Deadlines
For organizers: April 10, 2000
For consideration of contributed papers in Special Sessions: July 25, 2000
For abstracts: September 19, 2000

For consideration of contributed papers in Special Sessions: July 18, 2000
For abstracts: September 12, 2000

Invited Addresses

Paula Cohen, Université des Sciences et Technologies de Lille, France, will speak on geometry and its relation to physics.
Brian Greene, Columbia University, Title to be announced.
Sergey Novikov, University of Maryland-College Park and Landau Institute for Theoretical Physics, Title to be announced.
Alexander I. Suciu, Northeastern University, Title to be announced.

Special Sessions

Arithmetic Geometry and Modular Forms (Code: AMS SS D1), Dorian Goldfeld, Columbia University, and Paula Cohen.
Arrangements of Hyperplanes (Code: AMS SS C1), Michael J. Falk, Northern Arizona University, and Alexander I. Suciu, Northeastern University.
Combinatorial Group Theory (Code: AMS SS A1), Gilbert Baumslag, Alexei Myasnikov, and Vladimir Shpilrain, City College (CUNY).
Differential Algebra and Related Topics (Code: AMS SS E1), Li Guo and William Keigher, Rutgers University at Newark, and William Sit, City College (CUNY).
Meetings & Conferences

Columbia, South Carolina
University of South Carolina
March 16-18, 2001
Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of Notices: To be announced
Program first available on eMATH: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: August 15, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Lawrence, Kansas
University of Kansas
March 30-31, 2001
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: To be announced
Program first available on eMATH: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: June 28, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Hoboken, New Jersey
Stevens Institute of Technology
April 28-29, 2001
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program first available on eMATH: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: September 28, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Diego, California
San Diego Convention Center
January 6-9, 2002
Joint Mathematics Meetings, including the 108th Annual Meeting of the AMS and 85th Meeting of the Mathematical Association of America (MAA).
Associate secretary: John L. Bryant
Announcement issue of Notices: To be announced
Program first available on eMATH: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: April 4, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Lyon, France
July 17-20, 2001
First Joint International Meeting between the AMS and the Société Mathématique de France.
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program first available on eMATH: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

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

Williamstown, Massachusetts
Williams College
October 13-14, 2001
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program first available on eMATH: To be announced
Program issue of electronic Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: March 11, 2001
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
Presenters of Papers

Washington, District of Columbia; January 19-22, 2000

Numbers following the name indicate the speaker's position on the program.

AMS-MAA-SIAM Invited Lecturer, • AMS Invited Lecturer, • AMS Retiring Presidential Address, • MAA Invited Lecturer, □ AWM Emmy Noether Lecturer, ▪ NAM William W.S. Claytor Lecturer, • ASL Invited Lecturer, • AMS-MAA-MSEB-SIAM Invited Lecturer, • MAA Student Lecturer, • Special Session Speaker, ▪ Graduate Student, ▪ Undergraduate Student

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WASHINGTON, DC - Presenters of Papers

January 2000

NOTICES OF THE AMS

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University Grants Committee of the Hong Kong Special Administrative Region through the
University Grants Committee of the Hong Kong Special Administrative Region. Its
strategic plan is an ambitious one, reflecting its aspirations to become one of the leading universities in the Asia-Pacific region by achieving excellence in teaching and research. The student population for 1999-2000 is approximately 16,200 (11,000 full-time and 5,200 part-time).

The medium of instruction is English.

Applications are invited for the following post:

Assistant Professor
Department of Mathematics [Ref. A93541]

The Department, which has a strong emphasis in Applied and Computational Mathematics, is seeking applicants at the Assistant Professor level to begin in September 2000. Applicants should have a PhD in Mathematics or a related discipline with strong research record or excellent research potential as well as a commitment to teaching undergraduate and postgraduate students. Preference will be given to applicants with a knowledge of Statistics and/or Computing Mathematics.

Monthly Salary and Conditions of Service

HKS46,190 to HKS77,165 per month

(Exchange rate: US$1 = HKS7.8 approximately)

Appointees will be on fixed-term gratuity-bearing contract with contract-end gratuity. Excellent fringe benefits include medical and dental schemes, annual leave, and housing assistance where applicable.

Information and Application

Information concerning the post and the University is available on the University’s World Wide Web home page http://www.cityu.edu.hk or the University’s listserver accessed by E-mail at “hrmail@citylnk.cityu.edu.hk”, or from the Human Resources Office, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong (Fax: (852) 2788 1154 or 2788 933 4/E-mail: hrrecruit@cityu.edu.hk).

Please send your application in the form of an application letter enclosing a current curriculum vitae and the names and addresses of three academic referees to the Human Resources Office, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong (Fax: (852) 2788 1154 or 2788 933 4/E-mail: hrrecruit@cityu.edu.hk). Applications in the form of an application letter enclosing a current curriculum vitae and the names and addresses of three academic referees to the Human Resources Office, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong (Fax: (852) 2788 1154 or 2788 933 4/E-mail: hrrecruit@cityu.edu.hk). Information concerning the post and the University is available on the University’s World Wide Web home page http://www.cityu.edu.hk or the University’s listserver accessed by E-mail at “hrmail@citylnk.cityu.edu.hk”, or from the Human Resources Office, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong (Fax: (852) 2788 1154 or 2788 933 4/E-mail: hrrecruit@cityu.edu.hk).

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Program of the Sessions

Monday, January 17

AMS Short Course on Quantum Computation: The Grand Mathematical Challenge for the 21st Century and the Millennium
9:00 AM - 5:00 PM
Organizer: Samuel J. Lomonaco, University of Maryland Baltimore County

AMS Short Course on Environmental Mathematics
9:00 AM - 5:00 PM
Organizer: V. S. Manoranjan, Washington State University

MAA Short Course on Fuzzy Mathematics
9:00 AM - 5:00 PM
Organizer: Kiran Bhutani, Catholic University of America

Tuesday, January 18

MAA Board of Governors
8:30 AM - 4:00 PM

AMS Short Course on Quantum Computation: The Grand Mathematical Challenge for the 21st Century and the Millennium
9:00 AM - 5:00 PM
Organizer: Samuel J. Lomonaco, University of Maryland Baltimore County

AMS Short Course on Environmental Mathematics
9:00 AM - 5:00 PM
Organizer: V. S. Manoranjan, Washington State University

Wednesday, January 19

Joint Meetings Registration
7:30 AM - 4:00 PM

Mathematical Sciences Employment Center
7:30 AM - 5:00 PM
Open for receipt of all interview request forms (forms accepted between 9:30 a.m. and 4:00 p.m.; none accepted on Thursday or Friday).

AMS-MAA-MER Special Session on Mathematics and Education Reform, I
8:00 AM - 10:50 AM
Organizers: William H. Barker, Bowdoin College
Jerry L. Bona, University of Texas at Austin
Naomi Fisher, University of Illinois at Chicago
Kenneth C. Millett, University of California, Santa Barbara

Papers flagged with a solid triangle (△) have been designated by the author as being of possible interest to undergraduate students.
Abstracts of papers presented in the sessions at this meeting will be found in Volume 21, Issue 1 of Abstracts of papers presented to the American Mathematical Society, ordered according to the numbers in parentheses following the listings.
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<td>Marilyn P. Carlson, Arizona State University (950-98-1014)</td>
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<td>8:30 AM</td>
<td>Undergraduate Mathematics Students’ Understanding of the Role of Definitions and the Consequences of These Understandings on Students’ Ability to Use Definitions in a Mathematically Acceptable Way. Barbara S Edwards, Oregon State University (950-98-454)</td>
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<td>9:00 AM</td>
<td>Effects on students learning topics in collegiate mathematics of pedagogy based on APOS Theory, using cooperative learning, students writing computer programs and in-class problem solving. Ed Dubinsky, Georgia State University (950-98-597)</td>
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<tr>
<td>9:30 AM</td>
<td>Minorities are invisible in Mathematics. Preliminary report. William Y Velez, University of Arizona (950-98-507)</td>
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<td>Increasing the number of minority Ph.D.s in mathematics. Preliminary report. David Manderscheid, University of Iowa (950-97-102)</td>
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AMS Special Session on Mathematical Aspects of Consensus Theory, I

**8:00 AM - 10:45 AM**

Organizer: Melvin F. Janowitz, University of Massachusetts, Amherst

- 8:00 AM Welcoming Remarks, M.F. Janowitz
- 8:05 AM Understanding Arrow’s Theorem and voting paradoxes through symmetry. Donald G Saari, Northwestern University (950-91-196)
- 8:45 AM Optimal Voting Rules. H. Peyton Young, Johns Hopkins University (950-90-662)
- 9:55 AM Using the local majority rule to reach an agreement on the global majority. Preliminary report. Aleksandar Pekec, Duke University (950-95-676)

AMS Special Session on Holomorphic Dynamics and Related Issues, I

**8:00 AM - 11:00 AM**

Organizers: Mikhail Lyubich, SUNY at Stony Brook

Kevin Pilgrim, University of Missouri at Rolla

Michael Yampolsky, Institute des Hautes Etudes

**8:00 AM** Dynamics in two complex dimensions. Preliminary report. John Smillie*, Cornell University, and Eric Bedford, Indiana University (950-37-1159)

**8:50 AM** Growing trees, laminations and the dynamics on the Julia set. Alexander Blokh*, University of Alabama at Birmingham, and Genadi Levin, Hebrew University of Jerusalem (950-37-1101)

AMS Special Session on Invariants of Knots and 3-Manifolds, I

**8:00 AM - 10:50 AM**

Organizers: Dubravko Ivanusic, George Washington University

Mark E. Kidwell, U.S. Naval Academy

Jozef H. Przytycki, George Washington University

Youngwu Rong, George Washington University

Ted Stanford, U.S. Naval Academy

**8:00 AM** On a theorem of Wu. (23) Lorenzo Traldi, Lafayette College (950-57-267)
Program of the Sessions - Washington, DC, Wednesday, January 19 (cont'd.)

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tr>
<td>8:00AM</td>
<td>AMS Special Session on Quantum Computation and Information, I</td>
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<tr>
<td>8:00AM</td>
<td>AMS Special Session on Operator Algebras, I</td>
</tr>
<tr>
<td>8:00AM</td>
<td>MAA Minicourse #12: Part A</td>
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</tbody>
</table>

AMS Special Session on Quantum Computation and Information, I

8:00 AM - 10:45 AM

Organizers: Samuel J. Lomonaco, Jr., University of Maryland, Baltimore County
Howard E. Brandt, Army Research Labs

8:00 AM
The entanglement-assisted capacity of a quantum channel.
Peter W Shor, AT&T Labs - Research (950-94-77)

8:35 AM
Manipulating pure state quantum entanglement.
Lucien Hardy, Oxford University, UK (950-81-74)

9:10 AM
On the structure of the entangled states.
Michael A. Nielsen, California Institute of Technology (950-81-92)

9:45 AM
Improved two-party and multi-party purification protocols.
John A. Smolin*, IBM Research, and Elizba N Maveva, California Institute of Technology (950-81-1105)

10:20 AM
Entangled chains.
William K Wootters, Williams College (950-81-1054)

AMS Special Session on Operator Algebras, I

8:00 AM - 10:50 AM

Organizers: May M. Nilsen, University of Nebraska, Lincoln, and Texas A&M University
David R. Pitts, University of Nebraska, Lincoln

8:00 AM
Quantum Dixmier algebras. Preliminary report.
Iwan Praton, Franklin and Marshall College (950-17-297)

8:30 AM
The Exactness and Novikov Conjectures for Discrete Groups. Preliminary report.
Erik Guentner* and Jerome Kaminker, IUPUI (950-47-936)

9:00 AM
Non-commutative n-tuples and dilation theory.
David W Kribs, University of Waterloo (950-47-238)

9:30 AM
Approximation properties of group C*-algebras, boundaries, and the Novikov Conjecture.
Erik Guentner and Jerome Kaminker*, IUPUI (950-46-834)

10:00 AM
Applications of free entropy to von Neumann algebras.
Leming Ge*, Univ. of New Hampshire, and Junhao Shen, Univ. of Penn. (950-46-962)

10:30 AM
Wandering Vector Multipliers.
Deguang Han, McMaster University, and David R Larson*, Texas A&M University (950-47-973)

MAA Minicourse #12: Part A

8:00 AM - 10:00 AM

Transforming anxiety into hatred: Rethinking this standard model of reaching liberal arts students and the general public.
Organizers: Edward B. Burger, Williams College
Michael Starbird, University of Texas at Austin
MAA Minicourse #1: Part A
8:00 AM - 10:00 AM
Mathematical finance.
Organizers: Walter R. Stromquist, Berwyn, PA

MAA Minicourse #7: Part A
8:00 AM - 10:00 AM
Getting students involved in undergraduate research.
Organizers: Joseph A. Gallian, University of Minnesota-Duluth
             Aparna W. Higgins, University of Dayton
             Stephen G. Hartke, Rutgers University

AMS Session on Algebraic Geometry
8:00 AM - 8:55 AM
8:00AM Characteristic Pairs Along the Resolution Sequence.
     Kent M Neuber, Southeastern Louisiana University (950-14-115)
8:15AM On polarized surfaces of low degree whose adjoint bundles are not spanned.
     Gian Mario Besana*, Eastern Michigan University, and Sandra Di Rocco, Royal Institute of Technology (950-14-477)
8:30AM A Construction of Codes from Higher-dimensional Varieties.
     Gary L Salazar, Louisiana State University (950-14-882)
8:45AM Open subschemes of Hilb \(^n\) that are isomorphic to A\(^n\)\(_k\).
     Mark E Huibregtse, Skidmore College (950-14-1150)

AMS General Session
8:00 AM - 10:40 AM
8:00AM "Speed-up" properties of major subsets and supersets of computably enumerable sets.
     Preliminary report.
     Lisa R Calminas, Northwestern State University of Louisiana (950-03-1204)
8:15AM M"obius Inversion and Codes over Rings.
     Marcus Greferath, Ohio University, and Stefan E Schmidt*, M.I.T. (950-05-1010)
8:30AM Free stochastic measures via noncrossing partitions.
     Michael Anshelevich, UC Berkeley (950-46-1058)
8:45AM Minimal matrices and Kronecker products.
     Ernesto Vallejo, National University of Mexico (950-05-1163)
9:00AM A new face ring for mixed simplicial and cubical complexes.
     Preliminary report.
     Margaret A. Readdy, Stockholm University (950-05-758)
9:15AM The V-invariant of a polynomial knot.
     Alan H Durfee, Mount Holyoke College (950-57-149)
9:30AM Transitions of Ridges in Parameterized Families of Functions.
     Robert S Keller, Loras College (950-68-1130)
9:45AM Some integral equations from the theory of probability.
     Preliminary report.
     Ty Lee, University of Maryland (950-45-54)

10:00AM Efficient computing of minimum-cost grid network flows and applications to the discrete Monge-Kantorovich mass transfer problem.
     Preliminary report.
     Eugene Belogay, Purdue University (950-90-1258)

10:15AM A Structure Theory and Related Results for Orthomodular Lattices with Applications to Non-Commutative Measure Theory and Quantum Logic. Preliminary report.
     Bruce J Logan*, St. Paul’s College, and Richard J Greechie, Louisiana Tech University (950-06-164)

10:30AM The Mindy Waterhouse method for selecting an supremum point. Preliminary report.
     C. S. Felicitas, C.F.C.T.E., Inc. (950-68-04)

MAA Session on The Use of History in the Teaching of Mathematics, I
8:00 AM - 10:55 AM
Organizers: V. Frederick Rickey, United States Military Academy
            Florence Fasanelli, College-University Resource Institute
            Victor J. Katz, University of the District of Columbia

8:00AM Using projects involving technology in a history of mathematics class.
     Lee H Armstrong, University of Central Florida (950-A1-312)
8:20AM HPM-History and Pedagogy of Mathematics: An Exploration of Scope and Barriers.
     Alphonse Buccino, University of Georgia Emeritus (950-A1-555)
8:40AM Original Sources vs. Survey.
     Linda Marie Saliga, The University of Akron (950-A1-865)
9:00AM Modern Mathematical Revolutions: A Historical Approach. Preliminary report.
     Robert W Case, Northeastern University (950-A1-1161)
     Joanne V Peeperle, El Paso Community College (950-A1-1070)
9:40AM Using Near-original Sources in the Graduate Analysis Course for Teachers.
     Phillip E Johnson, UNC Charlotte (950-A1-397)
10:00AM Getting to One: Pre-Service Teachers meet Zeno.
     Joan D Lukas*, University of Massachusetts Boston, and Judy Clark, University of Massachusetts (950-A1-763)
10:20AM Teaching calculus at three Argentinian universities during the period 1991-1999: A comparison.
     Sandra Alda Visokolskis, University of Cordoba, and Carla Fernanda Gomez*, Bias Pascal University (950-A1-988)
     David Dennis, Univ. of Texas at El Paso (950-A1-953)

MAA Session on Integrating Mathematics and Other Disciplines, I
8:00 AM - 10:55 AM
Organizers: William G. McCallum, University of Arizona
            Duff G. Campbell, United States Military Academy

WASHINGTON, DC, Wednesday, January 19 - Program of the Sessions

January 2000
NOTICES OF THE AMS
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Deborah Hughes Hallett, University of Arizona  
David C. Lay, University of Maryland, College Park  
Nicholas Lusito, SUNY Farmingdale  
Jim Rolf, United States Military Academy  
Yajun Yang, SUNY Farmingdale

8:00AM Calculus That Matters in the Life Sciences.  
> (74) Patti Frazer Lock, St. Lawrence University (950-B1-785)

8:15AM Spreadsheets and Mathematics for the Life Sciences.  
> (75) Edward H Grossman* and Jane Gallagher, City College of CUNY (950-B1-611)

8:30AM The Biology and Economics of Bee-keeping: A Native American Summer Program. Preliminary report.  
Kate C McElwee* and Joseph C Watkins, University of Arizona (950-B1-986)

8:45AM Creating an Integrated Biology and Mathematics Course for High School Students.  
> (77) Juan Estrada and Michael D Green*, Metropolitan State University (950-B1-633)

9:00AM BioCalc at Illinois.  
> (78) Jerry Uhl*, Univ of Illinois at Urbana, and Sandy Lazarowicz, Cornell University (950-B1-460)

> (79) Mysore S Jagadish* and John F Goehl, Barry University (950-B1-547)

9:30AM Modeling the Flight of a Missile.  
> (80) Gerald C Kobylski*, Randall E Donaldson and Bryndol Sones, United States Military Academy (950-B1-761)

9:45AM Integration of Mathematics and Physics: Workshop and Interdisciplinary Course. Preliminary report.  
Yuen S Chi and Irina L Neymotin, SUNY-Farmingdale (950-B1-745)

10:00AM The Golden Ratio in Physics - Revisited.  
> (82) Tom Foley, St. Joseph’s University (950-B1-895)

10:15AM Conversations with Electrical Engineers. Preliminary report.  
> (83) William G McCallum, University of Arizona (950-B1-1026)

10:30AM Interdisciplinary Curriculum - Natural or Synthetic?  
> (84) Gary W Krahn, United States Military Academy (950-B1-1094)

William Barker, Bowdoin College (950-B1-755)

MAA Session on Innovative Uses of the World Wide Web in Teaching Mathematics, I  

8:00AM - 10:40 AM

Organizers:  
Brian E. Smith, McGill University  
Marcelle Bessman, Jacksonville University

8:00AM Numbers, News, and the Net.  
> (86) John M. Harris and Gregory S. Rhoads*, Appalachian State University (950-C1-598)

8:15AM MATours: Inquiry-based hypertext materials in discrete mathematics.  
> (87) Larry Copes, Augsburg College and Institute for Studies in Educational Mathematics (950-C1-1009)

8:30AM Using Javascript for an Active Discrete Math Class.  
> (88) Douglas E. Ensley, Shippensburg University (950-C1-573)

8:45AM On-Line Quizzes for Students to Check their Readiness for College Algebra.  
> (89) Bryce F Hanlon, University of Arizona (950-C1-604)

9:00AM Web-based Homework and Quizzes. Preliminary report.  
Jimmy Smith*, Jeff Hirst and Holly P. Hirst, Appalachian State University (950-C1-1072)

9:15AM Using Web-Based Interactive Materials in a Studio Classroom.  
> (91) David A Smith* and Lawrence C Moore, Duke University (950-C1-921)

9:30AM The Global Classroom. Preliminary report.  
> (92) Marcelle Bessman, Jacksonville University (950-C1-1263)

9:45AM The Global Classroom, A Visitor's Perspective.  
> (93) Marcelle Bessman, Jacksonville University, and Douglas A Quinnney*, University of Keele (950-C1-1262)

10:00AM Using the Web to Motivate and Apply Symbolic Logic. Preliminary report.  
Florence S Gordon, New York Institute of Technology (950-C1-473)

10:15AM Applets, Data Sets and Other Web Resources in a Business Statistics Class.  
Brian E Smith, McGill University (950-C1-820)

10:30AM NetMath at Illinois.  
> (96) Jerry Uhl, Univ of Illinois at Urbana-Champaign, and Debra Woods*, University of Illinois at Urbana-Champaign (950-C1-954)

MAA Session on Environmental Mathematics in the Classroom, I  

8:00AM - 10:35 AM

Organizers:  
Ben Fusaro, Florida State University  
Patricia C. Kenschaft, Montclair State University

8:00AM HS Students Tackle Issues in Plant Growth. Preliminary report.  
Stephanie Fitchett, Florida Atlantic University (950-P1-708)

8:20AM Environmental Mathematics in a Liberal Arts Class. Preliminary report.  
Holly P Hirst* and James R Smith, Appalachian State University (950-P1-1049)

8:40AM The Interpolation of Hydraulic Head Contours.  
> (99) Kelly M Knapp* and Linda C Thiel, Ursinus College (950-P1-496)

9:00AM Water Purification. Preliminary report.  
> (100) Gerald C Kobylski, United States Military Academy (950-P1-760)

9:20AM Pollution in the Great Lakes: Discrete and Continuous Solutions.  
Paul J Laumakis, Rowan University (950-P1-803)

9:40AM Environmental Awareness in the Calculus Classroom. Preliminary report.  
Patti Frazer Lock, St. Lawrence University (950-P1-789)

10:00AM Population Growth and Optimal Harvesting. Preliminary report.  
James T Sandefur, Georgetown University (950-P1-210)

Martin E Walter, University of Colorado (950-P1-207)

AMS Special Session on Geometric Analysis, I  

8:05AM - 10:50 AM

Organizers:  
Paul C. Yang, University of Southern California  
Matthew J. Gursky, Indiana University
8:05 AM  How to use integrals to count lattice points in polytopes. Preliminary report.  Matthias Beck, Temple University (950-52-384)

8:40 AM  Hölder Continuity of Polycrystals Whose Interfaces Flow by Curvature.  David G. Caraballo, Embry-Riddle Aeronautical University (950-49-738)

9:15 AM  Existence and compactness results of conformal metrics with constant scalar curvature and constant boundary mean curvature. Zheng-Chao Han* and Yanyan Li, Rutgers University (950-58-1045)

9:50 AM  Topology and Sobolev spaces. Preliminary report.  Haim Brezis, Rutgers University and the University of Paris VI, and Yanyan Li*, Rutgers University (950-35-963)

10:25 AM  The geometry of the first non-zero Stekloff eigenvalue.  Jose F Escobar, Cornell University (950-35-1160)

AMS Special Session on Ergodic Theory and Topological Dynamics of $Z^d$ and $R^d$ Actions, I

8:30 AM - 10:50 AM

Organizers: E. Arthur Robinson, George Washington University  Ayele A. Sahin, North Dakota State University

8:30 AM  Expansive subdynamics for algebraic $Z^d$-actions.  Douglas A Lind, University of Washington (950-37-365)

9:00 AM  An Example of a Flow with a Single Nonperiodic, Nonexpansive Direction.  Kathleen M Madden, Drew University (950-58-859)

9:30 AM  Rank one group actions with mixing simple $Z$ subactions.  Blair F Madore, SUNY Potsdam (950-37-1183)

10:00 AM  Examples of Rank One $Z^d$ Actions. Preliminary report.  Cesar E Silva, Williams College (950-37-1038)

10:30 AM  Multiple mixing for rank one group actions.  Andres del Junco*, University of Toronto, and Reem Yassawil, Trent University (950-28-878)

AMS Special Session on Nonlinear Eigenvalue Problems and Applications, I

9:00 AM - 10:50 AM

Organizers: Alfonso Castro, University of Texas at San Antonio  Maya Chhetri, Mississippi State University  Ratnasingham Shivaji, Mississippi State University

9:00 AM  Sturm Theorems via Picone’s Identity.  (120) Walter Allegretto, University of Alberta, Edmonton, Canada (950-35-551)


10:00 AM  Recent Developments on Semipositone Systems.  (122) Maya Chhetri, University of North Carolina at Greensboro (950-35-1082)

10:30 AM  Nonexistence of nonnegative solutions for classes of semilinear elliptic systems.  Ratnasingham Shivaji*, Georgia Southern University and Mississippi State University, and Hai Dang, Mississippi State University (950-35-319)

AMS Session on Global Analysis, Manifolds

9:00 AM - 10:40 AM

9:00 AM  A non-fixed point theorem for Hamiltonian Lie group actions.  Christopher J Allday*, University of Hawaii, Volker Puppe, University of Konstanz, and Volker Hauschild, Unical (950-57-133)


9:30 AM  Group theoretic conditions under which closed aspherical manifolds are covered by Euclidean space.  Hanspeter Fischer* and David G Wright, Brigham Young University (950-57-655)

9:45 AM  Adding 2-cells to a 2-complex with an eye to $\mathbb{T}_2$.  (127) Michael P Hitchman, Lewis and Clark College (950-57-917)


AMS Session on Optimization

8:30 AM - 9:40 AM

8:30 AM  A Circular Problem.  (115) William T Mahavier, Nicholls State University (950-49-294)

8:45 AM  Direct Method for Variational Problems via Hybrid Functions.  Moshe Razzaghi, Mississippi State University (950-49-402)

9:00 AM  A Sufficient Optimality Theorem for Pseudoconvex Programs.  Thural Kugendran, City University of New York (950-49-741)


9:30 AM  A gradient method to solve a nonlinear optimization problem arising in computational anatomy.  M F Beg, M I Miller, J T Ratnacher*, Center for Imaging Science, Johns Hopkins University, and L Younes, CMLA, ENS-Cachan, France (950-49-1212)

AMS Session on Finite Differences and Functional Equations

9:00 AM - 10:55 AM

9:00 AM  Differentiability Results for a Dynamical System with Multi-point Boundary Values.  (131) Bonita A Lawrence, University of South Carolina-Beaufort (950-37-1046)

AMS-MAA-SIAM Invited Address

11:10 AM – NOON

(140) Title to be announced.
Brian Greene, Columbia University

Exhibits and Book Sale

NOON – 5:30 PM

AMS Colloquium Lecture: Lecture I

1:00 PM – 2:00 PM

(141) Riemann surfaces in dynamics, topology, and arithmetic, Part I.
Curtis T. McMullen, Harvard University

MAA Invited Address

2:15 PM – 3:05 PM

(142) Combinatorics at the crossroads: Progress, problems and prospects.
Ronald L. Graham, University of California at San Diego and AT&T Labs (950-00-10)

AMS-MAA-MER Special Session on Mathematics and Education Reform, II

2:15 PM – 6:00 PM

Organizers: William H. Barker, Bowdoin College
Jerry L. Bona, University of Texas at Austin
Naomi Fisher, University of Illinois at Chicago
Kenneth C. Millett, University of California, Santa Barbara

AMS-MAA-MER Special Session on Mathematics and Education Reform, I

2:15 PM – 6:00 PM

Organizers: William H. Barker, Bowdoin College
Jerry L. Bona, University of Texas at Austin
Naomi Fisher, University of Illinois at Chicago
Kenneth C. Millett, University of California, Santa Barbara

AMS Invited Address

10:05 AM – 10:55 AM

(139) The proof of the Kepler conjecture.
Thomas C. Hales, University of Michigan, Ann Arbor (950-52-05)
AMS Special Session on Holomorphic Dynamics and Related Issues, II

2:15 PM - 5:50 PM

Organizers: Mikhail Lyubich, SUNY at Stony Brook
Kevin Pilgrim, University of Michigan at Rolla
Michael Yampolsky, Institut des Hautes Études

2:15 PM
Residually $S_2$-ideals and applications.
Alberto Corso, Michigan State University (950-13-413)

2:45 PM
Weakly Cohen-Macaulay ideals of small second analytic deviation.
Claudia Polini, Hope College (950-13-414)

3:15 PM
F-rational rings and the integral closures of ideals.
I. C. O. and Roger Wiegand, University of Nebraska (950-13-856)

4:15 PM
Normal ideals of graded rings.
Sara Faridi, University of Michigan (950-13-638)

4:45 PM
Ascent of finite Cohen-Macaulay type.
Graham J. Leuschke* and Roger Wiegand, University of Nebraska (950-13-787)

5:15 PM
The Buchsbaum-Rim polynomial and the Rees algebra of a parameter modules.
Jung-Chen Liu, National Taiwan Normal University (950-13-566)

AMS Special Session on Quantum Computation and Information, II

2:15 PM - 5:35 PM

Organizers: Samuel J. Lomonaco, Jr., University of Maryland, Baltimore County
Howard E. Brandt, Army Research Labs

2:15 PM
State-sum Invariants of Knotted Curves and Surfaces from Quandle Cohomology.
Daniel D. Jelsovsky*, University of South Florida, J. S. Carter, University of South Alabama, Seiichi Kamada, Osaka City University, Laurel Langford, University of Wisconsin-River Falls, and Masahico Saito, University of South Florida (950-57-111)

2:45 PM
The noncommutative deRham homology of the noncommutative deRham cohomology.
Charles D. Frohman, The University of Iowa (950-57-1066)

3:15 PM
A subcategory of a cobordism category.
Preliminary report.
Patrick M. Gilmer, Louisiana State University (950-57-734)

3:45 PM
Cyclic Group Actions on Manifolds.
Preliminary report.
Adam S. Sikora, Univ. of Maryland at College Park (950-57-1200)

4:15 PM
Minimal crossing number of alternating knots in $S^3$.
Preliminary report.
Charles Frohman, University of Iowa, and Joanna Kania-Bartoszynska*, Boise State University (950-57-1223)

4:45 PM
Relating Hopf-algebraic invariants of 3-manifolds.
Preliminary report.

AMS Special Session on Invariants of Knots and 3-Manifolds, II

2:15 PM - 6:00 PM

Organizers: Dubravko Ivansic, George Washington University
Mark E. Kidwell, U.S. Naval Academy
Jozef H. Przytycki, George Washington University
Yongwu Rong, George Washington University
Ted Stanford, U.S. Naval Academy
### AMS Special Session on Nonlinear Eigenvalue Problems and Applications, II

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<td>Maya Chhetri, Mississippi State University</td>
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<td>Ratnasingham Shivaji, Mississippi State University</td>
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<td>2:15 PM</td>
<td>Type-II Superconductivity and Nonlinear Eigenvalue Problems.</td>
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<td>M. S. Berger, University of Massachusetts (950-81-128)</td>
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<td>Alfonso Castro*, The University of Texas at San Antonio, and Victor Padron, Universidad de los Andes, Venezuela (950-35-201)</td>
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<td>John M. Neuberger, Northern Arizona University (950-35-823)</td>
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<td>Jorge Cossio*, Carlos Mejia, Universidad Nacional de Colombia, and Alfonso Castro, The University of Texas at San Antonio (950-35-198)</td>
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<td>Jinlu Li, Shawnee State University, Portsmouth, Ohio (950-49-1073)</td>
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<td>4:45 PM</td>
<td>Resonance Problems for the p-Laplacian.</td>
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<td>Stephen B. Robinson, Wake Forest University (950-35-1255)</td>
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### AMS Special Session on Integral Equations and Applications, II

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<th>Time</th>
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<tr>
<td>2:15 PM</td>
<td>Organizers: Constantin Cordero, University of Texas at Arlington</td>
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<td>Mehran Mahdavi, Bowie State University</td>
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<td>2:15 PM</td>
<td>New problems in optimal control of Volterra equations.</td>
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<td>S. A. Belbas, Univ. of Alabama (950-45-154)</td>
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<td>Xin Zhi Liu, University of Waterloo (950-39-124)</td>
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<td>Abdul J. Jerri*, Clarkson University, and Russell L. Herman, University of North Carolina at Wilmington (950-45-1208)</td>
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<td>3:45 PM</td>
<td>Symmetric Rapidly Oscillating Periodic Solutions.</td>
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<td>Anatoli F. Ivanov, Pennsylvania State University (950-34-1162)</td>
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<td>4:15 PM</td>
<td>Quenching and Explosion in Diffusion Problems with Local and Nonlocal Features.</td>
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<td>Catherine A. Roberts*, Northern Arizona University, and W. E. Olmstead, Northwestern University (950-45-106)</td>
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<td>Mario Ahues and Alain Largillier*, Universite de Saint Etienne, France (950-45-159)</td>
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<td>Boris P. Belinskiy and Peter Caithamer*, University of Tennessee at Chattanooga (950-60-38)</td>
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### AMS Special Session on Operator Algebras, II

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<tr>
<td>2:15 PM</td>
<td>Organizers: May M. Nilsson, University of Nebraska, Lincoln, and Texas A&amp;M University David R. Pitts, University of Nebraska, Lincoln</td>
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<td>2:15 PM</td>
<td>The joint similarity problem for weighted Bergman shifts.</td>
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<td>Sarah H. Ferguson*, Wayne State University, and Srdjan Petrovic, Western Michigan University (950-47-264)</td>
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<td>2:45 PM</td>
<td>Flow equivalence and graph groupoid isomorphism.</td>
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<td>Doug Drinen, Dartmouth College (950-46-232)</td>
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<td>3:15 PM</td>
<td>Order Preserving Limits of Finite Dimensional Nest Algebras. Preliminary report.</td>
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<td>Alan Hopkenwasser*, University of Alabama, and Stephen C. Power, Lancaster University (950-47-205)</td>
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<td>Jonathan M. Rosenberg, University of Maryland (950-19-330)</td>
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<tr>
<td>4:15 PM</td>
<td>Break</td>
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<tr>
<td>4:30 PM</td>
<td>Irreducible Representations of Limit Algebras.</td>
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<td>Preliminary report.</td>
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<td>Elias Katsoulis, East Carolina University (950-47-112)</td>
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<tr>
<td>5:00 PM</td>
<td>Some applications of norming C*-algebras.</td>
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<tr>
<td></td>
<td>Preliminary report.</td>
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5:30PM C*-algebras over a CW-complex with fibres a non-commutative torus.
Chun-Gil Park, Chungnam National University
(950-46-1102)

MAA Minicourse #13: Part A

2:15PM - 4:15PM
Teaching contemporary statistics with active learning.
Organizers: Beth L. Chance, California Polytechnic State University
Robin H. Lock, St. Lawrence University
Mary R. Parker, Austin Community College
Allan J. Rossman, Dickinson College

MAA Minicourse #8: Part A

2:15PM - 4:15PM
Facilitating active learning: Concrete ways to foster student participation.
Organizer: Sandra L. Rhoades, San Diego State University

AMS Session on Group Theory

2:15PM - 5:40PM

2:15PM On the upper near Frattini subgroups of free products of groups with or without amalgamations.
Mohammad K Azarian, University of Evansville
(950-20-176)

2:30PM Extendible Elements of the Alternating Groups.
Owen J Brison, University of Lisbon, and Wasin So, Sam Houston State University
(950-20-182)

2:45PM The Double Coset Problem in Algebraic Groups.
William Ethan Duckworth, University of Oregon
(950-20-283)

3:00PM Commuting Automorphisms of Groups.
Gary L Wails, University of Southern Mississippi
(950-20-336)

Jennifer J Ziebarth, University of Wisconsin, Madison
(950-20-586)

3:30PM Using recurrence relations to count certain elements in symmetric groups. Preliminary report.
Stephen P. Glashy, The University of the South Pacific
(950-20-690)

3:45PM Covering of abelian groups by its proper subgroups.
Kandasamy Muthuvel, UW Oshkosh
(950-20-735)

4:00PM Some analogues of a group problem of P. Erdos and B.H. Neumann.
Luise-Charlotte Kappe, SUNY-Binghamton, John C Lennox, UWC of Cardiff, and James Wiegold, UWC Cardiff
(950-20-839)

4:15PM Perfect Order Subsets in Finite Abelian Groups.
Carrie E Finch* and Lenny K Jones, Shippensburg University
(950-20-795)

4:30PM Permutable Subgroups of a Direct Product of Finite Groups.
Joseph Evan, SUNY Binghamton
(950-20-867)

4:45PM Radicals and Semisimplicity in the Projective System of Semigroups \( \{ Z_2 \times \cdots \} \). Preliminary report.
Y. Phoebe Ho, Central Missouri State University
(950-20-884)

5:00PM Finiteness Properties of Diagram Groups.
Daniel S Farley, SUNY-Binghamton
(950-20-1179)

5:15PM Elementary symmetric functions of Murphy operators, and the centre of an Iwahori-Hecke algebra of type A.
Andrew R Francis, University of Virginia
(950-20-1215)

5:30PM The Orbit Method for Finite Groups. Preliminary report.
Aleksandrs Mihailovs, Shepherd College
(950-20-1244)

AMS Session on Fourier Analysis and Approximation

2:15PM - 5:55PM

Xiaoping Shen, Eastern Connecticut State University
(950-42-168)

2:30PM On the Computation of Nonharmonic Fourier Series by interpolation.
William H Heller, University of Texas-Pan American
(950-42-471)

2:45PM On the Construction of Positive Scaling Vectors.
David K Ruch*, Metropolitan State College of Denver, and Patrick J Van Fleet, University of St. Thomas
(950-42-609)

3:00PM Good-λ Inequalities for Wavelets. Preliminary report.
Sarah V. Cook, Washburn University
(950-42-640)

3:15PM Using the Axiom of Choice to find large sets of uniqueness. Preliminary report.
J. Marshall Ash, DePaul University
(950-42-885)

3:30PM Local Smoothing Results for a Family of Averaging Operators. Preliminary report.
David T Kung, University of Wisconsin - Madison
(950-42-1165)

3:45PM When Fourier phase or magnitude characterizes non-uniformly spaced discrete-time functions. Preliminary report.
Andrew J Siefker, Murray State University
(950-42-1176)

4:00PM Absolute Summability Factors for Fourier Series.
Syed M. Mazhar, Kuwait University
(950-42-1288)

4:15PM Remez-type inequalities in Weighted Spaces.
Michael Ganzburg, Hampton University
(950-41-55)

4:30PM A Sharp Inequality of Markov-type for Polynomials Associated with Laguerre Weight.
Holly Carley*, Xi Lin and Ram N Mohapatra, University of Central Florida
(950-41-63)

4:45PM On cubic lacunary fourier series.
Joseph L. Gerver, Rutgers University - Camden
(950-41-145)

5:00PM Greedily choosing terms from the harmonic series.
Valerio De Angelis, Xavier University of Louisiana
(950-41-372)
5:15 PM Determining the stability of a multidimensional (M,c)-refinable function.
Julie A Belock, West Chester University of Pennsylvania (950-41-743)

5:30 PM Quasi-Invariant Signatures and Wavelets.
Emil-Adrian I Cornea, Northern Illinois University (950-41-977)

5:45 PM A central limit theorem for complex-valued probabilities. Preliminary report.
Natalia A Humphreys*, Purdue University, and Bogdan M Baishanski, The Ohio State University (950-41-997)

AMS Session on Rings and Algebras
2:15 PM - 5:55 PM

2:15 PM Multivariable Hilbert Polynomials.
Alexander Levin, The Catholic University of America (950-13-27)

2:30 PM U-factorizations in Commutative Rings with Zero Divisors.
Michael C Axtell, University of Iowa (950-13-199)

2:45 PM On Reductions of a Certain Class of Ideals. Preliminary report.
Sherwood Washburn, Seton Hall University (950-13-788)

3:00 PM Normal Subgroups of G(2,A).
Christopher A Terry, Augusta State University (950-13-828)

Cynthia J Woodburn, Pittsburg State University (950-13-862)

3:30 PM An analysis of the maximal growth of Hilbert functions. Preliminary report.
Kimberly J. Presser, University of South Carolina (950-13-914)

3:45 PM N-Dimensional Chaotic Attractors with Crystallographic Symmetry.
Jeffrey P Dumont, Lafayette College, Flynn J Heiss*, SUNY Geneseo, Kevin C Jones, University of Illinois at Chicago, Clifford A Reiter and Lisa M Vislocky, Lafayette College (950-06-349)

4:00 PM Join Congruence Relations and Closure Relations. Preliminary report.
Laura H Montague, Dartmouth College (950-06-482)

Nathan R Ritter, University of Massachusetts - Amherst (950-06-650)

4:30 PM The Convex Partitions of a Partially Ordered Set.
Scott R. Sykes, University of West Georgia (950-06-790)

4:45 PM On Extensions of Nilpotent Lie Algebras. Preliminary reports.
Bill Yankosky, Chowan College (950-17-907)

5:00 PM Semisimple Differential Graded Algebras.
Stephen T Aldrich*, University of Kentucky, and Juan Ramon Garcia Rozas, University of Almeria (950-18-138)

Kelly J Pearson, University of Oregon (950-18-363)

5:30 PM Homotopy Theory of Modules.
Changchoo Joanna Su, State University of New York at Binghamton (950-18-577)

5:45 PM Ideals and Homology in Additive Categories.
Lucian M Ionescu, Kansas State University (950-18-677)

MAA Session on Mathematical Modeling in Biology Via Differential Equations
2:15 PM - 6:15 PM

Organizers: Sunil Tiwari, Sonoma State University Sanjay Rai, Jacksonville University Robert Robertson, Huntington College

2:15 PM Constraints in the Use of Free Amino Acids (FAA) in the Osmoregulation of Tigriopus californicus. Preliminary report.
Dale R Lockwood and Eric S Marland*, University of California, Davis (950-92-288)

2:50 PM A model for an SI disease in an age-structured population.
Fred Brauer, University of British Columbia

3:25 PM Qualitative and numerical properties of a nonlinear system of delay-differential equations in population modeling.
Dennis W. Brewer, University of Arkansas

4:00 PM Absolute stability, conditional stability and bifurcation in Kaimanov-type predator-prey systems with discrete delays.
Shigui Ruan, Dalhousie University

Mary Lou Zeeman*, University of Texas at San Antonio, and Christopher Zeeman, Oxford, UK. (950-34-582)

5:10 PM Stability and persistence of a SIR epidemic model with time delay.
Wanbiao Ma, Osaka Prefecture University

5:45 PM Synchronization of biological oscillators.
Sunil K. Tiwari, Sonoma State University

MAA Session on Interdisciplinary Applications for College Algebra, I
2:15 PM - 6:00 PM

Organizers: Donald B. Small, United States Military Academy Della D. Bell, Texas Southern University Ahmad Kamalvand, Houston-Tillotson College

Jane-Jane Lo, Cornell University (950-01-347)

2:35 PM All things considered.
Kalpana A Godbole, Michigan Technological University (950-01-1141)

2:55 PM From Zero to Hero: The Transformation of a Remedial Intermediate Algebra Course into a College Algebra Course at an Urban Community College.
Fred Peskoff, Borough of Manhattan Community College/CUNY (950-01-465)

3:15 PM CBL Experiments for Entry Level Courses.
Janno J. L. Eary, Oklahoma State University (950-01-500)

3:35 PM A Modeling Alternative to College Algebra at Oklahoma State University.
Eileen E Durand, Oklahoma State University (950-01-223)

3:55 PM College Algebra for the Biological Sciences (CABS) at the State University.
Rick W Pongratz, Oklahoma State University (950-01-247)
Applications in college algebra: Effective learning strategies.
- Elaine Hubbard, Kennesaw State University (950-E1-362)

College Algebra with Applications to the Management, Life, and Social Sciences.
- Ronald J. Harshbarger, Univ of South Carolina Beaufort (950-E1-702)

Data-driven Mathematics and the Concept of Function.
- Robert R Mann, Southeast Community College (950-E1-315)

How to Pop the Perfect Popcorn.
- George W Moss, University of Virginia at Wise (950-E1-396)

Experience Curves as an Application of the Power Function in the College Algebra Course.
- Scott R Herriott, Maharishi University of Management (950-E1-356)

MAA Session on Interdisciplinary Collaborations to Improve Service Courses in Mathematics and Statistics, I

2:15 PM - 5:45 PM
Organizers: Linda H. Boyd, Georgia Perimeter College
Thomas L. Moore, Grinnell College

Introduction.
- John H. Harris, Lemoyne-Owen College

- Carolyn B Morgan, Hampton University (950-F1-987)

A Developmental Approach to Teaching Calculus using Writing and Presentations.
- Charles S Allen and Carol E Collins, Drury University (950-F1-1177)

A Team-Taught Course in Math and Physics.
- Jon L Shupenus, Joseph Myers, Chris Lehner, Robert Fuller, Duff Campbell, Thomas Lainis, and Jeff Strickland, US Military Academy (950-F1-879)

Archaeometrics: Statistics in the Humanities.
- Jim Bentley, Winthrop University, Donald L. Bentley, and Adolfo Rumbos, Pomona College (950-F1-945)

Computer Mathematics Course Development and Collaboration.
- Elizabeth Chu, Josephine Freedman, Suffolk County Community College (950-F1-835)

Collaboration in Teaching and Learning: An Interdisciplinary Finite Mathematics Service Course.
- Morteza Shafi-Mousavi and Paul Kochanowski, Indiana University South Bend (950-E1-557)

Project-Driven Mathematics for the Earth and Life Sciences.
- Steven D. Leonhardi and Barry A. Peratt, Winona State University (950-F1-935)

Integrating Local and Community Issues in Mathematics Service Courses.
- Faiz Al-Rubae, University of North Florida (950-F1-410)

Discussion.

AMS Panel Discussion

2:15 PM - 5:15 PM
Organizer: Robby Robson, Oregon State University

Putting and finding mathematics on the Web.

SUMMA Special Presentation

2:15 PM - 3:35 PM
Organizer: William A. Hawkins, SUMMA
Presenters: John H. Harris, Lemoyne-Owen College
Abid S. Elkhader, Northern State University

MAA Committee on Computers in Mathematics Education Panel Discussion

2:15 PM - 3:35 PM
Through the looking glass.
Organizers: Mary L. Platt, Salem State College
Marcelle Bessman, Jacksonville University

MAA Special Presentation

2:15 PM - 3:05 PM
Why study the history of mathematics?
Moderator: Donald J. Albers, MAA
Organizer: Ronald Calinger, Catholic University of America
Presenters: I. M. James, Oxford University
Joseph Dauben, City University of New York

AMS Special Session on Geometric Analysis, II

2:30 PM - 5:50 PM
Organizers: Paul C. Yang, University of Southern California
Matthew J. Gursky, Indiana University

Einstein Metrics, Minimal Volumes, and Seiberg-Witten Theory.
- Claude R LeBrun, SUNY Stony Brook (950-F1-995)

A gluing construction for solutions of the Einstein constraint equations.
- Daniel Pollack, University of Washington, Jim Isenberg, University of Oregon, and Rafe Mazzeo, Stanford University (950-F1-769)

Construction of complete minimal hypersurfaces with finitely many ends in euclidean n-space.
- Frank Pacard, Universite Paris 12, France (950-F1-775)

Break

Construction of minimal surfaces by gluing methods.
- Seon-Deog Yang, Indiana University (950-F1-918)

Minimal surfaces without area bounds.
- William P. Minicozzi, Johns Hopkins University, and Tobias H. Colding, NYU (950-F1-769)

AMS Special Session on Ergodic Theory and Topological Dynamics of $Z^d$ and $R^d$ Actions, II

2:30 PM - 5:20 PM
Organizers: E. Arthur Robinson, George Washington University
Ayse A. Sahin, North Dakota State University

Rigidity of measurable structure for algebraic actions of higher-rank abelian groups.
- Svetlana Katok, The Pennsylvania State University (950-F1-449)
Program of the Sessions – Washington, DC, Wednesday, January 19 (cont’d.)

3:00 PM
Isomorphism rigidity of simple algebraic $2^k$-actions.
Bruce Kitchens*, IBM Watson Research Center, and
Klaus Schmidt, Erwin Schrödinger Institute
(950-37-225)

3:30 PM
Measurable rigidity and disjointness for $2^k$ actions
by toral automorphisms. Preliminary report.
Boris V Kalinin* and Anatole Katok, The
Pennsylvania State University (950-00-646)

4:00 PM
The symbolic dynamics of tiling the integers.
Ethan Coven, Wesleyan University, William Geller*,
IUPUI, Sylvia Silberger, Hofstra University, and
William Thurston, U.C. Davis (950-37-1211)

4:30 PM
Dynamics of multi-dimensional symbolic
subsituitions.
Clifford W Hansen, The George Washington
University (950-37-624)

5:00 PM
Rotational Symmetry and the Topology of
Substitution Tilings. Preliminary report.
Nicholas S Ormes*, Charles Radin and Lorenzo
Sadun, University of Texas (950-37-710)

AWM Panel Discussion
2:45 PM – 4:05 PM
How to increase the number of tenured women in
mathematics departments.
Organizer: Jean E. Taylor, Rutgers University
Panelists:
Mille Dresselhaus, M.I.T.
Elaine Hansen, Haverford College
Maria Klawe, University of British Columbia
Jerry Ostriker, Princeton University
Karen Uhlenbeck, University of Texas
at Austin

AMS Session on Differential Geometry
3:15 PM – 5:25 PM

3:15 PM
Canonical contact hypersurfaces of Kaehler
manifolds. Preliminary report.
Ramesh Sharma, University of New Haven
(950-53-125)

3:30 PM
Weakly symmetric spaces and polar actions.
Hieu D Nguyen, Rowan University (950-53-190)

3:45 PM
Classification of minimal submanifolds by total
Gauss curvature. Preliminary report.
Tracy I Bowers, Lehig University (950-53-228)

4:00 PM
The Double Bubble Conjecture. Preliminary report.
Frank Morgan, Williams College (950-53-255)

4:15 PM
The compact, Einstein, 6-dimensional total space of
an almost Kähler submersion, $F^2 \times M^6 \times N_3$,
which satisfies the AH$_2$ condition of A. Gray is
Kähler. Preliminary report.
Bill Watson, St. John’s University (950-53-357)

4:45 PM
Singularities of the Binormal Surface.
Daniel L Dreibeilis, University of North Florida
(950-93-938)

5:00 PM
Grassmannians via projection operators and some
of their special submanifolds. Preliminary report.
Ivko M Dimitric, Penn State University-Fayette
(950-53-1205)

5:15 PM
Simplex Packings. Preliminary report.
Jean B Mastrangelo*, Immaculata College, Lisa
Traynor, Bryn Mawr College, and E. Miller Maley,
IDA Center for Communications Research
(950-52-399)

MAA Special Presentation
3:15 PM – 4:05 PM
A metaphorical unveiling of Archimedes’ palimpsest
on the method: in memoriam to Wilbur Knorr.
Moderator: Joseph Dauben, City University of New
York
Organizer: Ronald Calinger, Catholic University of
America
Presenters: Reviel Netz, Stanford University
Edith Sylla, North Carolina State

MAA Invited Address
3:20 PM – 4:10 PM
(289) Mathematics and modeling.
Wade Ellis, Jr., West Valley College (950-98-09)

MAA Session on Association for Research on
Undergraduate Mathematics Education Contributed
Papers, I
3:45 PM – 6:00 PM
Organizers: Julie Clark, Emory and Henry College
M. Kathleen Heid, Pennsylvania State
University
Rina Zazkis, Simon Fraser University

3:45 PM
Fostering Reflective Thinking in Complex Analysis: A
Pam Crawford, Jacksonville University
(950-D1-928)

4:00 PM
Too Many Skills, Too Little Structure: The Case of
Differential Equations.
Debasree Raychaudhuri, Simon Fraser University
(950-D1-826)

4:15 PM
An Examination of Student Performance Data in
Recent APOS-Based Papers.
Kirk E Wellers, Bethel College, Julie M Clark, Emory
& Henry College, and Michael A McDonald,
Occidental College (950-D1-448)

4:30 PM
Influencing Preservice Middle School Teachers’
Beliefs on Mathematics-Specific Technology Use in
Mathematics Instruction: The Effects of a
Technology-based Capstone Mathematics Course.
James Eagle*, James A Epperson and Gary A
Harris, Texas Tech University (950-D1-1126)

4:45 PM
Changes in Teacher Technology Use During the
Implementation of a Reform Calculus Curriculum.
Preliminary report.
Thomas B Fox, University of Houston-Clear Lake
(950-D1-1209)

5:00 PM
Visual Representation Use In Solving Applied
Calculus Problems: Gender and Performance Level
Differences.
Elizabeth A George, Ball State University
(950-D1-701)

5:15 PM
Evaluating the Effect of a Transitions Course: A
Comparative Study of Subsequent Student
Performance. Preliminary report.
Douglas D. Smith*, Kenneth R. Gurganus, Paul G.
Shotsberger and Kenneth W. Spackman, University of
North Carolina at Wilmington (950-D1-1152)

5:30 PM
Investigating Students’ Understanding of Proofs in
Advanced Calculus or Analysis.
William J. Shipley, Mount Saint Mary’s College
(950-D1-137)

5:45 PM
Focusing on Multiples.
Rina Zazkis, Simon Fraser University (950-D1-301)
MAA-Young Mathematicians Network Panel Discussion
3:45 PM - 5:05 PM
Finding your second job.
Moderator: Michael Prophet, University of Northern Iowa
Organizers: Kevin E. Charlwood, Washburn University
Philip E. Gustafson, Mesa State University
Panelists: Evelyn L. Hart, Colgate University
Frank Sottile, University of Wisconsin
Edward Aboufadel, Grand Valley State University
T. Christine Stevens, Saint Louis University

AMS Special Session on Beautiful Graph Theory, II
4:00 PM - 5:50 PM
Organizers: Gary Chartrand, Western Michigan University
Frank Harary, New Mexico State University

4:00 PM
Strong Distance in Strong Oriented Graphs.
Gary T Chartrand, David J Erwin, Michael E Raines* and Ping Zhang, Western Michigan University (950-05-971)

4:30 PM
The Peripheral Appendage Number of Edge-Deleted Graphs. Preliminary report.
Steven J Winters, University of Wisconsin Oshkosh (950-05-605)

5:00 PM
(a, b)-choosability: Beauty from Ugliness.
Glenn G Chappell, Southeast Missouri State University (950-05-912)

5:30 PM
"Colorful" trees in edge-colorings of graphs.
Tao Jiang, University of Illinois at Urbana-Champaign (950-05-724)

AWM Business Meeting
4:05 PM - 4:25 PM

MAA Special Presentation
4:15 PM - 5:05 PM
Composing the history of twentieth-century mathematics.
Moderator: Daniele Struppa, George Mason University
Organizer: Ronald Calinger, Catholic University of America
Presenters: Michael I. Monastyrsky, Institute of History and Science, Moscow
David Roberts, National Museum of American History

AMS-MAA-MSEB-SIAM Joint Committee on Employment Opportunities Workshop
5:30 PM - 7:00 PM
Making the most of the job search process.
Organizer: Thomas W. Rishel, Cornell University

Mathematical Sciences Institutes Reception
5:30 PM - 7:30 PM

Young Mathematicians Network Discussion
7:15 PM - 8:15 PM
Concerns of young mathematicians: A town meeting.

AMS Josiah Willard Gibbs Lecture
8:30 PM - 9:30 PM
(304) Physics, computability, and mentality.
Sir Roger Penrose, Oxford University

AWM Reception
9:30 PM - 11:00 PM

Thursday, January 20
MAA Department Chairs Liaison Breakfast
7:00 AM - 8:30 AM

Mathematical Sciences Employment Center
7:00 AM - 7:30 PM
Distribution of all interview schedules (7:00-8:15 a.m.).
Interviews (8:15 a.m.-4:40 p.m.).
Interview Center open until 7:30 p.m.
Joint Meetings Registration

7:30 AM - 4:00 PM

AMS-MAA-MER Special Session on Mathematics and Education Reform, III

8:00 AM - 10:55 AM

Organizers: William H. Barker, Bowdoin College
Jerry L. Bona, University of Texas at Austin
Naomi Fisher, University of Illinois at Chicago
Kenneth C. Millett, University of California, Santa Barbara

8:00 AM
Girls on Track: Middle Grade Girls Modelling
Community Problems - An Experiment in Progress. Preliminary report.
Sarah Berenson, Tiffany Barnes, Laurie Cavey*, North Carolina State University, and Virginia Knight, Meredith College (950-97-1278)

8:30 AM
Solomon Friedberg, Boston College (950-98-475)

9:00 AM
Discussion

9:30 AM
Panel Discussion on A Facilitated Dialog on Teaching Reform Issues. Preliminary report.
William J. Davis, (Starter)*, The Ohio State University, Steven G Krantz*, Washington University, Alan C Tucker*, SUNY at Stony Brook, Steven M Zucker*, Johns Hopkins University, and Lauren McGarity, (Facil.), Alternative Solutions, Inc (950-98-601)

AMS-MAA Special Session on Mathematics in Business, Government and Industry, I

8:00 AM - 10:50 AM

Organizers: Mary Lynn Reed, National Security Agency
Navah Langmeyer, National Security Agency

8:00 AM
Walter Stromquist, Berwyn, PA (950-90-1107)

8:30 AM
Tracking and classifying vehicles using invariance theory. Preliminary report.
Thomas Patrick Bidigare, ERIM International (950-22-603)

9:00 AM
Phil Fong, Carnegie Mellon University, and Peder A Olsen*, IBM, T. J. Watson Research Center (950-62-506)

9:30 AM
John F. Dillon, National Security Agency (950-05-1186)

10:00 AM
Speeding up computational proof. Preliminary report.
Isabel Beichl, NIST, and Francis Sullivan*, IDA (950-28-354)

10:30 AM
Ink jet printing. What math has to do with it?. Preliminary report.
Antonio Cabal, Eastman Kodak Company (950-76-240)

AMS Special Session on Mathematical Aspects of Consensus Theory, II

8:00 AM - 10:45 AM

Organizer: Melvin F. Janowitz, University of Massachusetts, Amherst

8:00 AM
Richard A Cramer-Benjamin, Niagara University (950-05-744)

8:30 AM

9:05 AM
Condorcet and convexity axioms for consensus on graphs. Preliminary report.
Henry Martyn Mulder, Erasmus Universiteit (950-05-504)

9:40 AM
The Arrovian program for consensus n-trees. Preliminary report.
Robert C Powers, University of Louisville (950-90-340)

10:15 AM
Peter C Fishburn, AT&T Shannon Laboratory (950-05-246)

AMS Special Session on Effective Methods and Commutative Algebra, II

8:00 AM - 10:50 AM

Organizers: Anna Guerrieri, Universita degli Studi dell'Aquila
Irene Swanson, New Mexico State University

8:00 AM
Elizabeth A Arnold, University of Maryland, College Park (950-13-1025)

8:30 AM
An Intersection Multiplicity in Terms of Ext-modules. Preliminary report.
C-Y. Jean Chan, University of Utah (950-13-645)

9:00 AM
Koszul property and rate of standard graded algebras. Preliminary report.
Maria Evelina Rossi, Universita' di Genova, Italia (950-13-1261)

9:30 AM
Multigraded modules: A presentation.
Hara Charalambous, University at Albany, SUNY (950-13-725)

10:00 AM
Approximating infinite resolutions. Preliminary report.
David Eisenbud, MSRI and University of California, Berkeley, and Craig Huneke*, University of Kansas (950-13-503)

10:30 AM
Residual Representation of Algebraic-Geometric Codes. Preliminary report.
Reinhold P Hübl, Universität Regensburg (950-14-610)

AMS Special Session on Holomorphic Dynamics and Related Issues, III

8:00 AM - 11:00 AM

Organizers: Mikhail Lyubich, SUNY at Stony Brook
Kevin Pilgrim, University of Missouri at Rolla
Michael Yampolsky, Institut des Hautes Études
8:00AM Twisted face-pairing manifolds and Kleinian groups. Preliminary report.

8:50AM On saddle sets for dynamics in the complex projective plane. Mattias Jonsson*, University of Michigan, and Jeffrey Diller, University of Notre Dame (950-57-189)

9:20AM Dessins d'enfant and Hubbard trees. Preliminary report. Kevin M Pilgrim, University of Missouri at Rolla (950-11-509)

9:50AM Newton's method in two variables—an example of Hubbard. Preliminary report. Jeffrey A Diller, University of Notre Dame (950-57-860)

10:20AM Conformally invariant scaling limits. Oded Schramm, Microsoft Research (950-60-874)

AMS Special Session on Invariants of Knots and 3-Manifolds, III

8:00 AM - 10:50 AM

8:00AM Bordism dependence of refined quantum invariants of 3-manifolds. Preliminary report. Ivella Bobtcheva, Ancona, Italy, and Frank Quinn*, Virginia Tech (950-57-101)

8:30AM Vassiliev invariants and cohomology of Lin's knot complex. Preliminary report. Ilya S. Kofman, University of Maryland, College Park (950-57-107)

9:00AM Foliations of spanning surfaces for links in homology spheres. Preliminary report. Gretchen Wright, Bronx Community College, CUNY (950-57-98)

9:30AM On the n-function of links. Xiaosong Lin, University of California, Riverside (950-57-1013)

10:00AM Homology cylinders: an extension of the mapping class group. Preliminary report. Jerome P. Levine, Brandeis University (950-57-45)


AMS Special Session on Quantum Computation and Information, III

8:00 AM - 10:45 AM
Organizers: Samuel J. Lomonaco, Jr., University of Maryland, Baltimore County Howard E. Brandt, Army Research Labs Louis H. Kauffman, UIC (950-68-61)

8:00AM Quantum Computation and the Jones Polynomial. Preliminary report.

8:35AM Universal quantum computation by $S_3$ anyons. Preliminary report. Alexei Y. Kitaev, Microsoft Research (950-81-293)

9:00AM The Shor/Simon Quantum Algorithm from the Perspective of Group Representation Theory. Preliminary report. Samuel J Lomonaco, University of Maryland Baltimore County (950-81-174)

9:45AM Quantum Computation by Geometrical Means. Jiannis Pachos, Institute for Scientific Interchange (IS) (950-81-73)


AMS Special Session on Singularities in Algebraic and Analytic Geometry, III

8:00 AM - 10:45 AM
Organizers: Ruth I. Michler, University of North Texas Caroline Melles, U. S. Naval Academy

8:00AM Deformations of isolated hypersurface singularities. Preliminary report. Ruth I Michler, University North Texas (950-14-1106)


10:00AM Desingularization and modular Galois descent. Shreeram S. Abhyankar, Purdue University (950-14-144)

AMS Special Session on Integral Equations and Applications, III

8:00 AM - 10:50 AM
Organizers: Constantin Costin, University of Texas at Arlington Mehran Mahdavi, Bowie State University

8:00AM Semilinear Volterra integro-differential equations with nonlocal initial conditions. Preliminary report. Mark McKibben*, Goucher College, and Sergiu Alizicovici, Ohio University (950-45-29)


9:00AM Iterative Methods for Optimal Control Processes described by Integral Equations. Werner Schmidt, Halle University (950-45-630)


10:25AM A Volterra Equation Modeling a Moving Hot Spot in a Reactive-Diffusive Medium. C. M. Kirk, Montclair State University, and W. E. Olmstead*, Northwestern University (950-45-457)
Program of the Sessions – Washington, DC, Thursday, January 20 (cont’d.)

MAA Minicourse #10: Part A
8:00 AM – 10:00 AM

Interdisciplinary lively applications projects.
Organizers: Richard D. West, U. S. Military Academy
Laurette B. Foster, Prairie View A&M University
Marie M. Vanisko, Carroll College

MAA Minicourse #15: Part A
8:00 AM – 10:00 AM

The Fibonacci and Catalan numbers.
Organizer: Ralph P. Grimaldi, Rose-Hulman Institute of Technology

MAA Minicourse #4: Part A
8:00 AM – 10:00 AM

Computer-based modeling with difference equations and matrices.
Organizers: Mazen Shahin, College Misericordia
Richard E. Bayne, Howard University

AMS Session on Ordinary Differential Equations
8:00 AM – 10:55 AM

8:00 AM Right Focal Eigenvalue Problems on a Measure Chain.
John Davis, Baylor University, Johnny Henderson, Auburn University, and Denise T Reid*, Valdosta State University (950-34-41)
8:15 AM Three Symmetric Positive Solutions for a Second Order Boundary Value Problem.
Johnny Henderson*, Auburn University, and Richard I. Avery, Dakota State University (950-34-118)
8:30 AM Controllability of hybrid integro-differential systems.
Seenith Sivasundaram, Embry-Riddle Aeronautical University (950-34-206)
8:45 AM Asymptotes of the Solution to an IVP of Ion Recombination of n Molecules: -ions: dx/dt = -X(A' + M); +ions: dx/dt = -YAC. Zero net charge is assumed and preserved:
\[ \sum x(i) = \sum y(i); \sum x(i) - \sum y(i) = 0. \]
William M. Wagner, CALYPSO; Amuse, OH (950-34-412)
9:00 AM On almost periodicity of some solutions of the equation \( x'(t) = Ax(t) \) in abstract spaces. Preliminary report.
Gaston M N’Guerekata, Morgan State University (950-34-802)
9:15 AM Universal scalings in homoclinic doubling cascades.
Ale Jan Homburg, IPST, Univ. of Maryland, and Todd R Young*, Ohio Univ. and IPST, Univ. of Maryland (950-34-983)
9:30 AM Nonperiodic dissipative systems.
Zhitko S Athanassov, Institute of Mathematics, Bulgarian Academy of Sciences, Sofia, Bulgaria (950-34-1020)
9:45 AM Solvability of a Nonlinear Second Order Conjugate Eigenvalue Problem on a Measure Chain. Preliminary report.
John M Davis, Baylor University, Rajendra Prasad, Andhra University, and William K.C. Yin*, LaGrange College (950-34-1143)

Semen Koksai, Florida Institute of Technology (950-34-1283)
Patricia F. Giurgescu, Pace University (950-60-922)
10:30 AM Diffusion-Driven Instability in Reaction-Diffusion Systems.
Liancheng Wang* and Michael Y Li, Mississippi State University (950-35-163)
10:45 AM Introducing DAEs in an ODEs course. Preliminary report.
Wieslaw Marszalek, DeVry Institute, NJ (950-34-1171)

AMS Session on Applied Mathematics
8:00 AM – 10:55 AM

8:00 AM On a Two-Stage Population Model with Space Limitations and State-Dependent Delay. Preliminary report.
Sanjay Rai*, Jacksonville University, and Robert L Robertson, Huntington College (950-92-203)
8:15 AM HOPS: Hybrid Optimizer of Protein Structure.
> (363) Preliminary report.
Sean L. Forman* and Alberto M. Segre, The University of Iowa (950-92-386)
8:30 AM Optimal patterns for suturing wounds of arbitrary configuration - A numerical approach.
Dawn A Lott-Crumpler*, New Jersey Institute of Technology, and Hans R Chaudhry, New Jersey Institute of Technology and University of Medicine and Dentistry of New Jersey (950-92-453)
8:45 AM Orientational constraints and protein structure determination. I. the algorithm. Preliminary report.
Jeffrey K Denny and John R Quine*, Florida State University (950-92-558)
9:00 AM Orientational Constraints and nuclear magnetic resonance, II: PISEMA wheels. Preliminary report.
Jeffrey K Denny*, J R Quine, Florida State University, J Wang and T A Cross, National High Magnetic Field Laboratory (950-92-559)
Kbenesh W Blayneh, Florida A&M University (950-92-1230)
9:30 AM Robust control for nonlinear systems with switching costs. Preliminary report.
Joseph Ball, Matrin Day and Jerawan Choudoung*, Virginia Tech (950-93-81)
9:45 AM Study of Exponential Stability of Wave Systems Via Distributed Coupling Stabilizer.
Mahmoud Najafi, Kent State University (950-93-139)
10:00 AM An Algorithm for Solving Bond Pricing Problem. Preliminary report.
Elias Deeba*, University of Houston-Downtown, Ghassan Dibeh, Lebanese American University, and Shishen Xie, University of Houston-Downtown (950-90-131)
Christopher J Lacke, Rowan University (950-90-1079)
Washington, DC, Thursday, January 20 - Program of the Sessions

10:30AM A Simulation Model of Recall Operations at an Air Force Base.
L. Vincent Edmondson*, Central Missouri State University, and Steven B. Burton, Montgomery, AL (950-90-1154)

10:45AM Completeness and the Jacobi Group.
(373) Karen L Shuman, Dartmouth College (950-94-591)

AMS Session on Operator Theory and Functional Analysis

8:00AM - 10:55 AM

8:00AM Restrictions of BK Spaces. Preliminary report.
(374) Lyn I Phy, Lehigh University (950-46-300)

8:15AM On a class of Monge-Kantorovich Problem: Dual of C^k.
(375) Preliminary report.
Yewande Olubummo, Spelman College (950-46-355)

8:30AM Generalized Backward Shifts On Banach Spaces C(K).
(376) Rajagopalan Minakshisundaram, Tennessee State University, and Sundaresan Kondagunta*
Cleveland State University (950-46-161)

8:45AM Operators on C(H,Y) that are pointwise limits of a sequence of weakly compact operators.
(377) Elizabeth M Bator*, University of North Texas, and Dawn R Salvens, Midwestern State University (950-46-883)

9:00AM On Ky Fan’s best approximation and its applications. Preliminary report.
(378) Sankatha P. Singh, Memorial University of Newfoundland (950-47-224)

9:15AM Commutants of Certain Composition Operators.
(379) Tami S Worner, Wayne State College (950-47-241)

9:30AM Filling in the holes in the spectrum. Preliminary report.
(380) Gabriel T Prajitura, Bucknell University (950-47-746)

9:45AM Composition Operators on Weighted Bergman Spaces with Subnormal Adjoint. Preliminary report.
(381) Alexander E Richman, University of Virginia (950-47-858)

10:00AM The Product of a Composition Operator with the Adjoint of a Composition Operator Induced by Linear Fractional Maps on the Weighted Hardy Spaces.
(382) John H Clifford, University Michigan Dearborn (950-47-1182)

10:15AM Blow-up Due to Moving Heat Sources of Various Shapes, Sizes and Intensities. Preliminary report.
(383) Colleen M Kirk*, Montclair State University, and W. E OImstead, Northwestern University (950-45-1249)

10:30AM Asymptotic formulae for steady state voltage potentials in the presence of conductivity imperfections.
(384) Arup Mukherjee, Rutgers University (950-45-94)

10:45AM Operators with bounded conjugation orbits.
(385) Driss Drissi, Kuwait University (950-47-1294)

AMS Session on Algebraic and General Topology

8:00AM - 10:55 AM

8:00AM Dimension associated with fractals, including the Julia Set. Preliminary report.
(386) Margaret M. LaSalle, University of Southwestern Louisiana (950-54-337)

8:15AM Simplicial Complexes for Shepard Groups which are Stratified by the Corresponding Arrangement.
(387) Stephen D Szydlik, University of Wisconsin Oshkosh (950-54-501)

8:30AM A non-metrizable collectionwise Hausdorff tree without 
(388) 
without CW-subtrees.
Akira Iwasa* and Peter J Nyikos, University of South Carolina (950-54-543)

8:45AM Embedding of Biconvergence Group. Preliminary report.
(389) Jamuna P. Ambasht, Benedict College (950-54-628)

9:00AM A continuous extension theorem in linearly ordered spaces. Preliminary report.
(390) Guanshen Ren, College of St. Scholastica (950-54-910)

9:15AM Weak P-points of Stone Spaces. Preliminary report.
(391) Joni E Baker, University of Wisconsin-Madison (950-54-1172)

9:30AM Mapping on Uniquely Arcwise Connected Spaces.
(392) Lee K Mohler*, Saint Martin’s College, and Joseph B Fugate, University of Kentucky (950-54-1193)

(393) Gangadhar R Hiremath, Miles College (950-54-1216)

10:00AM Lefschetz coincidence theory for maps between spaces of different dimensions. Preliminary report.
(394) Peter Saveliev, Wabash College (950-55-314)

10:15AM The Hopf Rings for KO, KU, and bo. Preliminary report.
(395) Dena S Cowen*, John Carroll University, and Neil P Strickland, University of Sheffield (950-55-909)

(396) Stephen T Ahearn, University of Virginia (950-55-1104)

10:45AM The topological fundamental group and generalized covering spaces. Daniel Kalman Biss, MIT (950-55-1297)

SIAM Minisymposium on Discrete Methods in Information Technology

8:00 AM - 9:55 AM

Organizer: Fan Chung Graham, University of California San Diego

8:00AM Sorting and Correlation: Mathematical Bridges in Action. Preliminary report.
(398) William T Trotter, Arizona State University (950-05-1033)

8:30AM Two Combinatorial Line-Assignment Problems.
(399) Peter Winkler, Bell Labs, Lucent Technologies (950-05-951)

9:00AM From Erdos to Algorithms. Preliminary report.
(400) Joel H Spencer, Courant Institute (950-05-157)

9:30AM Distance realization problems with applications to Internet tomography. Preliminary report.
(401) Fan Chung Graham*, Ronald L. Graham, UCSD, Mark Garrett and David Shalit for, Telford Technology (950-05-754)

SIAM Minisymposium on 3D Navier-Stokes and Euler Equations

8:00 AM - 9:55 AM

Organizer: Basil Nicolaenko, Arizona State University

8:00AM Incompressible macroscopic limits of kinetic equations. Claude W. Bardos, Ecole Normale Superieure de Cachan
### MAA Session on The Use of History in the Teaching of Mathematics, II

**8:00 AM - 10:55 AM**

Organizers: V. Frederick Rickey, United States Military Academy
Florence Fasanelli, College-University Resource Institute
Victor J. Katz, University of the District of Columbia

**8:00 AM**
- Annotated Time Lines. Preliminary report.
  - Scott Hochwald, University of North Florida (950-A1-923)

**8:20 AM**
  - Della D. Fenster, University of Richmond (950-A1-329)

**8:40 AM**
- History of math for teachers in grades 4-9.
  - Robert G. Stein, California State University, San Bernadino (950-A1-1168)

**9:00 AM**
  - Claudia M Rankins, Hampton University (950-A1-462)

**9:20 AM**
- Actively Preparing Teachers to Use History.
  - Dick Jardine, Keene State College (950-A1-774)

**9:40 AM**
- The Incorporation of the Biographies of Mathematicians into a Mathematics for Humanities Majors Course. Preliminary report.
  - Katherine Safford-Ramus, St. Peter's College (950-A1-707)

**10:00 AM**
- Some relations of Fermat's work on quadratic forms with the teaching of abstract algebra.
  - Mysore S Jagadish, Barry University (950-A1-668)

**10:20 AM**
- The Nature of Number: An Historical Investigation for Inservice Teachers.
  - Daniel E Otero, Xavier University (950-A1-780)

**10:40 AM**
- The Leibniz-Newton Class Action Suit.
  - Jean Marie McDill, Cal Poly, San Luis Obispo (950-A1-933)

### MAA Session on Innovative Uses of the World Wide Web in Teaching Mathematics, II

**8:00 AM - 10:40 AM**

Organizers: Brian E. Smith, McGill University
Marcella Bessman, Jacksonville University

**8:00 AM**
- Distance Learning from a Traditional Classroom: A Win-Win Proposition. Part I: Experiences.
  - Jeremy Haefner* and Gene Abrams, University of Colorado (950-C1-216)

**8:15 AM**
- Distance Learning from a Traditional Classroom: A Win-Win Proposition. Part II: A Live Demonstration.
  - Gene Abrams* and Jeremy Haefner, University of Colorado (950-C1-215)

**8:30 AM**
- Using the World Wide Web to Share Instructional Materials in a Large Undergraduate Department.
  - Marcia Birken* and Patricia Clark, Rochester Institute of Technology (950-C1-660)
8:45 AM: Incorporating WWW Information into Business
Statistics Classes.
Sue B Schou, Idaho State University (950-C1-583)

9:00 AM: Lights, Camera, Calculus! Designing a TeleWeb
Mary Ellen Davis* and Virginia W. Parks, Georgia Perimeter College (950-C1-339)

Hari Pulapaka* and Denise T Reid, Valdosta State University (950-C1-65)

9:30 AM: TI-Interactive Will Foster Student Interaction with the Web.
Allan E Bellman, James Hubert Blake High School (950-C1-929)

Lothar A Dohse* and Peter W Kendrick, University of North Carolina at Asheville (950-C1-295)

10:00 AM: Online classroom interaction using the Web.
Daniel H Steinberg, Oberlin College (950-C1-711)

10:15 AM: Using the Web and WebCT in "Explorations in Mathematics".
Daniel L Dreibelbis, University of North Florida (950-C1-934)

Philip B Yasskin*, G. Donald Allen and Michael Stecher, Dept of Math, Texas A&M Univ (950-C1-1145)

MAA Session on The Role of Mathematicians in the Development of Mathematics Teachers and Their Students, I

8:00 AM - 10:55 AM
Organizers: Diane M. Spresser, National Science Foundation
John S. Bradley, National Science Foundation
Alfred B. Manaster, University of California San Diego

8:00 AM: Mathematics for Inservice High School Teachers.
Preliminary report.
Scott Hochwald, University of North Florida (950-G1-932)

8:15 AM: Mathematics, Physics, and Education: A Link-To-Learn Project Partnership. Preliminary report.
Jon A Beal, Clarion University of Pennsylvania (950-G1-731)

8:30 AM: The Role of Mathematicians in a City under Siege by Algebra Ignorance.
Antonio M Lopez, Jr., Loyola University, New Orleans (950-G1-875)

8:45 AM: The MARS Mathematics Courses: A Series for Elementary Teachers in the Baltimore City Public Schools.
Duane A Cooper, University of Maryland (950-G1-1219)

9:00 AM: Connecting Math Research to the Classroom.
Tricia A Franti, Chassell High School (950-G1-913)

9:15 AM: Developing an Advanced Master's Degree in Mathematics Education. Preliminary report.
Holly P Hirst* and Deborah A Crocker, Appalachian State University (950-G1-1099)

9:30 AM: Collaborating on content, development, and assessment for in-service middle school teachers.
Leonard J Lipkin, University of North Florida (950-G1-1089)

9:45 AM: What is that little n? Recursion and subscript notation in middle school. Preliminary report.
Deborah S. Franzblau*, College of Staten Island, CUNY, and Lisa B. Warner, Totten Intermediate School (950-G1-693)

10:00 AM: Partnership Program in Mathematics for Prospective and Practicing K-8 Teachers.
Patricia M Baggett*, New Mexico State University, Andrzej Ehrenfeucht, University of Colorado, Patrick Morandi, New Mexico State University, Karin Matray, Las Cruces Public Schools, and Patrick Scott, New Mexico State University (950-G1-1098)

10:15 AM: Professional Development Workshops for K-12 Teachers.
Cheryl L Olsen, Shippensburg University (950-G1-1224)

10:30 AM: Professional Development for Inservice Teachers.
Wayne Patty, Virginia Tech (950-G1-416)

10:45 AM: Discussion and closing comments led by organizer, John Bradley.

AMS Special Session on Geometric Analysis, III

8:05 AM - 10:50 AM
Organizers: Paul C. Yang, University of Southern California
Matthew J. Gursky, Indiana University

8:05 AM: Geometry of Hölder imbeddings, slices and quasiconformal equivalence.
Stephen M. Buckley, National University of Ireland, and Alexander Stanoyevitch*, University of Guam (950-G1-46-93)

8:40 AM: Holomorphicity of proper harmonic maps.
Lei Ni*, Purdue University, and Songying Li, University of California (950-G1-861)

Christina A Sormani, Lehman College, City University of New York (950-G1-53-153)

Gailin Y Wang, University of California at Irvine (950-G1-1178)

10:25 AM: Flow lines on a space of dual Legendrian curves.
Abbas Bahri, Rutgers University (950-G1-58-72)

AMS Special Session on Nonlinear Eigenvalue Problems and Applications, III

8:30 AM - 10:50 AM
Organizers: Alfonso Castro, University of Texas at San Antonio
Maya Chhetri, Mississippi State University
Ratnasingham Shivaji, Mississippi State University

Carl V. Lutzer, University of Kentucky (950-G1-35-911)

9:00 AM: An Extension of the Krein-Rutman Theorem.
Jon T Jacobsen, Penn State (950-G1-1055)

Pablo Padilla*, University of Mexico, Ramon Plaza, Courant Institute, and Faustino Sanchez, School of Science, UNAM (950-G1-1267)
Program of the Sessions - Washington, DC, Thursday, January 20 (cont’d.)

10:00 AM Structure of Solutions to Nonlinear Diffusion Equations in $R^n$. Preliminary report.
Alan L Edelson, University of California, Davis (950-35-981)

10:30 AM Symmetry properties of positive entire solutions of Yamabe type equations on groups of Helsenberg type.
Nicola Garofalo and Dimitri N. Vassilev*, Purdue University (950-35-100)

AMS Special Session on Ergodic Theory and Topological Dynamics of $Z^d$ and $R^d$ Actions, III

8:30 AM - 10:50 AM
Organizers: E. Arthur Robinson, George Washington University
Aysel A. Sahin, North Dakota State University

8:30 AM Safe states can be so infrequent as to be negligible. Preliminary report.
Robert Burton*, Oregon State University, and Arthur E Robinson, George Washington University (950-37-1048)

9:00 AM The Complete Description of $Z^d$ Loosely Bernoulli Systems.
Aimee Johnson*, Swarthmore College, and Aysel A. Sahin, North Dakota State University (950-37-480)

9:30 AM On the existence and non-existence of finitary codings for a class of random fields.
Jeffrey E Steif*, Georgia Institute of Technology, and Jacob van den Berg, CWI (950-28-381)

10:00 AM Oscillation in Ergodic Theory: Higher Dimensional Results.
Roger L Jones, DePaul University, Joseph M Rosenblatt*, University of Illinois at Urbana-Champaign, and Mate Wierdl, University of Memphis (950-28-421)

10:30 AM Invariant measures and entropy of $Z^d$ shifts of finite type. Preliminary report.
Arthur E Robinson, Jr., George Washington University, and Aysel A Sahin*, North Dakota State University (950-37-1197)

AWM Emmy Noether Lecture

9:00 AM - 9:50 AM
The mathematics of optimization.
Margaret H. Wright, Lucent Technology

AMS-MAA Special Session on in Memory of Gian-Carlo Rota, I

9:00 AM - 10:50 AM
Organizers: Richard P. Stanley, MIT
Rodica Simion, The George Washington University

9:00 AM Recollections and Appreciations.
Herbert S Wilf, University of Pennsylvania (950-05-317)

9:30 AM Remarks on Plothmeric Algebras and Vector Symmetric Functions.
Joel A Stein, California State University San Bernardino (950-05-689)

10:00 AM Homology invariants for permutation representations of symmetric groups. Preliminary report.
Andre Joyal*, UQAM, and Terrence Bisson, Canisius College (950-05-1240)

10:30 AM Multiple Left Regular Representations Associated with Alternants of the Symmetric Groups.
Francois Bergeron*, Universite du Quebec a Montreal, Adriano M Garsia and Glenn Tesler, UCSD (950-05-311)

MAA-Project NExT Panel Discussion

9:00 AM - 10:20 AM
Making connections with faculty in other disciplines.
Moderator: Joseph A. Gallian, University of Minnesota-Duluth
Organizer: T. Christine Stevens, Saint Louis University
Panelists: Gregory S. Chirkjian, Johns Hopkins University
Jan E. Holly, Colby College
Daniel P. Maki, Indiana University
Lee L. Zia, University of New Hampshire

MAA Women in Mathematics Poster Session

9:00 AM - 11:00 AM
Outreach programs for women and girls in mathematics.
Organizer: Kathleen A. Sullivan, Seattle University

Exhibits and Book Sale

9:30 AM - 5:30 PM

MAA Invited Address

10:05 AM - 10:55 AM
Looking back: An historian’s perspective on American mathematics.
Karen H. Parshall, University of Virginia (950-01-11)

AMS-MAA-SIAM Invited Address

11:10 AM - NOON
(470) Ranks of elliptic curves.
Karl Rubin, Stanford University (950-11-327)

Open House Reception at MAA Headquarters

NOON - 3:00 PM

MAA Session on Integrating Mathematics and Other Disciplines, III

12:45 PM - 3:40 PM
Organizers: William G. McCallum, University of Arizona
Duff G. Campbell, United States Military Academy
Deborah Hughes Hallett, University of Arizona
David C. Lay, University of Maryland, College Park
Nicholas LoSito, SUNY Farmingdale
Jim Rolf, United States Military Academy
Yajun Yang, SUNY Farmingdale

1:00 PM  A Beginning Mathematics Course for Art/Design Majors. Preliminary report. Doris J. Schattschneider, Moravian College (950-B1-513)


1:30 PM  Connecting with Other Disciplines in a Team Teaching Setting. Preliminary report. Philip S Blau, Boston University, College of General Studies (950-B1-998)

1:45 PM  Intertwining Music and Mathematics in Modular Settings. Preliminary report. Satish C Bhatnagar, University of Nevada, Las Vegas (950-B1-1029)

2:00 PM  Functions of Number Theory in Music. Craig M Johnson, Marywood University (950-B1-599)

2:15 PM  Integrating the freshman year in math, chemistry, and engineering. Preliminary report. Robert L Wilson, Univ of Wisconsin - Madison (950-B1-491)

2:30 PM  A cross-listed course in fractals and chaotic dynamics. Preliminary report. Aaron Klebanoff, Rose-Hulman Institute of Technology (950-B1-1259)

2:45 PM  Pattern analysis and neural networks as a centerpiece for interdisciplinary courses. Douglas R Hundley, Whitman College (950-B1-514)

3:00 PM  Theory of Computation for Mathematics Majors. William A Marion, Valparaiso University (950-B1-664)

3:15 PM  The Communications Network Design Problem. Fred J Rispoli* and Steve Cosares, Dowling College (950-B1-1044)

3:30 PM  Integrating Mathematics into a Computational Science Curriculum at a Liberal Arts Environment. Preliminary report. Ignatios E Vakalis, Capital University (950-B1-697)

AMS Colloquium Lecture: Lecture II

1:00 PM - 2:00 PM

(483) Riemann surfaces in dynamics, topology, and arithmetic, Part II. Curtis T. McMullen, Harvard University

AMS-MAA-MER Special Session on Mathematics and Education Reform, IV

1:00 PM - 3:30 PM

Organizers: William H. Barker, Bowdoin College, Jerry L. Bona, University of Texas at Austin, Naomi Fisher, University of Illinois at Chicago, Kenneth C. Millett, University of California, Santa Barbara

1:00 PM  Learning to make a difference.

1:30 PM  Can one person make a difference? Yes!

2:00 PM  Mentoring: Myths and Realities, Dangers and Responsibilities.

2:30 PM  Rethinking K-12 Mathematics Education.

AMS-MAA Special Session on Mathematics in Business, Government and Industry, II

1:00 PM - 3:50 PM

Organizers: Mary Lynn Reed, National Security Agency

Navah Langmeyer, National Security Agency

1:00 PM  Graph Partitioning and Clustering. Preliminary report. Arnaldo Horta, Department of Defense (950-05-1235)

1:30 PM  The Mathematics of Finding Information on the Web. Laura A Mathier, Department of Defense (950-65-250)

2:00 PM  Phone Call Graphs: Models, Measurements, and Open Problems. Preliminary report. Joan Feigenbaum, AT&T Labs - Research (950-68-183)


3:00 PM  Biostatistical consulting at Mayo Clinic - Real math in a complex world. Kent R. Bailey, Mayo Clinic (950-62-783)

3:30 PM  Selling Out: Mathematicians as "Quants" in the Finance Industry. Brian K Boonstra, Bank One (950-90-892)

AMS Special Session on Mathematical Aspects of Consensus Theory, III

1:00 PM - 3:40 PM

Organizer: Melvin F. Janowitz, University of Massachusetts, Amherst

1:00 PM  Voting Power when Using Preference Methods.

1:35 PM  An Algorithm to Compute Nash Equilibria in Probabilistic, Multiparty Spatial Models of Electoral Competition.

2:10 PM  Converting the Masses: Modeling Opinion Formulation via Threshold Processes.

2:40 PM  A Mathematical Analysis of a Voting Procedure by Charles Dodgson (a.k.a. Lewis Carroll).

Michael A Jones*, Montclair State University, and Diana M Thomas, New Jersey City University (950-91-1115)

Joe Adams, University of California at Santa Barbara (950-90-843)
AMS Special Session on Effective Methods and Commutative Algebra, Ill

1:00 PM - 3:50 PM

Organizers: Anna Guerrieri, Universita Degli Studi dell'Aquila
            Irene Swanson, New Mexico State University

1:00PM Normal blow-ups and their expected defining equations.
     Mark Johnson*, University of Arkansas, and Susan Morey, Southwest Texas State University
     (950-13-606)

1:30PM Tight closure in cubical cone rings. Preliminary report.
     Adela Vrabcu, University of Michigan
     (950-13-430)

2:00PM Combinatorics of the toric Hilbert scheme.
     Diane Maclagan*, University of California, Berkeley, and Rekha R Thomas, Texas A&M
     (950-14-1234)

2:30PM Deciding when an element is in a tight closure.
     Melvin Hochster, University of Michigan, Ann Arbor
     (950-13-1185)

3:00PM The Inverse Problem in Gröbner Basis Theory.
     Amelia Taylor, University of Kansas
     (950-13-904)

3:30PM Special solutions of holonomic systems. Preliminary report.
     Uli Walther, MSRI
     (950-14-837)

AMS Special Session on Geometric Analysis, IV

1:00 PM - 3:50 PM

Organizers: Paul C. Yang, University of Southern California
            Matthew J. Gursky, Indiana University

1:00PM Estimates and Existence Results for some Fully Nonlinear Elliptic Equations on Riemannian Manifolds.
     Jeff A Viaclovsky, The University of Texas at Austin
     (950-35-864)

1:35PM Conformal compactification and Kleinian group.
     Alice Chang, Princeton University, Jie Qing*, UCSC, and Paul Yang, Princeton University
     (950-53-1285)

2:10PM Eigenvalue estimates for Paneitz type operators.
     Xingwang Xu, National University of Singapore
     (950-58-656)

2:45PM Manifolds with indefinite metrics whose skew-symmetric curvature operator has constant eigenvalues. Preliminary report.
     Tan Zhang, University of Oregon
     (950-53-229)

3:20PM Dirac Spinors and Surface Shape.
     George J Kamberov, Washington University
     (950-53-1092)

AMS Special Session on Nonlinear Eigenvalue Problems and Applications, IV

1:00 PM - 3:50 PM

Organizers: Alfonso Castro, University of Texas at San Antonio
            Maya Chhetri, Mississippi State University
            Ratnasingham Shivaji, Mississippi State University

1:00PM Periodic Traveling Waves for a Nonlocal Reaction-Diffusion Equation.
     Peter W Bates*, Brigham Young University, and Fengxin Chen, U. Texas San Antonio
     (950-35-589)

1:30PM Traveling Wave Solutions for a Nonlocal Field-Field System.
     Fengxin Chen*, University of Texas at San Antonio, and Peter W. Bates, Brigham Young University
     (950-35-675)
AMS Special Session on Singularities in Algebraic and Analytic Geometry, IV

1:00 PM - 3:50 PM
Organizers: Ruth I. Michler, University of North Texas
Caroline Melles, U. S. Naval Academy

1:00 PM
Monomialization of Morphisms.
S. Dale Cutkosky, Univ. Missouri (950-14-376)

1:15 PM
Inverse systems for singular subschemes of P^n.
Anthony A. Iarrobino, Jr., Northeastern University (950-14-1167)

2:30 PM
Weak Subintegral Closure & Rees Valuations of Ideals.
Marie A Vitulli, University of Oregon (950-14-1202)

3:10 PM
Planar Line Arrangements. Preliminary report.
Eriko Hironaka, Florida State University (950-14-920)

AMS Special Session on Integral Equations and Applications, IV

1:00 PM - 3:50 PM
Organizers: Constantin Corduneau, University of Texas at Arlington
Mehran Mahdavi, Bowie State University

1:00 PM
Asymptotic behavior to Volterra partial integrodifferential equation with noise.
Yoshihiro Hamaya, Okayama University of Science (950-45-151)

1:30 PM
Boundedness in Volterra integro-differential equations.
Tetsuo Furumochi, Shimane University, Japan (950-34-165)

2:00 PM
On some neutral equations with causal operators.
Mehran Mahdavi, Bowie State University (950-45-621)

2:30 PM
Zephyrinus C Okonkwo*, Albany State University, Albany, GA, and Errol G Rowe, North Carolina A & T State University (950-45-960)

3:00 PM
Bounded Variation Regularization of Nonlinear Integral Equations of the First Kind. Preliminary report.
M. Zuhair Nashed, University of Delaware (950-45-1298)

AMS Special Session on Operator Algebras, III

1:00 PM - 3:50 PM
Organizers: May M. Nielsen, University of Nebraska, Lincoln, and Texas A & M University
David R. Pitts, University of Nebraska, Lincoln

1:00 PM
Random unitaries in non-commutative tori, and an asymptotic model for q-circular systems. Preliminary report.
James A. Mingo, Queen's University, Kingston, Ontario, Canada, and Alexandru M. Nica*, University of Waterloo, Waterloo, Ontario, Canada (950-47-1059)

1:30 PM
Noncommutative complex analysis and Bargmann-Segal multipliers.
Nik Weaver* and Richard Rochberg, Washington University (950-47-172)

2:00 PM
Cartan G-spaces and their transformation-group C*-algebras.
Astrid an Huef, University of Denver (950-46-129)

2:30 PM
Norms of Inner Derivations of TAF Algebras. Preliminary report.
Timothy D Hudson*, East Carolina University, and Douglas W. B. Somerset, University of Aberdeen (950-47-989)

3:00 PM
On the Classification of Binary Shifts of Minimal C*-algebras.
Geoffrey L. Price, United States Naval Academy (950-46-119)

3:30 PM
Involutions of nonself-adjoint operator algebras. Preliminary report.
Justin R Peters, Iowa State University (950-47-322)

MAA Minicourse #11: Part A

1:00 PM - 3:00 PM
Discrete dynamical systems: Mathematics, methods, and models.
Organizers: David C. Arney, U. S. Military Academy
John S. Robertson, Georgia College and State University

MAA Minicourse #14: Part A

1:00 PM - 3:00 PM
Modern physics and the mathematical world.
Organizer: George DeRise, Thomas Nelson College

MAA Minicourse #5: Part A

1:00 PM - 3:00 PM
Exploring abstract algebra topics through interactive labs.
Organizers: Allen C. Hibbard, Central College
Kenneth M. Levasseur, University of Massachusetts at Lowell

AMS Session on Combinatorics, I

1:00 PM - 3:40 PM
1:00 PM
Reconstruction Conjecture for Graphs Having Exactly One Unicyclic Subgraph.
Shyam Kumar Gupta* and Gagan Singla, Jr., Indian Institute of Technology, New Delhi (950-05-19)

1:15 PM
A reluctant colonial mathematician.
Paul C Pasles, Villanova University (950-01-98)
AMS Session on Mechanics

1:00 PM - 2:40 PM

1:00 PM
Paul G Warne*, Maryland College, and Debra A Polignone Warne, University of Tennessee (950-73-502)

1:15 PM
Variational principles for elastic bodies with fractal holes.
Feodor M Borodich*, The University of Liverpool, and Alexey Y Volovikov, Steklov Mathematical Institute (950-73-1062)

1:30 PM

1:45 PM

2:00 PM
Radu C Cascaval, University of Memphis (950-76-1000)

2:15 PM
Dynamics of the Ginzburg-Landau Vortices. Mahmoud Affouf, Penn State/Scranton Campus (950-82-1005)

2:30 PM
Andrew Vogt, Georgetown University (950-81-1221)

SIAM Minisymposium on Analysis of Krylov Space Methods in Numerical Linear Algebra

1:00 PM - 2:55 PM

Organizer: Anne Greenbaum, University of Washington

1:00 PM
Multiple Recursion Conjugate Gradient Algorithms. (564) Teri L Barth*, TRW, and Tom A Manteuffel, University of Colorado at Boulder (950-15-658)

1:30 PM
Analyzing Krylov Subspace Methods by Their Projections. Preliminary report.
Eric de Sturler, University of Illinois at Urbana-Champaign (950-65-1248)

2:00 PM
Computable convergence bounds for GMRES.
(562) Joerg Liesen, University of Bielefeld, Germany (950-65-759)

2:30 PM
When Loss of Orthogonality Means Convergence.
(563) Zdenek Strakos, Emory University (950-65-282)

MAA Session on Interdisciplinary Applications for College Algebra, II

1:00 PM - 3:45 PM

Organizers: Donald B. Small, United States Military Academy
Della D. Bell, Texas Southern University
Ahmad Kamalvand, Houston-Tillotson College

1:00 PM
College algebra reform should be a friend and not a foe. Preliminary report.
William P. Fox, Francis Marion University (950-16-209)

1:20 PM
Applying Algebra to Fairness and Equity Problems.
(565) Joseph Malkevitch, York College (CUNY) (950-16-343)

1:40 PM
Enriching College Algebra with Concepts from Music Theory, Engineering, and Euler's Algebra.
(566) Anton Gieser, Pennsylvania State University (950-16-220)

2:00 PM
Carl V Lutzer, University of Kentucky (950-16-899)

2:20 PM
Fitting Functions to Data in a Precalculus Course.
(567) Preliminary report.
Todd M Swanson, Hope College (950-16-390)

2:40 PM
A Team Test Approach in College Algebra.
(568) William J. Shiple, Mount Saint Mary's College (950-16-233)

3:00 PM
The South Dakota Native American Mathematics and Orthology program at Northern State University.
(570) A. S. Elkhader* and Dan A Tallman, Northern State University (950-16-244)

3:20 PM
The Contemporary College Algebra Program.
(571) Preliminary report.
Della D Bell*, Texas Southern University, and Ahmad Kamalvand, Huston-Tillotson College (950-16-845)

MAA Session on The Role of Mathematicians in the Development of Mathematics Teachers and Their Students, II

1:00 PM - 3:15 PM

Organizers: Diane M. Sprenz, National Science Foundation
John S. Bradley, National Science Foundation
Alfred B. Manaster, University of California San Diego

1:00 PM  Learning and Teaching Mathematics: A Summer Institute for Elementary School Teachers.
          Debra K. Borkovitz* and Pat Willott, Wheelock College (950-G1-896)

1:15 PM  Getting a Mathematics Department Involved in Middle Grades Mathematics: A California Case Study.
          Joseph R. Fiedler* and Javier Trigos-Arrieta, CSU Bakersfield (950-G1-916)

1:30 PM  CalcLab for Teachers: Synthesizing In-Depth Learning of High School Calculus with Issues of Teaching and Learning.
          Stephen Monk, University of Washington (950-G1-1156)

1:45 PM  What Works in Professional Development for K-12 Teachers of Mathematics.
          Gloria A. White, Texas Higher Education Coordinating Board and Austin Community College (950-G1-854)

2:00 PM  Lessons from an Outreach Program: MENI, Mathematical Experiences in Northwest Indiana.
          Mary T Treanor, Valparaiso University (950-G1-947)

2:15 PM  Innovations resulting from collaboration between university and K-12 teachers of mathematics.
          Reginald D Traylor*, University of the Incarnate Word, and Ellen C Szecci, Northeast ISD (950-G1-670)

2:30 PM  Providing inservice training and curricular support for K-12 math teachers through local science centers.
          Daniel H Steinberg, Oberlin College (950-G1-714)

2:45 PM  Discussion and closing comments led by organizer, Alfred Manaster.

MAA Panel Discussion

1:00 PM - 2:20 PM

CBMS mathematics education of teachers report.

Organizer: Ronald C. Rosier, CBMS

Panelists: Alan C. Tucker, SUNY at Stony Brook
            W. James Lewis, University of Nebraska

MAA CRAFTY-CUPM-Committee on Two-Year Colleges Panel Discussion

1:00 PM - 2:20 PM

What does algebra mean in the twenty-first century?

Organizers: Sheldon P. Gordon, SUNY at Farmingdale
            Linda A. Klme, University of Massachusetts at Boston
            Ray E. Collings, Georgia Perimeter College

Panelists: Linda H. Boyd, Georgia Perimeter College
            Wade Ellis, West Valley College
            Carole B. Lacampagne, U.S. Department of Education
            Zalman P. Usiskin, University of Chicago

AMS-MAA Special Session on in Memory of Gian-Carlo Rota, II

2:00 PM - 3:50 PM

Organizers: Richard P. Stanley, MIT
            Rodica Simion, The George Washington University

AMS Special Session on Ergodic Theory and Topological Dynamics of $Z^d$ and $R^d$ Actions, IV

2:00 PM - 3:50 PM

Organizers: E. Arthur Robinson, George Washington University
            Ayse A. Sahin, North Dakota State University

AMS Project NExT-YMN Poster Session

2:00 PM - 3:45 PM

Organizers: Kenneth A. Ross, University of Oregon
            Kevin E. Charland, Washburn University

MAA Student Workshop

2:00 PM - 3:45 PM

Theorems in stone and bronze.

Organizer: Helaman Ferguson, Laurel, Maryland

AMS Retiring Presidential Address

2:15 PM - 3:05 PM

Reflections and twists.

Arthur M. Jaffe, Harvard University

January 2000 Notices of the AMS 147
Program of the Sessions - Washington, DC, Thursday, January 20 (cont'd.)

MAA Special Presentation
2:30 PM - 3:50 PM
Great theorems of mathematics.
Organizers: Douglas E. Ensley, Shippensburg University
Cheryl Olson, Shippensburg University
Presenters: Farhad Jafari, University of Wyoming
Elena A. Marchisotto, California State University Northridge
Daniel Velleman, Amherst College
Roger A. Wiegand, University of Nebraska, Lincoln

AMS-MAA-MSEB Joint Panel Discussion
2:30 PM - 3:45 PM
Projects of the Mathematical Sciences Education Board.
Organizer: James D. Gates, MSEB
Presenters: Deborah Loewenberg Ball, University of Michigan
Jay Lebov, Center for Science, Mathematics, and Engineering Education
Harvey B. Keynes, University of Minnesota, Minneapolis

Joint Prize Session and Reception
4:00 PM - 6:00 PM

MAA Video Presentation
5:15 PM - 6:00 PM
The Four Color Conjecture Theorem.
Organizer: Robin Wilson, The Open University

MAA Session on Innovative Uses of the World Wide Web in Teaching Mathematics, III
5:20 PM - 7:00 PM
Organizers: Brian E. Smith, McGill University
Marcelle Bessman, Jacksonville University

MAA Special Presentation
6:30 PM - 7:20 PM
Stamping through the millennium.
Organizer: Robin Wilson, The Open University

Friday, January 21
Pi Mu Epsilon and MAA Student Chapter Advisors' Breakfast
7:00 AM - 8:00 AM

Joint Meetings Registration
7:30 AM - 4:00 PM

AMS-MAA Special Session on Innovative Development Programs for Teaching Assistants and Part-Time Instructors, I
8:00 AM - 10:55 AM
Organizers: Teri Jo Murphy, University of Oklahoma
Neil Calkin, Clemson University
Ethel Wheland, University of Akron

MAA Minicourse #6: Part A
5:30 PM - 7:30 PM
Teaching with Web-based interactive modular materials.
Organizers: David A. Smith, Duke University
Lawrence C. Moore, Duke University

MAA Committee on Industrial and Governmental Mathematics Welcome Reception
5:30 PM - 6:30 PM

MAA Two-Year College Reception
5:30 PM - 7:00 PM

MAA Special Presentation
6:30 PM - 7:20 PM
The number years: A mathematical game show.
Organizers: Arthur T. Benjamin, Harvey Mudd College
Eric J. Libicki, University of Southern California
Jennifer J. Quinn, Occidental College

NOTICES OF THE AMS  VOLUME 47, NUMBER 1
AMS Special Session on Mathematical Aspects of Consensus Theory, IV

8:00 AM - 10:45 AM
Organizer: Melvin F. Janowitz, University of Massachusetts, Amherst

8:00 AM
When are the usual set representations injective?
Richard Cramer-Benjamin, Niagara University, Preliminary report.

9:05 AM
Consensus phylogenetic trees: Character and taxonomic congruence revisited.
Fred S. Roberts, Rutgers University, Preliminary report.

9:35 AM
Consensus supertrees and subtrees.
David J. Bryant, CRM Universite de Montreal, Preliminary report.

10:15 AM
About NP-hard problems for the consensus in numerical taxonomy.
Jean-Pierre Barthélémy* and François Brucker, ENST Bretagne (950-05-479)

AMS Special Session on Effective Methods and Commutative Algebra, IV

8:00 AM - 10:50 AM
Organizers: Anna Guerrieri, Universita Degli Studi dell’Aquila, Irene Swanson, New Mexico State University

8:00 AM
Computation of multivariable Hilbert polynomials.

8:30 AM
Invariants of ideals having principal reductions.
Marco D’Anna*, Universita’ di Catania, Anna Guerrieri, Universita’ di L’Aquila, and William Heinzer, Purdue University (950-13-483)

9:00 AM
On the associated graded ring of Cohen-Macaulay local rings.
Hsin-Ju Wang, Taiwan (950-13-564)

9:30 AM
On multilinear forms, jacobian ideals and hyperdeterminants.
Giandomenico Boffi, University of Trieste (950-13-569)

10:00 AM
Computation using Macaulay’s inverse system.
Anthony A. Iarrobino, Jr., Northeastern University (950-13-1122)

10:30 AM
Free resolutions for polynomial functors.
Alexandre B Tchernev*, University at Albany, SUNY, and Jerzy Weyman, Northeastern University (950-13-838)

AMS Special Session on Recent Advances in Complex and Harmonic Analysis, I

8:00 AM - 10:50 AM
Organizers: Carlos A. Berenstein, University of Maryland, College Park
Stephen D. Casey, American University
Bao Qin Li, Florida International University
David F. Walnut, George Mason University
C. C. Yang, Hong Kong University of Science and Technology

8:00 AM
Wavelet frames for square-summable sequences.
Jean-Pierre Gabardo, McMaster University, Preliminary report.

8:30 AM
Determinacy in truncated trigonometric moment problems and the extension property.
Jean-Pierre Gabardo, McMaster University (950-42-939)

9:00 AM
Positive Sampling Series.
Gilbert G. Walter, Univ Wisc-Milwaukee (950-41-478)

9:30 AM
Paley-Wiener-type and Boas-type theorems for a class of integral transforms.
Ahmed I. Zayed*, University of Central Florida, and Tuan Vu-Kim, University of Kuwait (950-42-332)

10:00 AM
Complex and Harmonic approximation, Preliminary report.
Paul M. Gauthier, Universite de Montreal (950-32-476)

10:30 AM
Normality and shared values.
Lawrence Zalcman, Bar Ilan University, and Xuecheng Pang, East China Normal University (950-30-1081)

AMS Special Session on Holomorphic Dynamics and Related Issues, IV

8:00 AM - 10:50 PM
Organizers: Mikhail Lyubich, SUNY at Stony Brook
Kevin Pilgrim, University of Missouri at Rolla
Michael Yampolsky, Institut des Hautes Études

8:00 AM
Symmetry and renormalization.
Marco Martens, IBM-Watson Research Center (950-37-822)

8:50 AM
Divergence groups have Bowen’s property.
Christopher J. Bishop, SUNY at Stony Brook (950-30-1004)

9:50 AM
A universal parabolic map, Preliminary report.
Michael Yampolsky, IHES (950-58-773)

10:20 AM
Periodic orbits and external rays.
John W Milnor, SUNY Stony Brook (950-37-1173)

AMS Special Session on Invariants of Knots and 3-Manifolds, IV

8:00 AM - 10:50 AM
Organizers: Dubravko Ivancic, George Washington University
AMS Special Session on Homotopy Theory, I
8:00 AM - 10:50 AM
Organizers: W. Stephen Wilson, Johns Hopkins University
Jack Morava, Johns Hopkins University
Bernard Badzioch, University of Notre Dame
(632)

8:00 AM
Algebraic theories in homotopy theory.
(632)

8:30 AM
A Model Structure on the Category of Pro-Simplicial Sets.
(633)
Daniel C Isaksen, Universitaet Bielefeld
(950-55-105)

9:00 AM
(634)
Jeffrey A Strom*, Dartmouth College, and Charles A. McGibbon, Wayne State University (950-55-389)

9:30 AM
The Gray Filtration on Phantom Maps.
(635)
Ha M Le*, Wayne State University, and Jeffrey A Strom, Dartmouth College (950-55-593)

10:00 AM
Generalized Bousfield Classes and Localizing Model Categories. Preliminary report.
(636)
Mark W Johnson, University of Notre Dame (950-55-602)

10:30 AM
(637)
Lowell Abrams* and Charles Weibel, Rutgers University (950-18-429)

AMS Special Session on Quantum Computation and Information, V
8:00 AM - 10:45 AM
Organizers: Samuel Lomonaco, Jr., University of Maryland, Baltimore County
Howard E. Brandt, Army Research Labs

8:00 AM
Quantum Robots.
(627)
Paul Benioff, Physics Division, Argonne National Laboratory (950-81-75)

8:35 AM
Pauli Exchange Errors in Quantum Computation.
(628)
Mary Beth Ruskai, University of Massachusetts Lowell (950-81-76)

9:10 AM
On relations between quantum computers and classical computers. Preliminary report.
(629)
John M Myers*, Harvard University, and F. Hadi Madjidi, Concord, MA (950-81-83)

9:45 AM
Simulations of Quantum Logic Operations in a Nuclear-Spin Quantum Computer with Large Number of Qubits.
(630)
Gennady P Berman*, Gary D Doolen, Los Alamos National Laboratory, Gustavo V Lopez, Departamento de Fisica, Universidad de Guadalajara, and Vladimir I Tsifrinovich, Polytechnic University (950-81-592)

10:20 AM
Geometric Algebra Methods in Ensemble Quantum Computing by NMR.
(631)
Timothy F Havel, Harvard Medical School, Boston, MA (950-81-53)

AMS Minicourse #12: Part B
8:00 AM - 10:00 AM
Transforming anxiety into hatred: Rethinking this standard model of reaching liberal arts students and the general public.
Organizers: Edward B. Burger, Williams College
Michael Starbird, University of Texas at Austin

AMS Special Session on Operator Algebras, IV
8:00 AM - 10:50 AM
Organizers: May M. Nilsen, University of Nebraska, Lincoln, and Texas A & M University
David R. Pitts, University of Nebraska, Lincoln

8:00 AM
Investigating some prewavelets by using Ruelle transfer operators. Preliminary report.
(638)
Beth P Peterson, Lamar University (950-47-249)

8:30 AM
Groupoids and C*-algebras for infinite graphs.
(639)
Jack Spielberg, Arizona State University (950-46-1201)

9:00 AM
(640)
Allan P Donsig*, University of Nebraska-Lincoln, and Aristides Katavolos, University of Athens (950-46-893)

9:30 AM
Hecke C*-Algebras.
(641)
Rachel W Hall, St. Joseph’s University (950-16-305)

10:00 AM
A simple approach to limit distributions of Haar unitary systems. Preliminary report.
(642)
Michal Dostal, Prague, and Don Hadwin*, University of New Hampshire (950-47-1019)

10:30 AM
Locally Inner Actions on C0(X)-Algebras.
(643)
Siegfried Echterhoff, Westfalische Wilhelms-Universitat Muenster, and Dana P Williams*, Dartmouth College (950-46-440)

MAA Minicourse #1: Part B
8:00 AM - 10:00 AM
Mathematical finance.
Organizer: Walter R. Stromquist, Berwyn, PA
MAA Minicourse #7: Part B

8:00 AM – 10:00 AM

Getting students involved in undergraduate research.
Organizers: Joseph A. Gallian, University of Minnesota-Duluth
Aparna W. Higgins, University of Dayton
Stephen G. Hartke, Rutgers University

AMS Session on Number Theory, I

8:00 AM – 9:55 AM

8:00 AM Multiplier Systems on Hecke Groups.
Abdul Hassen, Rowan University (950-11-32)

8:15 AM Small limit points of the set of algebraic integers with two conjugates outside the unit circle.
Preliminary report.
David R. Garth, Kansas State University (950-11-64)

8:30 AM Linear equivalence of algebraic number fields.
Marius M Somodi, Louisiana State University (950-11-114)

8:45 AM Vanishing Theorems in the Witt Ring. Preliminary report.
Thomas C Palfrey, Xavier University of Louisiana (950-11-180)

9:00 AM On the Crosscorrelation of Sequences with the Decimation Factor d = \( \frac{p^n - 1}{p - 1} \).
Donald D Mills*, Southeastern Louisiana University, Eva-Nuria Mueller and Wolfgang Willems, Otto-von-Guericke Universitaet (950-11-116)

9:15 AM The isotropy of 4-dimensional torsion quadratic forms over \( \mathbb{R}(x, y) \) and \( \mathbb{C}(x, y) \).
Preliminary report.
Anthony J Bevelacqua, University of Kentucky (950-11-239)

9:30 AM Universal ternary forms in totally real number fields. Preliminary report.
Azar N Khosravani, University of Wisconsin Oshkosh (950-11-344)

9:45 AM Cardan Polynomials and the Reduction of Radicals.
Thomas J Osler, Rowan University (950-11-497)

SIAM Minisymposium on Applications of Inverse Problems in Partial Differential Equations

8:00 AM – 9:55 AM

Organizer: C. Maeve McCarthy, Murray State University

8:00 AM Stability and Reconstruction for an Inverse Problem in Thermal Imaging.
Lester F Caudill, University of Richmond (950-11-1139)

8:30 AM Finding discontinuous shallow water seabed properties. Preliminary report.
Joyce R McLaughlin, Rensselaer Polytechnic Institute (950-11-1085)

9:00 AM Inverse Problems for Anisotropic Elastic Media.
Lizabeth V Rachele, Tufts University (950-11-941)

9:30 AM Inverse Scattering Problems in Layered Backgrounds.
Peter B Monk, University of Delaware (950-35-840)

MAA Session on Teaching Statistical Reasoning

8:00 AM – 10:15 AM

Organizers: K. L. D. Gunawardena, University of Wisconsin Oshkosh
Nkechi M. Agwu, Borough of Manhattan Community College
Mary Sullivan, Rhode Island College

8:00 AM Introduction by K.L.D. Gunawardena.

8:05 AM In-Class Projects for Teaching Probability and Statistics.
Carol E Marchetti, Rochester Institute of Technology (950-M1-579)

8:20 AM Statistical reasoning and the prospective elementary teacher.
Mary Sullivan, Rhode Island College

8:35 AM Labs and Projects for an Introductory Statistics Preliminary report.
Laura A McSweeney, Fairfield University (950-M1-776)

8:50 AM A Data-Oriented, Active Learning, Post-Calculus Introduction to Statistical Concepts, Methods, and Theory.
Allan J Rossman*, Dickinson College, Beth L Chance, Cal Poly, and Karla V Ballman, Mayo Clinic (950-M1-298)

9:05 AM Team Projects and a Poster Session Final Exam - Second Trial.
Melvin A Nyman, Alma College (950-M1-458)

9:20 AM Teaching Statistical Reasoning at West Point.
Steven B Horton* and Dennis J Day, United States Military Academy (950-M1-571)

9:35 AM Statistical Reasoning for Business and Economics Students.
John D. McKenzie, Jr., Babson College (950-M1-1190)

9:50 AM R.J. Bosovich and the line of best fit.
Radoslav M. Dimitric, City College of San Francisco (950-M1-320)

Jason D Rosenhouse, Dartmouth College (950-M1-679)

MAA Student Papers

8:00 AM – 9:25 AM

Graduate student paper session.
Organizer: Howard L. Penn, U.S. Naval Academy

PME Council

8:00 AM – 11:00 AM

MAA Session on Looking to Our Future: Recruiting and Preparing the Next Generation of Mathematics Teachers, I

8:05 AM – 10:55 AM

Organizers: Jay A. Malmstrom, Oklahoma City Community College
Gary L. Britton, University of Wisconsin-Washington County
Marjorie Enneking, Portland State University
James Loats, Metropolitan State College of Denver
Program of the Sessions - Washington, DC, Friday, January 21 (cont’d.)

Mary Robinson, University of New Mexico

8:05 AM - 10:50 AM
A Statewide Approach To Addressing Two-Year College Teacher Preparation Issues in Virginia.
Susan S Wood, J. Sargeant Reynolds Community College (950-H-1198)

AMS-AWM-SIAM Special Session on Linear Algebra and Optimization, I

8:15 AM - 10:50 AM
Organizers: Dianne P. O'Leary, University of Maryland, College Park
Margaret H. Wright, Bell Laboratories

8:15 AM
Computing and Displaying Confidence Intervals for Images. Preliminary report.
Dianne P. O'Leary*, University of Maryland, and James C. Nagy, Emory University (950-65-299)

9:00 AM
Elizabeth D Dolan, Argonne National Laboratory, Robert Michael Lewis, Institute for Computer Applications in Science and Engineering, and Virginia Torczon*, College of William & Mary (950-49-961)

9:40 AM

10:20 AM
Yuying Li, Cornell University (950-65-771)

AMS-MAA Special Session on The History of Mathematics, I

8:30 AM - 10:50 AM
Organizers: Karen H. Parshall, University of Virginia
David E. Zitarelli, Temple University

8:30 AM
An analytical society? In search of nineteenth-century British analysts. Adrian C Rice, Randolph-Macon College (950-01-388)

9:00 AM
Individuals and Institutions in the Emergence of a Modern Mathematical Community in China. Joseph W. Dauben, CUNY Graduate Center (950-01-546)

9:30 AM
Patronage from Dukes to Foundations and the Development of Mathematical Fields. Florence D. Fasanelli, College-University Resource Institute (950-01-889)

10:00 AM
International Contributions to British Mathematical Journals, 1800-1900. Preliminary report. Sloan E. Despeaux, University of Virginia (950-01-634)

10:30 AM
A Sideways Look at Hilbert’s 23 Problems of 1900. Ivor Grattan-Guinness, Middlesex University (UK) (950-01-516)

AMS Special Session on Beautiful Graph Theory, IV

8:30 AM - 10:50 AM
Organizers: Gary Chartrand, Western Michigan University
Frank Harary, New Mexico State University

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AMS Special Session on Beautiful Graph Theory, IV

8:30 AM - 10:50 AM
Organizers: Gary Chartrand, Western Michigan University
Frank Harary, New Mexico State University

8:30 AM
AMS Session on Complex Variables

8:30 AM - 9:45 AM

Mohammed A Qazi, University of Central Florida (95-06-898)

8:45 AM Domains with a prescribed number of minimum points of the hyperbolic metric. Preliminary report.
Brian T Gill*, Seattle Pacific University, and Thomas H MacGregor, University at Albany, SUNY (95-06-919)

9:00 AM Examples from a Class of Meromorphic Harmonic Polynomials. Preliminary report.
John W Thompson, University of Pittsburgh at Johnstown (95-06-1023)

9:15 AM A Jensen-Type Theorem. Preliminary report.
Catherine A Beneteau*, Seton Hall University, and Boris Korenblum, The University at Albany (95-06-1103)

9:30 AM Linear Fractional Transformations in Complex Euclidean Space.
Jerry R Muir, Jr.*, Rose-Hulman Institute of Technology, and Ted J Saffirude, University of Kentucky (95-06-32-387)

9:45 AM On n-concavity of covering spaces with parameters.
Cezar Joiita, SUNY at Buffalo (95-06-1111)

MAA Committee on Student Chapters Presentation

8:30 AM - 10:00 AM

Mathematical experiences for students outside the classroom
Organizers: Tom Kelley, Metropolitan State College of Denver
Richard L. Poss, St. Norbert College

AMS Invited Address

9:00 AM - 9:50 AM

9:00 AM Higher order elliptic equations in conformal geometry.
Sun-Yung Alice Chang, Princeton University (95-06-35-07)

ASL Invited Address

9:00 AM - 9:25 AM

9:00 AM Title to be announced.
Manuel Lerman, University of Connecticut

AMS-MAA Special Session on in Memory of Gian-Carlo Rota, III

9:00 AM - 10:55 AM

Organizers: Richard P. Stanley, MIT and Rodica Simion, The George Washington University

9:00 AM Random Variables, Umbral Calculus, and Polynomial Sequences.
Brian D Taylor, Wayne State University (95-06-1277)

9:30 AM Applications of the classical umbral calculus.
George E Andrews, Pennsylvania State University (95-06-510)

AMS Session on Linear Algebra

9:00 AM - 11:00 AM

9:00 AM Free product Z_3 * Z_3 of rotations with rational entries.
Guoyang Liu*, The Catholic University of America, and Lewis C Robertson, Wesleyan University (95-06-15-79)

9:15 AM Limiting Values of the Variance and the Moments of the Dimension of a Sum or Intersection of Random Vector Subspaces.
Geoffrey D. Dietz*, University of Dayton, and David E. Dobbs, University of Tennessee (95-06-15-113)

9:30 AM Applying linear algebra and set theoretic heuristics founding the basis for System Availability Analysis under the Kalinowski Algorithm. Preliminary report.
Kevin M Kalinowski, General Dynamics Land Systems (95-06-578)

9:45 AM More Preconditioners via Subspace Projection.
Eugene C Boman, Penn State University, DuBois Campus (95-06-15-585)

Shafiu Jibrin*, University of Minnesota, Morris, and Irwin S. Pressman, The Fields Institute, Toronto (95-06-90-515)

10:15 AM Patterns of Matrices that Do Not Have P-completion.
Luz M DeAlba*, Drake University, and Leslie Hogben, Iowa State University (95-06-15-733)

Constantine Georgakis, DePau University (95-06-891)

10:45 AM Closest Matrices in the Space of Doubly Stochastic Matrices.
Raja N Khoury, Collin County Community College (95-06-15-28)

MAA Poster Session

9:00 AM - 11:00 AM

Environmental mathematics.
Organizers: Ahalm Tannouri, Morgan State University
William D. Stone, New Mexico Institute of Mining and Technology
MAA Committee on Computers in Mathematics Education Panel Discussion
9:00 AM - 10:50 AM
Pedagogical use of computer algebra in mathematics teaching.
Organizers: Bert K. Waites, Ohio State University
V. S. Ramamurthi, University of North Florida
Panelists: John W. Kenelly, Clemson University
Jeanette R. Palmiter, Portland State University
Bernhard Kutzler, University of Linz, Austria
Wade Ellis, West Valley College
L. Carl Leinbach, Gettysburg College

MAA Panel Discussion
9:00 AM - 10:20 AM
Quantitative literacy: National questions and local solutions.
Organizer: Richard A. Gillman, Valparaiso University
Panelists: Steven F. Bauman, University of Wisconsin
Judith F. Moran, Trinity College
Linda R. Sons, Northern Illinois University
Lynn A. Steen, St. Olaf College
Janet E. Teeguarden, DePauw University

ASL Invited Address
9:30 AM - 9:55 AM
Symmetry and the Ramsey degree of finite relational structures.
Willem L. Fouche, University of Pretoria

Exhibits and Book Sale
9:30 AM - 5:30 PM

ASL Invited Address
9:30 AM - 9:55 AM
Title to be announced.
Zachary Robinson, East Carolina University

SIAM Invited Address
10:05 AM - 10:55 AM
Natural patterns.
Alan Newell, University of Warwick and University of Arizona (950-35-126)

ASL Invited Address
10:35 AM - 11:00 AM
Forced expansions.
Meir Buzaglo, Hebrew University of Jerusalem

AMS-MAA-SIAM Invited Address
11:10 AM - NOON
Stochastic differential equations in financial mathematics: From Black-Scholes to the present.
George C. Papanicolaou, Stanford University

Retirement Luncheon in honor of H. Hope Daly
NOON - 2:00 PM

AMS Colloquium Lecture: Lecture 3
1:00 PM - 2:00 PM
Riemann surfaces in dynamics, topology, and arithmetic, Part III.
Curtis T. McMullen, Harvard University

ASL Invited Address
1:00 PM - 1:45 PM
Title to be announced.
Timothy J. Carlson, Ohio State University

AMS-MAA Special Session on Innovative Development Programs for Teaching Assistants and Part-Time Instructors, II
1:00 PM - 4:55 PM
Organizers: Teri Jo Murphy, University of Oklahoma
Neil Calkin, Clemson University
Ethel Wheland, University of Akron
1:00 PM Shaping the Preparation of Future Mathematics Faculty. Preliminary report.
Solomon Friedberg, Boston College, and Lee L Zia*, University of New Hampshire (950-98-1131)
1:35 PM Case Studies for Mathematics Graduate Student Teaching Preparation and Development. Preliminary report.
James J Madden, Louisiana State University (950-00-408)
2:10 PM The LaCEPT model for instructional leadership. Preliminary report.
Lisa A. Mantini, Oklahoma State University (950-98-1184)
3:20 PM Two-Stage TA Training at Oklahoma State University: Combining a Mentorship with Academic Coursework. Preliminary report.
Elena A Marchisotto, California State University, Northridge. Preliminary report.
Jodie D Novak, University of Northern Colorado (950-98-171)
AMS-MAA Special Session on The History of Mathematics, II

1:00 PM - 2:50 PM
Organizers: Karen H. Parshall, University of Virginia
David E. Zitarelli, Temple University

1:00PM A Tenth-century Iranian Treatise on Problem-solving Methods in Geometry.
Jan P. Hogendijk, University of Utrecht (950-01-366)

Yibao Xu, Graduate Center of CUNY (950-01-1011)

2:00PM Four centuries of spherical trigonometry in Sanskrit. Preliminary report.
Kim Plofker, Brown University (950-01-955)

2:30PM Historical Reflections on the Role of Discovery
David L Roberts, Laurel, MD (950-01-490)

AMS-AWM-SIAM Special Session on Linear Algebra and Optimization, II

1:00 PM - 4:50 PM
Organizers: Dianne P. O'Leary, University of Maryland, College Park
Margaret H. Wright, Bell Laboratories

1:00PM Results on Iterative Regularization.
Misha E Klinzer, Tufts University, Medford, MA (950-65-1024)

1:40PM Approximating large systems by small systems:
Some theorems and some open questions.
Jane K Cullum, Los Alamos National Laboratory (950-15-881)

2:20PM The Unreasonable Effectiveness of the BICG Algorithm. Preliminary report.
Anne Greenbaum, University of Washington (950-65-730)

3:00PM How Non-Normality Can Affect the Solution of Linear Systems.
Ilse Ipsen, North Carolina State University (950-65-214)

3:40PM Structure preserving low rank approximation of linearly structured matrices.
Haesan Park*, Ben Rosen and Lei Zhang, Univ. of Minnesota (950-65-1149)

4:20PM Spectral Encounters of the Quaternion Kind.
Preliminary report.
Niloufer Mackey*, Western Michigan University, and D. Steven Mackey, Kalamazoo College (950-15-944)

AMS Special Session on The Feynman Integral and Applications, I

1:00 PM - 5:50 PM
Organizers: Gerald W. Johnson, University of Nebraska
Michel L. Lapidus, University of California, Riverside

1:00PM Feynman's Operational Calculus for Noncommuting Systems of Operators.
Brian Jefferyes, University of New South Wales, Kensington, Australia (950-47-647)

1:30PM Representation Space for the Feynman Operator
Calculus and Path-integral. Preliminary report.
Tepper L. Gill* and Woodford W. Zachary, Howard University (950-81-82)

2:00PM An Application of a Feynman Functional to the Global Positioning System.
Brian DeFacio* and Arjuna Flenner, University of Missouri-Columbia (950-85-455)

3:00PM Polylogarithms and Feynman path integrals. Preliminary report.
Pierre E Cartier, Ecole Normale Superieure de Paris and Institut des Hautes Etudes Scientifiques (950-81-378)

3:30PM Three approaches to the Feynman integral and their connection with the unitary group.
Gerald W. Johnson*, University of Nebraska - Lincoln, and Michel L. Lapidus, University of California, Riverside (950-81-291)

4:00PM What stochastic analysis can teach us about the geometry of quantum dynamics?
Jean-Claude Zambrini, University of Lisbon, Portugal (950-60-423)

4:30PM Metrical Quantization and Path Integrals with Continuity.
John R Klauder, University of Florida (950-81-406)

5:00PM Renormalization of Path Integrals and Absolute Continuity.
Sarada G Rajeev, University of Rochester (950-28-435)

5:30PM The Schroedinger and Black-Scholes equations: A common path integral approach using Henstock's non-absolute integration.
Patrick Muldowney, University of Ulster (950-28-627)

AMS Special Session on Algebraic Geometry and Commutative Algebra, I

1:00 PM - 6:00 PM
Organizers: Irena Peeva, Cornell University
Hema Srinivasan, University of Missouri, Columbia

1:00PM A Remark on Local Uniformization. Preliminary report.
Christel Rotthaus, Michigan State University (950-13-584)

1:30PM Liaison and Castelnuovo-Mumford regularity.
Marc F Chardin, CNRS and Universite Paris 6 (950-14-469)

2:00PM Cohomology of sheaves and free resolutions over exterior algebras. Preliminary report.
David Eisenbud, MSRI and UC Berkeley (950-14-155)

2:30PM Direct sums of modules over local rings. Preliminary report.
Roger A Wiegand, University of Nebraska (950-13-380)

3:00PM The LCM lattice.
Vesselin N. Gasharov*, Irena V. Peeva, Cornell University, and Volkmar Welker, Technische Universitat Berlin (950-13-1001)

3:30PM Break

4:00PM Induced Formal Deformations of Normal Local Domains.
Phillip A Griffith, University of Illinois (950-13-548)
AMS Special Session on Control Theory for Partial Differential Equations, I

1:00 PM – 5:50 PM

Organizer: Robert Triggiani, University of Virginia

1:00PM Feedback stabilization: Open loop and closed loop. (765) Preliminary report.

Thomas I Seidman, UMBC (950-93-705)

1:30PM Wave Motion in a Supported Elastic Beam. (766) Preliminary report.

David L Russell, Virginia Tech (950-35-877)

2:00PM Domain Decomposition in Optimal Boundary Control of the Maxwell System. (767) Preliminary report.

John E Lagnese, Georgetown University (950-93-1180)

2:30PM Unique continuation for solutions to systems of PDE. (768) Preliminary report.

Irena Lasiecka, University of Virginia (950-35-361)

3:00PM Shape sensitivity analysis for hyperbolic equations with Lipschitz-continuous domains. (769) Preliminary report.

Roberto Triggiani, University of Virginia (950-35-405)

3:30PM Break

4:00PM Decay rates in Interactive Hyperbolic-Parabolic PDE Models with Thermal Effects on the Interface. (770) Preliminary report.

Irena Lasiecka, University of Virginia (950-35-361)

4:30PM Continuous observability inequalities for hyperbolic equations with variable coefficients. (771) Preliminary report.

Roberto Triggiani, University of Virginia (950-35-405)

5:00PM Modelling and Control Problems for Thin Shells. (772) Preliminary report.

Pengfei Yao, Institute of Systems Science, The Chinese Academy of Science (950-35-648)

5:30PM Closed Range Weak or Mild Solution Operators and Nonconvex Optimal Control in terms of Generalized Gradients. (773) Preliminary report.

Nicola H Pavel, Ohio University (950-35-887)

AMS Special Session on Difference Equations and Their Applications in Social and Natural Sciences, I

1:00 PM – 5:50 PM

Organizers: Hassan Sedaghat, Virginia Commonwealth University

Abdul Aziz Yakubu, Howard University

Gerry Ladas, University of Rhode Island

Saber Elaydi, Trinity University

1:00PM Hamiltonian Systems on Time Scales. (774) Preliminary report.

Calvin D Ahlbrandt*, University of Missouri-Columbia, Martin Bohner, University of Missouri-Rolla, and Jerry Ridenhour, Utah State University (950-39-167)

1:30PM Riccati equation for a differential equation on a measure chain. Preliminary report. (775) Preliminary report.

Allan C Peterson, University of Nebraska-Lincoln (950-34-313)

2:00PM Asymptotic formula for solutions of asymptotically diagonal linear delay difference systems. (776) Preliminary report.

Shangbing Ai, University of Pittsburgh (950-39-523)
### MAA Minicourse #13: Part B

1:00 PM – 3:00 PM

Teaching contemporary statistics with active learning.

Organizers: Beth L. Chance, California Polytechnic State University
Robin H. Lock, St. Lawrence University
Mary R. Parker, Austin Community College
Allan J. Rossman, Dickinson College

### MAA Minicourse #2: Part B

1:00 PM – 3:00 PM

Projects in precalculus, calculus, and differential equations using biology and chemistry applications.

Organizers: Meghan A. Burke, Kennesaw State University
Sean F. Ellermeyer, Kennesaw State University

### MAA Minicourse #8: Part B

1:00 PM – 3:00 PM

Facilitating active learning: Concrete ways to foster student participation.

Organizer: Sandra L. Rhoades, San Diego State University

### AMS Session on Combinatorics, II

1:00 PM – 5:55 PM

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Speaker/University</th>
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<tbody>
<tr>
<td>1:00PM</td>
<td>The Lattice Polynomial of a Graph.</td>
<td>Jonathan J Wiens, University of Alaska Fairbanks</td>
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<td>1:15PM</td>
<td>The Mod Sum Number of the Wheel $W_n$.</td>
<td>Anna D Draganova, Pomona College, CA</td>
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<td>1:30PM</td>
<td>The Reversing Number of a Digraph.</td>
<td>Darren A. Narayan, Lehigh University</td>
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<td>1:45PM</td>
<td>Application of Upper and Lower Bounds for the Domination Number</td>
<td>W. Edwin Clark*, Mourad E. H. Ismail and Stephen Suen,</td>
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<td>to Vizing’s Conjecture.</td>
<td>University of South Florida</td>
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<td>2:00PM</td>
<td>Taut Distance-Regular Graphs.</td>
<td>Mark S MacLean, University of Wisconsin-Madison</td>
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<td>2:15PM</td>
<td>The Isoperimetric Constants of Certain Cayley Graphs Associated</td>
<td>Jason D. Rosenhouse, Dartmouth College</td>
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<td>with $PSL(2, Z_n)$.</td>
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<td>2:30PM</td>
<td>Minimum cardinality dominating sets of a tree: A linear programming</td>
<td>Teresa M Contenza, University of Kentucky</td>
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<td>3:00PM</td>
<td>The Role of Tangencies in Chain Explosions.</td>
<td>Kathleen Allgood, George Mason University</td>
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<td>3:15PM</td>
<td>Complete Automation of the Continuous Multi-WZ Method. Preliminary</td>
<td>Akalu Tefera, Temple University</td>
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<td>3:30PM</td>
<td>The Askey - Wilson operators and their inverses.</td>
<td>Sergei K Suslov, Arizona State University</td>
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<td>4:00PM</td>
<td>Boundedness of solutions of a nonlinear second order nonautonomous</td>
<td>Vladko L Kocic, Xavier University of Louisiana</td>
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<td>equation. Preliminary report.</td>
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<td>4:15PM</td>
<td>Reading Frame Invariant Cycles.</td>
<td>Kevin F McDougall, University of Wisconsin-Oshkosh</td>
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<td>4:45PM</td>
<td>A lattice path approach to counting partitions with minimum rank 1.</td>
<td>Dan B. Johnston, Washington University</td>
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<td>5:00PM</td>
<td>Embedding incomplete idempotent latin squares of order $n$ in</td>
<td>Atif A Abueida* and Chris A Rodger, Auburn University</td>
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<td>idempotent latin squares of order $2n$. Preliminary report.</td>
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<td>5:15PM</td>
<td>The Structure of Optimal Colorings for Rado Numbers. Preliminary</td>
<td>Daniel Schaal*, South Dakota State University, and</td>
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<td>report.</td>
<td>Adam Roesch, Augsburg College</td>
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<td>5:30PM</td>
<td>Improvements of Some Results on Cyclable Graphs. Preliminary report.</td>
<td>Irina Goia, MIT</td>
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<td>5:45PM</td>
<td>Rado Numbers for Some Nonhomogeneous Equations.</td>
<td>Kate Randall, St. Norbert College</td>
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</table>
AMS Session on Number Theory, II

1:00 PM - 4:55 PM

1:00PM | On the reductive dual pair (U(1),U(2)). Preliminary report. (804) Manouchehr Misaghi, The University of Iowa, Iowa City, IA (950-11-560)

1:15PM | Explicit families of elliptic curves with prescribed mod 6 representations. Preliminary report. (805) Joel P Roberts, Bowdoin College (950-11-565)

1:30PM | Universal Higher Order Bernoulli Polynomials. Preliminary report. (806) Arnold M Adelberg, Grinnell College (950-11-576)

1:45PM | On the Digital Sum and Length of 2m. (807) Robert E Kennedy* and Curtis N Cooper, Central Missouri State University (950-11-781)

2:00PM | Finding Moments of the Large Digit Function Using Delange's Method. (808) Curtis N Cooper* and Robert E Kennedy, Central Missouri State University (950-11-784)

2:15PM | Decompositions of a Class of Matrices Involving Generalized Geometric Progressions. Preliminary report. (809) Johann K Leida* and Peter Yang, University of St. Thomas (950-11-798)

2:30PM | Power bases for cyclotomic fields of conductor 2m. (810) Preliminary report.

2:45PM | On Optimal Subset Representations of Integer Sets. (811) Michael L Develin, Harvard University (950-11-869)

3:00PM | Fractal dimension of generalized binomial coefficients modulo a prime. Preliminary report. (812) John M Holtz, Gustavus Adolphus College (950-11-950)

3:15PM | Sums of powers of integers using L'Hospital's Rule. Preliminary report. (813) Carl A Libis, Antioch College (950-11-993)

3:30PM | Class numbers of cyclotomic function fields. (814) Joseph Palen, University of Michigan (950-11-1088)


4:00PM | Systems of Diagonal Equations over p-adic Fields. (816) Michael P Knapp, University of Michigan (950-11-1227)

4:15PM | An arithmetic property of certain rational powers. Preliminary report. (817) Gerry Myerson, Centre for Number Theory Research (950-11-1245)

4:30PM | Heisenberg graphs over the ring of integers modulo 2r. Preliminary report. (818) Danny Arrigo*, University of Central Arkansas, and West Vayo, University of Toledo (950-35-43)

4:45PM | Classification of Greedy Subset-Sum-Distinct Sequences. (819) Joshua S Von Korff, Harvard University (950-11-1296)

AMS Session on Partial Differential Equations

1:00 PM - 5:10 PM

1:00PM | A link between solutions of linear partial differential equations. (820) Danny Arrigo*, University of Central Arkansas, and West Vayo, University of Toledo (950-35-43)

1:15PM | Diffusion Tensor and Continuous Approach of Neural Networks In Image Restoration. Preliminary report. (821) Stacey E Chastain* and Yunnuel Chen, University of Florida (950-35-87)

1:30PM | Integral Properties for Solutions to the A-Harmonic Equation. Preliminary report. (822) Shusen Ding, Seattle University (950-35-549)

1:45PM | Existence, Regularity and Homogenization of Solutions to a Coupled Ginsburg Landau System for Layered Superconductors. Preliminary report. (823) Patricia Bauman and Yangsuk Ko*, Purdue University (950-35-270)

2:00PM | A geometric look at the volcano-shape of a functional for a family of elliptic PDEs. Preliminary report. (824) Joel W Fish, Northern Arizona University (950-35-310)

2:15PM | A New Model for Porosity Evolution in Chemical Vapor Infiltration. (825) Shi Jin and Xuelei Wang*, Georgia Institute of Technology (950-35-324)

2:30PM | Determination of conductivity in a heat equation. Preliminary report. (826) Ping Wang*, Penn State University, and Kewang Zheng, Hebei University of Science and Technology (950-35-346)

2:45PM | On Radiating Solutions to the Helmholtz Equation and Inverse Scattering. (827) Peter A. McCoy, U.S. Naval Academy (950-35-422)

3:00PM | Liouville Theorem for Generalized Harmonic Functions. (828) Alexander I Kheyfits, Bronx Community College of the City University of New York (950-31-306)

3:15PM | Nonlinear Degenerate Elliptic problems in Transonic Gas Dynamics. (829) Suncica Canic and Eun Heui Kim*, University of Houston (950-35-855)

3:30PM | Existence and Uniqueness Theorems for Singular Anisotropic Quasilinear Elliptic Boundary Value Problems. (830) S. Hill, Rowan University, Kristen S Moore*, University of Michigan, and W. Reichel, Universität Basel (950-35-967)

3:45PM | The inverse scattering problem for acoustic waves in unbounded inhomogeneous medium. (831) Andrzej W Kedzierawski, SUNY Geneseo (950-35-970)

4:00PM | The Perturbed Toda Lattice. (832) Russell L Herman, UNC Wilmington (950-35-1123)

4:15PM | A Remark on the Comparison Between the Spaces L1BV(R^n) and BV(R^n). Preliminary report. (833) Yudi Soeharyadi, The University of Memphis (950-35-1124)


5:00PM | Defect of Partially Invariant Solutions of Partial Differential Equations. (836) Terrance Quinn*, Texas A&M International University, Sanjay Rai, Jacksonville University, and C.C.A. Sastri, Dalhousie University (950-35-248)
AMS Session on Probability and Stochastic Processes

1:00 PM - 5:55 PM

1:00PM Random Sperner Systems. Preliminary report.  
Jayadev S. Athreya*, Iowa State University,  
Michelle Bylund, Brigham Young University,  
Anant P. Godbole, Michigan Technological University,  
and Jessica M. Maia, University of Washington (950-60-104)

1:15PM Stochastic Models for Seismic Records.  
Reza G Dargahi-Nobary, Bloomburg University (950-60-185)

1:30PM Change Points with Linear Trend for the Exponential Distribution.  
Asoka Ramanayake*, Univ of Wisconsin Oshkosh, and Arjun Gupta, Bowling Green State Univ (950-62-195)

1:45PM Asymptotics for Classical Proximity Graphs.  
Preliminary report.  
Daniel J Rose, Lehigh University (950-60-227)

2:00PM Some Properties of Brownian Motion via Wavelets.  
Preliminary report.  
Lisa E Marano* and Vladimir T Dobric, Lehigh University (950-60-285)

Joshua Levy, University of Central Oklahoma (950-60-486)

2:30PM Generalized Threshold Behavior for the Sidon Property.  
Lucas Fidkowski*, Harvard University, Anant Godbole, Michigan Technological University, Fumei Lam, Berkeley, and Donald Ying, Stanford (950-60-527)

2:45PM Stability in Distribution of Forward Stochastic Flows.  
Dan Kannan, University of Georgia, and Hong Zhang*, University of Wisconsin (950-60-550)

3:00PM Compositions of random Möbius transformations.  
Preliminary report.  
Satyajit Karmakar, Gordon College (950-60-588)

Lester N Coyle*, Loyola College in Maryland, and Anand N Vidyashankar, University of Georgia (950-60-739)

Michael G Monticino*, University of North Texas, and Theodore Hill, Georgia Institute of Technology (950-60-806)

Anita Balaji, Wellesley College, Erin Boyer, Bard College, Anant P. Godbole, Michigan Technological University, Fumei Lam, University of California, Berkeley, and Donald Ying*, Stanford University (950-60-873)

4:00PM Random Walk in an Alcove of an Affine Weyl Group.  
David J Grabiner, Bowling Green State University (950-60-950)

4:15PM On the minimum number of even submatrices of a random matrix. Preliminary report.  
Ashwani Sastry*, California Institute of Technology, and Anant P Godbole, Michigan Tech University (950-60-1032)

4:30PM On the Lower Bound of the Van der Waerden Numbers.  
Elm R Boyer*, Bard College, Anitashree Balaji, Wellesley College, Tze Yi Chan, Cambridge University, Tricia Frantti, Chassell, MI, and Anant P Godbole, Michigan Technological University (950-60-1052)

4:45PM General asymptotics of the density of a restricted coalescing random walk system.  
Elaine T McDonald, Sonoma State University (950-60-1076)

5:00PM Branching Processes in Varying Environment and a Carcinogenesis Model.  
Thomas W Polaski*, Winthrop University, and Julia Kimbell, Chemical Industry Institute of Toxicology (950-60-1153)

5:15PM Almost Sure Behavior of the Dominating Number of a Random Graph.  
Preliminary report.  
Michelle K Bylund*, Brigham Young University, Tricia Frantti, Chassell, MI, and Anant P Godbole, Michigan Technological University (950-60-467)

SIAM Minisymposium on Nonlinear Dynamics Theory for the Scientist

1:00 PM - 3:00 PM

Organizers: James A. Yorke, University of Maryland  
Kathleen T. Alligood, George Mason University

1:00PM Chaotic Piecewise-Linear Transformations.  
Lora Billings*, University of Delaware, and Erik Boltt, U.S. Naval Academy (950-37-764)

1:30PM Spurious Lyapunov Exponents Computed From Data.  
Joshua A Tempkin, Institute for Physical Science and Technology, University of Maryland (950-37-1187)

2:00PM Title: How basins of attraction evolve as a parameter is varied.  
James A. Yorke*, University of Maryland, and Helena E. Nusse, University of Groningen (950-37-1043)

2:30PM Projections, Embedding, and Fractal Dimensions.  
Brian R Hunt*, University of Maryland, and Vadim Yu Kaloshin, Princeton University (950-28-850)

MAA Session on Establishing and Maintaining Undergraduate Research Programs in Mathematics

1:00 PM - 3:20 PM

Organizers: Emelie Kenney, Siena College, Joseph A. Gallian, University of Minnesota-Duluth, Daniel J. Schaal, South Dakota State University

1:00PM The College of Wooster Applied Mathematics Research Experience.  
John R Ramsay, The College of Wooster (950-J1-1119)

Eric S Marland* and Carole Hom, University of California, Davis (950-J1-827)
Program of the Sessions - Washington, DC, Friday, January 21 (cont'd.)

2:00 PM  Undergraduate Research in Math and CS at the University of Richmond.  
Michael G Kerckhoff and James A Davis, University of Richmond VA 23173 (950-J-1485)

2:30 PM  Finding Funding for Undergraduate Research Programs.  
Daniel Schaal, South Dakota State University (950-J-1-403)

3:00 PM  The Grand Valley State University Summer Undergraduate Research Program.  
Edward F Aboufadel, Paul E Fishback and Steven J Schlicker, Grand Valley State University (950-J-1-382)

MAA Panel Discussion

1:00 PM - 2:20 PM  
Changing the academic culture.  
Moderator: David C. Arney, U.S. Military Academy  
Organizer: Donald B. Small, U.S. Military Academy  
Panelists: Laurette B. Foster, Prairie View A&M University  
John L. Scharf, Carroll College  
Robert W. Case, Northeastern University  
Maynard Thompson, Indiana University

MAA CUPM-CRAFTY Panel Discussion

1:00 PM - 2:30 PM  
Curricular reforms in client disciplines: Implications for post-calculus mathematics  
Moderators: David C. Lay, University of Maryland  
Sheldon P. Gordon  
Organizers: Sheldon P. Gordon, SUNY at Farmingdale  
David C. Lay, University of Maryland, College Park  
Panelists: Peter B. Henderson, SUNY at Stony Brook  
John Prados, University of Tennessee  
James Stith, American Institute of Physics  
Michael Ruane, Boston University

MAA Committee on the Mathematical Education of Teachers Poster Session

1:00 PM - 3:00 PM  
Innovations in mathematics programs which benefit future teachers.  
Organizer: Marjorie Enneking, Portland State University

MAA Committee on the Undergraduate Program in Mathematics Panel Discussion

1:00 PM - 2:20 PM  
Mathematics and mathematical sciences in 2010: What should graduates know?  
Moderator: D. J. Lewis, University of Michigan, Ann Arbor  
Organizer: Thomas R. Berger, Colby College  
Panelists: George W. Cobb, Mount Holyoke College

Joyce R. McLaughlin, Rensselaer Polytechnic Institute  
J. Douglas Faires, Youngstown State University

AMS Special Session on the History of Topology (in honor of Ralph Krause)

1:30 PM - 4:50 PM  
Organizer: Jack Morava, Johns Hopkins University  
1:30 PM  The evolution of mathematical logic in America.  
(866) Anil Nerode, Cornell University (950-03-1265)  
2:00 PM  Topology since 1962.  
(867) William Browder, Princeton University (950-57-1281)  
2:30 PM  The influence of algebraic geometry in stable homotopy theory. Preliminary report.  
Mark Mahowald, Northwestern University (950-01-804)  
3:00 PM  The development of cohomological physics.  
(869) Jim Stasheff, University of North Carolina at Chapel Hill (950-18-1287)  
3:30 PM  Non-commutative Topology.  
(870) Paul Baum, The Pennsylvania State University (950-01-1061)  
4:00 PM  Geometric topology in this half-century.  
(871) Robion C Kirby, University of California at Berkeley (950-57-974)  
4:30 PM  On the applications of topology.  
(872) Robert D MacPherson, Institute for Advanced Study (950-57-972)

ASL Invited Address

2:00 PM - 2:45 PM  
Saul A. Kripke, Princeton University

AMS-MAA Special Session on in Memory of Gian-Carlo Rota, IV

2:00 PM - 5:50 PM  
Organizers: Richard P. Stanley, MIT  
Rodica Simion, The George Washington University  
2:00 PM  Some Enumeration Problems Related to Counting Cache Misses.  
(874) Phil Hanlon, University of Michigan, Sid Chatterjee, University of North Carolina, Chapel Hill, Dean Chung, Amazon.com, and Alvy Lebeck, Duke University (950-05-1282)  
2:30 PM  Writing backwards: A little space can save a lot of time. Preliminary report.  
(875) Daniel E Loeb, Daniel H. Wagner Associates (950-05-335)  
3:00 PM  Generalized Rook Theory. Preliminary report.  
(876) Jay R Goldman, University of Minnesota, Minneapolis, and James Haglund, University of California at San Diego (950-05-446)  
3:30 PM  Quintic transformations generalizing the Rogers-Ramanujan identities.  
(877) Dennis Stanton, University of Minnesota (950-05-393)  
4:00 PM  Quasi-minuscule quotients and reduced words for reflections.  
(878) John R Stembridge, University of Michigan (950-05-594)
2:00 PM – 5:00 PM

AMS Special Session on Sixty Years of Mathematical Reviews

Organizer: Jane E. Kister, Mathematical Reviews

2:00 PM
Jane E Kister, Mathematical Reviews (950-00-853)

2:25 PM
The History of the First Sixty Years of Mathematical Reviews, a Magnificent Monument to Mathematical Research. Preliminary report.

V. Frederick Rickey, U. S. Military Academy (950-01-1218)

3:10 PM
The next 60 years of Mathematical Reviews. Preliminary report.

Andrew Odlyzko, AT&T Labs - Research (950-00-1022)

4:00 PM
Reception

AMS Special Session on Analytic Aspects of Jordan Theory, I

2:00 PM – 5:30 PM

Organizers: C. Martin Edwards, Oxford University

Kevin McCrimmon, University of Virginia

Bernard Russo, University of California, Irvine

Gotthard Rettigman, University of Bern

2:00 PM

Erhard Neher, University of Ottawa (950-17-1290)

3:00 PM
Jordan pairs and Hopf algebras. Preliminary report.

John R Faulkner, University of Virginia (950-17-488)

4:00 PM
All the moments and inverse moments of the Wishart distribution. Preliminary report.

Helene M Massam, University of Virginia (950-62-1292)

4:50 PM
Jordan tori. Preliminary report.

Yoji Yoshii, University of Ottawa (950-17-654)

AMS Special Session on Operator Theory, Systems Theory, and Interpolation in Several Complex Variables, I

2:00 PM – 5:50 PM

Organizers: Joseph A. Ball, Virginia Polytech Institute & State University

Cora S. Sadosky, Howard University

2:00 PM
Interpolating sequences on the bidisk. Preliminary report.

Jim Agler, U.C. San Diego, and John E McCarthy*, Washington University (950-46-927)

2:30 PM
Function theory on the polydisk, scattering systems with several evolutions and multidimensional linear systems.

Joseph A. Ball, Virginia Tech, Cora Sadosky*, Howard University, and Victor Vinnikov, Weizmann Institute (950-47-723)

3:00 PM
A New Application of Interpolation in Two Complex Variables to Control.

J W Helton, UCSD (950-47-439)

3:30 PM
Title: Interpolation and Computability.

James P Solazzo, Unlv. of Houston (950-47-452)

4:00 PM
Central Ifunitary Operators and Their Discriminant Curves.

Joseph A. Ball, Virginia Tech, and Victor Vinnikov*, Ben-Curion University of the Negev (950-47-456)

4:30 PM
Multivariable linear systems, scattering and operator models for row contractions. Preliminary report.

Joseph A. Ball, Virginia Tech, Blacksburg, Virginia (950-47-303)

5:00 PM
Isometric dilations of non-commuting n-tuples and representations of the Cuntz-Toeplitz algebra.

Kenneth R. Davidson*, David W. Kribs and Miron Shpigel, University of Waterloo (950-47-287)

5:30 PM
The curvature invariant of multivariable operator theory. Preliminary report.

William B Arveson, UC Berkeley (950-47-1116)

MMA Invited Address

2:15 PM – 3:05 PM

Prime numbers: What we still don't know.

Carl Pomerance, Bell Laboratories and Lucent Technologies

NAM’s Granville-Browne Session of Presentations by Recent Doctoral Recipients in the Mathematical Sciences

2:15 PM – 4:00 PM

Moderator: William A. Massey, Lucent Technologies

RMMC Board of Directors

2:15 PM – 4:15 PM

AMS Special session on Complex Hyperbolic Geometry and Conformal Geometry of the Heisenberg Group, I

2:30 PM – 5:20 PM

Organizers: William M. Goldman, University of Maryland

Hanna M. Sandler, American University

Richard Schwartz, University of Maryland

2:30 PM
Hyperbolic Surfaces via Loop Groups. Preliminary report.

Josef F. Dorfmeister and Magdalena D. Toda*, The University of Kansas (950-53-1191)

3:00 PM
Automorphic forms on the 4-ball and moduli of cubic surfaces.

Daniel J Allcock*, Harvard University, and Eberhard Freitag, University of Heidelberg (950-11-1030)

3:30 PM
Complex hyperbolic geometry and fundamental groups of some discriminant complements.

Daniel Allcock*, Harvard University, James A Carlson and Domingo Toledo*, University of Utah (950-14-1016)
4:00PM Nonarithmeticy of nonelementary groups in complex hyperbolic space.
   Inkang Kim, KAIST (950-51-651)

4:30PM On geometric finiteness of complete Kahler manifolds. Preliminary report.
   Mohan Ramachandran, SUNY at Buffalo (950-32-815)

5:00PM Existence of Riemann surface quotients.
   (903) Terrence Napier*, Lehigh University, and Mohan Ramachandran, SUNY at Buffalo (950-32-794)

MAA Session on Math and Math Sciences in 2010: What Should Graduates Know?, I
2:30 PM - 3:10 PM
   Organizers: Herbert E. Kasube, Bradley University
   Harriet Pollatsek, Mount Holyoke College

   2:30PM Introduction
   2:35PM What Did Graduates Know in 1910?: Patterns of Curricular Changes in Mathematics.
   Lawrence A D'Antonio, Ramapo College (950-L1-870)

   2:55PM A model that works but still needs fixing.
   (905) Peter G Hinman, University of Michigan (950-L1-1027)

AMS Committee on Science Policy Panel Discussion
2:30 PM - 4:00 PM

ASL Invited Address
3:00 PM - 3:45 PM
   (906) Complexity theoretic algebra and model theory. Jeffrey B. Remmel, University of California, San Diego

SIAM Minisymposium on Dispersive Waves and Stability
3:15 PM - 5:10 PM
   Organizer: Robert L. Pego, University of Maryland

   3:15PM Asymptotic and Modulational Stability of Patterns in the Optical Parametric Oscillator.
   Keith S Promislow*, Simon Fraser University, and J. Nathan Kutz, University of Washington (950-35-700)

   3:45PM Stability, and instability, of spiral waves.
   Bjorn Sandstede*, Ohio State University, and Arnd Scheel, FU Berlin (950-35-765)

   4:15PM Spatial wave dynamics and killer solitary waves. Preliminary report.
   Robert L Pego*, University of Maryland, and Mariana Haragus-Courcelle, Université de Bordeaux (950-76-682)

   4:45PM Convective Stability of Shock Profile Solutions of a Modified KdV-Burgers Equation.
   Jeff J Dodd, Jacksonville State University (950-35-204)

MAA Presentations by Teaching Award Recipients
3:30 PM - 5:00 PM

MAA Informal Session
5:00 PM - 7:00 PM
   Actuarial education.
   Organizer: James W. Daniel, University of Texas at Austin

MAA-ARUME Special Presentation
5:00 PM - 7:00 PM
   Research on undergraduate mathematics education.
   Organizer: Julie Clark, Emory and Henry College

MAA Panel Discussion
5:00 PM - 6:30 PM
   A guided tour of Project INTERMATH application projects.
   Organizer: David C. Arney, U.S. Military Academy

MAA Workshop
5:00 PM - 7:00 PM
   A workshop for teaching-assistant trainers.
   Organizer: Thomas W. Rishel, Cornell University

MAA-CUPM Poster Session
5:00 PM - 7:00 PM
   Undergraduate research student poster session.
   Organizer: Mario Martelli, CSU Fullerton

University of Illinois Gathering
5:00 PM - 7:00 PM

MAA Minicourse #3: Part B
6:00 PM - 8:00 PM
   The curves and surfaces of the digital age.
   Organizers: Colm K. Mulcahy, Spelman College
             Jeffrey A. Ehme, Spelman College

MAA Minicourse #9: Part B
6:00 PM - 8:00 PM
   Generating functions: Techniques and tricks.
   Organizer: Louis W. Shapiro, Howard University

MAA Committee on Mathematics and the Environment Dramatic Presentations
6:00 PM - 7:20 PM
   Unintended Consequences; The Adventures of Supermath; Hamlet, Prince of Modeling.
   Presenters: Ben Fusaro, Florida State University
             Barry Schiller, Rhode Island College
             Patricia C. Kenschaft, Montclair State University

NAM Reception
6:00 PM - 8:00 PM
Isololated Teachers of Statistics Annual Meeting
7:00 PM - 9:30 PM

MAA Student Lecture
7:30 PM - 8:20 PM
(911) Interactive geometry on the Internet.
Thomas F. Banchoff, Brown University

Saturday, January 22

Joint Meetings Registration
7:30 AM - 2:00 PM

AMS Special Session on Algebraic Geometry and Commutative Algebra, II
8:00 AM - 10:50 AM
Organizers: Irena Peeva, Cornell University
Hema Srinivasan, University of Missouri, Columbia

8:00 AM
Filtrations and Valuations. Preliminary report.
(912) Edward C Mosteig* and Moss E Sweedler, Cornell University (950-13-146)

8:30 AM
A Semiregularity Map and Applications to Deformations.
Ragnar O Buchweitz* and Hubert Flenner, Professor (950-14-872)

9:00 AM
Noetherian Hereditary Categories. Preliminary report.
Idun Reiten*, NTNU, and Michel Van den Bergh, Limburgs Universitair Centrum (950-13-772)

9:30 AM
Asymptotic Regularity.
(915) S. Dale Cutkosky, Univ. Missouri (950-13-379)

10:00 AM
Intersection Theorems for Modules and Complexes.
(916) Hans-Bjørn Foxby, University of Copenhagen (950-13-791)

10:30 AM
A generalized Krull height theorem, order ideals, and ideals of minors. Preliminary report.
David Eisenbud, MSRI, Craig Huneke, University of Kansas, and Bernd Ulrich*, Michigan State University (950-13-193)

AMS Special Session on Recent Advances in Complex and Harmonic Analysis, III
8:00 AM - 10:50 AM
Organizers: Carlos A. Berenstein, University of Maryland, College Park
Stephen D. Casey, American University
Bao Qin Li, Florida International University
David F. Walnut, George Mason University
C. C. Yang, Hong Kong University of Science and Technology

8:00 AM
The local Phragmen-Lindelof condition on varieties. Preliminary report.
(918) Rudiger W Braun, Heinrich-Heine Universität, Düsseldorf, Reinhold Meise, Heinrich-Heine Universität, Düsseldorf, and B. A Taylor*, University of Michigan (950-32-614)

8:30 AM
On Complex Hyperbolic Manifolds.
(919) Pit-Mann Wong, University of Notre Dame (950-32-614)

AMS Special Session on Modular Forms and Elliptic Curves, and Related Topics, I
8:00 AM - 10:50 AM
Organizers: Sharon Frechette, Wellesley College
Tamara Veenstra, University of Northern Iowa

8:00 AM
Elliptic curves and modular forms.
(924) Ken Ono, Penn State University and the University of Wisconsin, Madison (950-11-200)

8:30 AM
Traces of Division Polynomials.
(925) Antonio W. Bluher, National Security Agency (950-11-177)

9:30 AM
Selmer groups of quadratic twists of elliptic curves.
(926) Kevin James*, Penn State, and Ken Ono, Penn State University (950-11-150)

10:00 AM
Local zeta functions for elliptic curves. Preliminary report.
(927) Diane Meuser, Boston University, and Margaret Robinson*, Mount Holyoke College (950-11-792)

10:30 AM
The Degree of Modular Parametrization of Q-curves.
(928) Mark Douglas Morgan, Center for Computing Sciences (950-11-143)

AMS Special Session on Complex Hyperbolic Geometry and Conformal Geometry of the Heisenberg Group, II
8:00 AM - 10:20 AM
Organizers: William M. Goldman, University of Maryland
Hanna M. Sandler, American University
Richard Schwartz, University of Maryland

8:00 AM
Rigidity in complex hyperbolic and other symmetric rank one spaces.
(929) Boris Apanasov, University of Oklahoma (950-51-117)

8:30 AM
Generalized isometric spheres of elements of PU(1, n; C) and of rQ-curves.
(930) Shigeyasu Kamiya, Okayama University of Science (950-22-821)

9:00 AM
Geometry of hypersurfaces in quaternionic manifolds. Preliminary report.
(931) Yoshinobu Kamishima, Tokyo Metropolitan University (Tokyo, Japan) (950-51-659)

9:30 AM
The ends of hyperbolic 3-manifolds and 2-convexity. Preliminary report.
(932) Shihyoung Choi, Seoul National University (950-51-468)

10:00 AM
Curvature properties of positively curved Eschenburg spaces. Preliminary report.
(933) William C Dickinson, University of Pennsylvania (950-53-262)
AMS Special Session on Homotopy Theory, II
8:00 AM - 10:50 AM
Organizers: W. Stephen Wilson, Johns Hopkins University
Jack Morava, The Johns Hopkins University

8:00 AM
Topological gravity in dimensions two and four.
Preliminary report.
Jack Morava, The Johns Hopkins University (950-83-86)

8:30 AM
Compactified Spaces of Holomorphic Curves in Complex Grassmann Manifolds.
David E Hurutbise*, Penn State University, and Marc D. Sanders, Stanford University (950-55-116)

9:00 AM
Some applications of the stable homotopy Seiberg-Witten invariants to the connected sum of 4 manifolds. Preliminary report.
Mikio Furuta, RIMS, Kyoto University, Yukio Kametani, Keio University, and Norihiko Minami*, Nagoya Institute of Technology (950-55-1238)

9:30 AM
Po Hu, University of Chicago (950-55-400)

10:00 AM
Some Calculations Involving the Beta Genus of Spin Hypersurfaces. Preliminary report.
Jody L Fast, University of Kentucky (950-55-432)

10:30 AM
Equidistant Chern Character.
Paul Baum, The Pennsylvania State University (950-19-600)

AMS Special Session on Difference Equations and Their Applications in Social and Natural Sciences, II
8:00 AM - 10:50 AM
Organizers: Hassan Sedaghat, Virginia Commonwealth University
Abdul Aziz Yakubu, Howard University
Gerry Ladas, University of Rhode Island
Saber Elaydi, Trinity University

8:00 AM
Mary Ann Connors, United States Military Academy, West Point, NY (950-92-688)

8:30 AM
David M Chan*, NCSSM, and John E Franke, North Carolina State University (950-37-1221)

9:00 AM
Intraspecific competition in discrete-time patchy environments. Preliminary report.
Carlos Castillo-Chavez, Cornell University, and Abdul-Aziz Yakubu*, Howard University (950-92-2668)

9:30 AM
On a different model of disease transmission in homogeneous and uniformly mixed populations. Preliminary report.
Alma Virginia Lara Sagahon, FES-Cuautitlan, Universidad Nacional Autonoma de Mexico. (950-92-976)

10:00 AM
Pulse Vaccination in a Discrete Epidemic Model. Preliminary report.
Ronald E. Mickens, Clark Atlanta University (950-39-642)

10:30 AM
Data from HIV/AIDS Epidemic Modeled Using Difference Equations.
James A Yorke* and Frederick Suppe, University of Maryland (950-39-1063)

AMS Special Session on Research in Mathematics by Undergraduates, I
8:00 AM - 10:50 AM
Organizers: Darin R. Stephenson, Hope College
Leonard A. VanWyk, James Madison University

8:00 AM
Matings of the airplane with the 2/5 limb of the Mandelbrot set.
Scott O Wilson, Ithaca College (950-30-441)

8:30 AM
Rado Numbers.
Scott Jones*, University of Montana, Mary Joyce Plot, Western Carolina University, and Kate Rendall, St. Norbert College (950-05-407)

9:00 AM
Expected Areas of Randomly Generated Triangles.
Andrea Douglass*, Hope College, Courtney Fitzgerald, Niagara University, and Scott Mihalik, Hope College (950-60-799)

9:30 AM
Certain Classes of Type I Trees.
Lon H Mitchell* and Shivaram K Narayan, Central Michigan University (950-15-89)

10:00 AM
Semi-transitive Orientations of Circulant Graphs.
George L. Yuhash*, Virginia Tech, and Quinn B Saner, Boston University (950-05-1269)

10:30 AM
Perfect One Error Correcting Codes on Iterated Complete Graphs.
Be Birchall*, Reed College, and Jason Tedor, University of Alaska, Fairbanks (950-05-563)

AMS Special Session on Philosophies in Mathematics Education, I
8:00 AM - 10:55 AM
Organizer: Seymour Lipschutz, Temple University

8:00 AM
The TI-92 in the teaching of calculus.
Anthony M Gaglione, Naval Academy (950-98-622)

8:30 AM
Will this be on the exam?
William G McCallum, University of Arizona (950-98-428)

9:00 AM
Interweaving traditional calculus and technology.
Anthony Hughes, Temple University (950-98-447)

9:30 AM
A Cyber-TA named COW (Calculus on the Web).
Dan Reich, Temple University (950-98-424)

10:00 AM
Calculus in the next decade.
Daniel Reich*, Anthony Hughes*, Temple University, William McCallum*, University of Arizona, and Anthony M. Gaglione*, U.S. Naval Academy (950-98-484)

MAA Minicourse #10: Part B
8:00 AM - 10:00 AM
Interdisciplinary lively applications projects.
Organizers: Richard D. West, U. S. Military Academy
Laurette B. Foster, Prairie View & M University
Marie M. Vanisko, Carroll College

MAA Minicourse #15: Part B
8:00 AM - 10:00 AM
The Fibonacci and Catalan numbers.
Organizer: Ralph P. Grimaldi, Rose-Hulman Institute of Technology
MAA Minicourse #4: Part B

8:00 AM - 10:00 AM

Computer-based modeling with difference equations and matrices.
Organizers: Mazen Shahin, College Misericordia
Richard E. Bayne, Howard University

AMS Session on Combinatorics, III

8:00 AM - 10:55 AM

8:00 AM  Extremal Graphs with Independent Common Neighborhoods. Preliminary report.
Kenneth J. Roblee, Auburn University (950-05-1137)

8:15 AM  Zero Sum Ratio Numbers.
Mary Joyce Plott, Western Carolina University (950-05-1142)

8:30 AM  On the Crossing Number of Complete and Complete Bipartite Graphs. Preliminary report.
John F. Mackey, Dartmouth College (950-05-1164)

8:45 AM  The speed and size of graph properties.
David Weinreich*, Jozsef Balogh, The University of Memphis, and Bela Bollobas, The University of Memphis and Cambridge University (950-05-1095)

9:00 AM  Oscillation of the Speed of Hereditary Properties of Graphs.
Jozsef Balogh*, Bela Bollobas and David E. Weinreich, University of Memphis (950-05-1196)

9:15 AM  A Combinatorial Volume.
Susan L. Fooge, Eastern Kentucky University (950-05-1199)

9:30 AM  Orientations of Biased Graphs and Their Matroids.
Preliminary report.
Daniel C. Silliaty, Binghamton University (950-05-1217)

9:45 AM  Irreducible Triangulations of Pseudosurfaces.
Serge Lawrencenko* and Michael D. Plummer, Vanderbilt University (950-05-1239)

10:00 AM  Fair Division via a Generalized Tucker’s Lemma.
Francis Edward Su*, Harvey Mudd College and Cornell University, and Forest W. Simmons, Portland Community College (950-05-1252)

10:15 AM  The word posed and insertion-deletion codes.
Preliminary report.
Peter L. Erdos, A. Renyi Mathematics Institute, and David C. Torney*, Los Alamos National Lab (950-05-1275)

Fumio Lam*, U.C. Berkeley, and Donald Ying, Stanford (950-05-1276)

10:45 AM  The Minimum Forcing Number for the Torus and Hypercube.
Matthew E. Riddle, Carleton College (950-05-1295)

MAA Session on Looking to Our Future: Recruiting and Preparing the Next Generation of Mathematics Teachers, II

8:05 AM - 10:55 AM

Organizers: Jay A. Malmstrom, Oklahoma City Community College
Gary L. Britton, University of Wisconsin-Washington County
Marjorie Enneking, Portland State University
James Loats, Metropolitan State College of Denver
Mary Robinson, University of New Mexico

8:05 AM  Activity-based Mathematics Courses for Future K-8 Teachers at New Mexico State University.
Patrick Morandi* and Patricia M. Baggett, New Mexico State University (950-H1-1117)

Eric Muller*, Brock University, and Walter J. Whiteley, York University (950-H1-1021)

9:05 AM  Preparing Elementary Mathematics Specialists.
Judy S. O’Neal, North Georgia College & State University (950-H1-762)

9:35 AM  Accepting the challenge: K-8 teacher education mathematics majors.
Helen Gerretson, University of Northern Colorado (950-H1-309)

10:05 AM  A Seminar Exploring the Connections Between
Abstract Algebra and Secondary School Algebra for Pre-service Teachers. Preliminary report.
Dorothee J. Blum and Michael G. Wismer*, Millersville University (950-H1-888)

10:35 AM  Creating a stronger mathematics preparation for future elementary school teachers by working with College of Education faculty.
Sybilla Beckmann, University of Georgia (950-H1-1268)

AWM Workshop

8:20 AM - 4:10 PM

This session consists of several parts, including research talks by recent women Ph.D.s, posters by women graduate students, and a panel discussion.
Organizers: Gail Ragcliff, University of Missouri
Sue Geller, Texas A&M University
Catherine Roberts, Northern Arizona State University

AMS-MAA Special Session on The History of Mathematics, III

8:30 AM - 10:50 AM

Organizers: Karen H. Parshall, University of Virginia
David E. Zitarelli, Temple University

8:30 AM  Mathematics in Latvia through the centuries.
Daina Taimina* and Ingrida Henina, University of Latvia, Riga (950-01-263)

9:00 AM  Modular miracles.
John C. Stillwell, Monash University (950-01-134)

9:30 AM  Quadrilaterals from the Egyptians to Euler.
William W. Dunham, Muhlenberg College (950-01-26)

10:00 AM  Plagiarism and piracy: Isaac Todhunter and his mathematical textbooks.
June E. Barrow-Green, The Open University, Milton Keynes, UK (950-01-178)

10:30 AM  An Historical Lecture about Ramanujan Arranged in 3 Acts, an Interact, and an Exodion.
Bruce C. Berndt, University of Illinois at Urbana-Champaign (950-01-35)

AMS Special Session on Control Theory for Partial Differential Equations, II

8:30 AM - 10:50 AM

Organizer: Robert Triggiani, University of Virginia
AMS Special Session on Operator Theory, Systems Theory, and Interpolation in Several Complex Variables, II

8:30 AM - 10:50 AM

Organizers: Joseph A. Ball, Virginia Polytech Institute & State University
Cora S. Sadosky, Howard University

8:30 AM

Similarity Problems for Weighted Bargman Shifts.
Sarah H Ferguson*, Wayne State University, and
Srdjan Petrovic*, Western Michigan University

9:00 AM

Toeplitz Operators and Almost Periodic Factorization of Multivariable Matrix Functions.
Leiba Rodman*, Ilya M. Spitkovsky and Hugo Woerdeman*, College of William and Mary

9:30 AM

Spectral properties of Toeplitz operators with semi almost periodic symbols.
Albrecht Böttcher, TU Chemnitz, and
Sergei Grudskii, Rostov-on-Don State University, and
Ilya M Spitkovsky*, The College of William and Mary

10:00 AM

Positive Extensions and Riesz-Fejer Factorization for Two-Variable Trigonometric Polynomials.
Jeffrey S Geronimo, Georgia Institute of Technology, and Hugo J Woerdeman*, The College of William and Mary

10:30 AM

Higher order Hilbert-Schmidt Hankel forms and tensors of analytic kernels.
Sarah H. Ferguson*, Wayne State University, and
Richard Rochberg, Washington University at St. Louis

AMS Session on Field Theory

8:30 AM - 9:40 AM

8:30 AM

Quadratic Descent for Quaternion Algebras.
John R Swallow, Davidson College

8:45 AM

Generic Galois Extensions of Order p^3.
Meredith P Blue, University of Texas at Austin

9:00 AM

Rationality of certain linear automorphisms on rational function fields.
Mowaffaq A Hajja*, American University of Sharjah, Hamza Ahmad, Armstrong Atlantic State University, and Ming-chang Kang, National Taiwan University

9:15 AM

A generic Picard-Vessiot extension for GL_n and the inverse differential Galois problem.
Lourdes Juan, University of Oklahoma

9:30 AM

Relative Negligibility and Linear Automorphisms of Rational Function Fields.
Hamza Ahmad*, Lincoln University, Mowaffaq Hajja, The American University at Sharja, and Ming-chang Kang, National Taiwan University

AMS Session on Topological Groups

8:30 AM - 9:40 AM

8:30 AM

Pure and topologically pure bounded subgroups of LCA groups.
Peter Loth, Sacred Heart University

8:45 AM

The Existence of Disjoint Smallest Ideals in the Two-Sidedened Products on βS.
Shea D. Burns, Howard University

9:00 AM

Stone-Čech Compactification on Convergence Semigroups Defined by Nets.
Shing S So, Central Missouri State University

9:15 AM

The smallest ideal of (β(ω × ω), +). Preliminary report.
Gugu Moche, Howard University

9:30 AM

Piecewise syndeticity in a partial semigroup.
Jillian E. McLeod, Howard University

AWM Presentations by Recent Women Ph.D.s, I

8:30 AM - 10:20 AM

8:30 AM

Sub-Riemannian Geometry: The Martinet Case.
Monique Chyba, Princeton University

9:00 AM

Milnor’s Conjecture on Fundamentals Groups.
Christina Sormani, Lehman College, CUNY

9:30 AM

When is a noncompact manifold almost compact, an introduction to L^2-cohomology.
Eugenie Hunsicker, Lawrence University

10:00 AM

Polygonal knot theory and stuck unknots.
Heather Johnston, University of Massachusetts, Amherst

MAA Session on Innovations in the Use of Technology in Teaching Ordinary and Partial Differential Equations, II

8:45 AM - 10:45 AM

8:45 AM

Analytical and Numerical Solutions of PDEs Using CAS.
Dick Jardine, Keene State College

9:10 AM

Eigenfunction Visualizations For The H Atom.
Kelley B Mohrman and Joseph D Myers*, US Military Academy
9:35 AM

AMS Session on Numerical Analysis

9:00 AM - 10:55 AM

9:00 AM - 10:55 AM

Random Sampling from Low-Discrepancy Sequences. Preliminary report.
Giray Okten, Ball State University (950-65-130)

9:15 AM

Definite integrals of band-limited signals.
Yan Wu*, and Dale H Mugler, University of Akron (950-65-385)

9:30 AM

Convergence order and computational cost in solving nonlinear systems. Preliminary report.
Yixin Shi, Bloomsburg University of Pennsylvania (950-65-426)

9:45 AM

Multigrid Methods Using Wavelet Operators.
Doreen DeLeon, University of California, Los Angeles (950-65-833)

10:00 AM

A polynomial iterative method for certain asymmetric linear systems.
Katherine A Porter and James F Epperson*, University of Alabama in Huntsville (950-65-863)

10:15 AM

Modeling Non-Symmetric Josephson Junctions and Superconducting Weak Links.
Joan C Remski, University of Michigan-Dearborn (950-65-1067)

10:30 AM

A Version of Simpson's Rule for Multiple Integrals.
Alan L Horwitz, Penn State University (950-65-1071)

10:45 AM

Numerical Approximation of the Product of the Square Root of a Matrix with a Vector. Preliminary report.
James Baglama*, Ball State University, Edward J Allen and Sarah K Boyd, Texas Tech University (950-65-1148)

ASL Contributed Paper Session

9:00 AM - 9:50 AM

MAA-CRAFTY Panel Discussion

9:00 AM - 10:20 AM

Compromise and calculus reform: Calculus reform in the long run.
Panelists: Michael C. Reed, Duke University
William J. Davis, Ohio State University
Morton Brown, University of Michigan, Ann Arbor
Barbara A. Holland, John Wiley and Sons
Susan L. Ganter, Clemson University

MAA-CRUME Panel Discussion

9:00 AM - 10:20 AM

Improving mathematics education in the new century: Learning from the past, looking to the future.
Organizer: Joan Ferrini-Mundy, Michigan State University
Panelists: Carolyn A. Maher, Rutgers University
Judith Jacobs, California State Polytechnic University, Pomona
M. Kathleen Heid, The Pennsylvania State University
Program of the Sessions - Washington, DC, Saturday, January 22 (cont'd.)

NAM Panel Discussion
9:00 AM - 9:50 AM
Trends and assessments of minority students studying mathematics at the graduate level.

Mathematical Sciences Employment Center
9:00 AM - 2:00 PM
Interview Center open.

Exhibits and Book Sale
9:00 AM - NOON

NAM Business Meeting
10:00 AM - 10:50 AM

AMS Invited Address
10:05 AM - 10:55 AM
(1026) Dynamics of quadratic polynomials.
Mikhail Lyubich, State University of New York at Stony Brook (950-58-08)

ASL Invited Address
10:05 AM - 10:30 AM
(1027) Automorphisms and noninvariant properties of the computably enumerable sets.
Kevin Wald, University of Connecticut

AWM Graduate Student Poster Session
10:30 AM - 11:00 AM
10:30 AM Light refreshments will be served.
Irina A. Berchenko, University of Minnesota
(1029) High-Order Finite Difference Methods for Wave Equations.
Michelle L. Ghrist, University of Colorado
(1030) Definability of coefficients in solutions of linear systems over p-adic power series rings.
Concetta Maria Gomez, University of California, Berkeley
(1031) Combinatorics of the Toric Hilbert Schemes.
Diane Maclagan, University of California, Berkeley
(1032) Contact Processes on Trees in Random Environment.
Gana Mocioală, University of Florida
(1033) Continuous Methods for Solving Nonlinear Ill-Posed Operator Equations with Application to Gravitational Sounding Problem.
Alexandra Smirnova, Kansas State University
(1034) An Intersection Multiplicity in Terms of Ext-modules.
C-Y. Jean Chan, University of Utah
(1035) Existence of Rainbow Ramsey Numbers.
Linda Eroh, Western Michigan University
(1036) Normal Ideals of Graded Rings.
Sara Faridi, University of Michigan
(1037) Square Trees.
Susan Hollingsworth, University of Wisconsin, Madison
(1038) Formal Patching and Deformation of Wildly Ramified Covers of Curves.
Rachel J. Pries, University of Pennsylvania

AMS-MAA Special Session on The History of Mathematics, IV
1:00 PM - 4:30 PM
Organizers: Karen H. Parshall, University of Virginia
David E. Zitarelli, Temple University
1:00 PM From group representations to simple algebras:
Charles W. Curtis, University of Oregon (950-01-449)
1:30 PM Connections, Context, and Community: Abraham Wald and the Sequential Probability Ratio Test.
Patti W Hunter, Naperville, IL (950-01-649)

AMS Business Meeting
11:45 AM - 12:15 PM

AWM Panel Discussion
12:30 PM - 2:00 PM
Launching a career in mathematics.
Moderator: Sue Geller, Texas A&M University
Panelists: L. Pam Cook, University of Delaware
Helen G. Grundman, Bryn Mawr College
Jennifer L. McGreevey, Department of Defense
Jodie Novak, University of Northern Colorado

NAM William W.S. Claytor Lecture
1:00 PM - 2:00 PM
Notes on quantum electrodynamics on a negatively curved surface and the Selberg-Maass trace formula.
Floyd Williams, University of Massachusetts, Amherst

AMS Business Meeting
11:10 AM - 11:40 AM

MAA Business Meeting
11:45 AM - 12:15 PM

ASL Invited Address
10:45 AM - 11:10 AM
(1044) Title to be announced.
James Cummings, Carnegie Mellon University

NOTICES OF THE AMS VOLUME 47, NUMBER 1
### AMS Special Session on The Feynman Integral and Applications, III

1:00 PM - 4:50 PM

**Organizers:**
- Gerald W. Johnson, University of Nebraska
- Michel L. Lapidus, University of California, Riverside
- Anne Boutet de Monvel, Université Paris 7

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<td>Infinite dimensional oscillatory integrals: Their asymptotics and some applications</td>
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<td>Feynman type integral representation for propagators of self-interacting quantum fields in even spacetime dimensions</td>
<td>Alexander Dynkin, Ohio State University</td>
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<td>Traces: A useful tool on path spaces</td>
<td>Sylvie Paycha, Université Blaise Pascal</td>
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<td>David L. Skoug, University of Nebraska-Lincoln</td>
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<td>Integration Formulas Involving Fourier-Feynman Transforms via a Fubini Theorem</td>
<td>Timothy K. Huffman, Northwestern College (IA), M.K. Im, Han Nam University, David L. Skoug, University of Nebraska, and David A. Storvick, University of Minnesota</td>
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<td>3:30 PM</td>
<td>Integral transform and convolution of analytic functions on abstract Wiener space</td>
<td>Kun-S Chang*, Yonsei University, Seoul, Korea, Il Yoo, Yonsei University, Wonju, Korea, and Byoung S. Kim, Yonsei University, Seoul, Korea</td>
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<td>4:00 PM</td>
<td>Path distributions: Preliminary report</td>
<td>Erik G.F. Thomas, University of Groningen</td>
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<td>A Paley-Wiener Theorem for White Noise Analysis</td>
<td>Aurel I Stan, Northwestern University</td>
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### AMS Special Session on Recent Advances in Complex and Harmonic Analysis, IV

1:00 PM - 4:50 PM

**Organizers:**
- Carlos A. Berenstein, University of Maryland, College Park
- Stephen D. Casey, American University
- Bao Qin Li, Florida International University
- David F. Walnut, George Mason University
- C. C. Yang, Hong Kong University of Science and Technology

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<td>1:00 PM</td>
<td>On Fractional Calculus on Spaces of Homogeneous Type Lp-theory</td>
<td>Eduard A. Gatto* and Stephen Vagi, DePaul University (950-44-1039)</td>
</tr>
<tr>
<td>1:30 PM</td>
<td>Sampling in Multiresolution Spaces</td>
<td>Joseph D Lakey*, New Mexico State University, and Jeff Hogan, Macquarie University (950-42-639)</td>
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<tr>
<td>2:00 PM</td>
<td>Results in Sampling and Deconvolution</td>
<td>David F. Walnut, George Mason University (950-42-902)</td>
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<td>2:30 PM</td>
<td>Composition of pseudodifferential operators</td>
<td>Demetrio Labate, GeorgeTech (950-42-1207)</td>
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<tr>
<td>3:00 PM</td>
<td>Multivariate Refinable Interpolating Functions</td>
<td>Josip Derado, SAAC-Georgia Institute of Technology (950-41-1080)</td>
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<tr>
<td>3:30 PM</td>
<td>Bellman functions and Harmonic Analysis</td>
<td>Janine Wittwer, University of Chicago (950-42-304)</td>
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<tr>
<td>4:00 PM</td>
<td>Remarks on the local integrability of iterated maximal functions</td>
<td>Paul A. Hagelstein, University of Chicago (950-42-308)</td>
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<td>4:30 PM</td>
<td>Analytic Bezaux Equations, Sampling, and the Strongly Coprime Condition</td>
<td>Stephen D. Casey, American University (950-41-966)</td>
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### AMS Special Session on Algebraic Geometry and Commutative Algebra, III

1:00 PM - 5:00 PM

**Organizers:**
- Irena Peeva, Cornell University
- Hema Srinivasan, University of Missouri, Columbia

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<td>Resolution of Weyl Modules: The Rota Touch</td>
<td>David A Buchsbaum, Brandeis University</td>
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**Washington, DC, Saturday, January 22 - Program of the Sessions**

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1:00 PM - 4:50 PM

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- Michel L. Lapidus, University of California, Riverside
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AMS Special Session on Modular Forms and Elliptic Curves, and Related Topics, II

1:00 PM - 4:50 PM

Organizers: Sharon Frechette, Wellesley College
Tamara Veenstra, University of Northern Iowa

1:00PM Elliptic Curve Cryptography with Maple.
(1078) Neil P Sigmon, Chowan College (950-20-894)

1:30PM Ramanujan Type Buildings.
(1079) Cristina M Ballantine, Bowdoin College (950-11-391)

2:00PM Hecke Operators and Buildings. Preliminary report.
(1080) Thomas R Shemanske, Dartmouth College (950-11-148)

2:30PM Hecke Structure of Spaces of Half Integral Weight Cusp Forms: Decomposition Theorems and Applications.
(1081) Sharon M Frechette, Wellesley College (950-11-964)

3:00PM Theta Series over Function Fields. Preliminary report.
(1082) Holly J Rosson, Dartmouth College (950-11-417)

3:30PM Eisenstein Series, Dedekind symbols, and p-adic L-functions.
(1083) Duff G Campbell, United States Military Academy (950-11-118)

4:00PM Computational Advances in the Classification of Hilbert Modular Threefolds. Preliminary report.
(1084) Helen G. Grundman* and Lisa E. Lippincott, Bryn Mawr College (950-11-552)

4:30PM Modular forms of nonreal weight.
(1085) Paul C Pasles, Villanova University (950-11-97)

AMS Special Session on Operator Theory, Systems Theory, and Interpolation in Several Complex Variables, III

1:00 PM - 4:50 PM

Organizers: Joseph A. Ball, Virginia Polytechnic Institute & State University
Cora S. Sadosky, Howard University

1:00PM Some new results in the similarity problem.
(1086) Sergei Treil, Michigan State University (950-47-463)

1:30PM Interpolation on an Anulus.
(1087) Scott A McCullough, University of Florida (950-47-786)

2:00PM A counterexample to the infinite-dimensional version of the matrix Hunt-Muckenhoupt-Wheeden Theorem: Operator BMO and factorizations of H^1 log H^1(c^1).
(1088) Thomas Alastair Gillespie, University of Edinburgh, Fedor Nazarov, Michigan State University, Sandra Petrov*, University of Edinburgh, Sergei Treil and Alexander Volberg, Michigan State University (950-47-652)

2:30PM Hilbert spaces contractively included in the Hardy space of the bidisk.
(1089) Daniel D Alpay*, Ben-Gurion University, Vladimir Bolotnikov, College of William and Mary, Aad Dijksma, Groningen University, and Cora Sadosky, Howard University (950-46-281)

3:00PM Preliminary report.
(1090) Tavan T Trent, University of Alabama (950-47-779)

3:30PM On an Extension Problem for Polynomials.
(1091) Mihaly Bakonyi*, Georgia State University, and Dan Timotin, Institute of Mathematics of the Romanian Academy (950-47-968)

AMS Special Session on Difference Equations and Their Applications in Social and Natural Sciences, III

1:00 PM - 4:50 PM

Organizers: Hassan Sedaghat, Virginia Commonwealth University
Abdul Aziz Yakubu, Howard University
Gerry Ladas, University of Rhode Island
Saber Elaydi, Trinity University

1:00PM Existence and Behavior of Solutions of a Rational System Part I.
(1102) Edward A Grove, Gerasimos Ladas, Lynn C McGrath and Christopher T Teixeira*, University of Rhode Island (950-39-135)

1:30PM On the Recursive Sequence x(n+1) = (a + bx(n)) / (A + Bx(n) + Cx(n-1)). Preliminary report.
(1103) M. R. S. Kulenovic*, G. Ladas and N. R Prokup, University of Rhode Island (950-39-34)

2:00PM On a Rational Recursive Sequence with Even Delays.
(1104) Edward A Grove*, Gerasimos Ladas and Hamdi El-Mitwalli, University of Rhode Island (950-39-109)
2:30PM  Eventually Periodic Solutions of $x_{n+1} = \max \{A[n]/x[n], 1/x[n-1] \}$. Preliminary report.
   William J. Breiden, Edward A. Grove, Gerry Ladas, University of Rhode Island, and Candace M Kent*, Virginia Commonwealth Univ. (950-99-261)

3:00PM  On a nonautonomous max equation. Preliminary report.
   Soudabeh Valicenti*, University of Rhode Island, Jeff Steur, St. Michael's College, Gerry Ladas and Kim Cunningham, University of Rhode Island (950-39-261)

3:30PM  On the difference equation $x_{n+1} = \max \{A[n]/x[n], 1/x[n-1] \}$ with a period 3 parameter.

4:00PM  Continued fractions expansions of rotation numbers for plane maps.
   Timothy D. Sauer, George Mason University (950-39-108)

4:30PM  Analysis of a Two-Age Climax Species Population Model. Preliminary report.
   Shurron M. Farmer, Howard University (950-39-62)

AMS Special Session on Research in Mathematics by Undergraduates, II

1:00PM - 4:50PM

Organizers: Darin R. Stephenson, Hope College
   Leonard A. VanWyk, James Madison University

1:00PM  Igusa Local Zeta Functions for Elliptic Curves.
   Preliminary report.
   Mariana E. Campbell*, University of California, San Diego, Michael Joyce, Tulane University, Anushka Krishnanachandar, Amherst College, and Kimberly Schneider, Bowdoin College (950-11-191)

1:30PM  Modeling Turbulence on a Torus.
   Emily C. Clark, Clark University, Worcester MA, Lubomira Ivanova, Mount Holyoke College, South Hadley MA, Aaron Koll, UC Berkeley, Berkeley CA, Jenniffer Ross, Wellesley College, Wellesley MA, Yanir A. Rubinstein*, Technion, Haifa, Israel, and Mark A. Peterson, Mount Holyoke College, South Hadley MA (950-76-600)

2:00PM  Songs of Splitting and Systoles: An Odyssey of Triangular Tiling Groups. Preliminary report.
   Jason DeBlois*, University of Chicago, Lisa J. Powell, Harvard University, Nicholas R. Baeth, Pacific Lutheran University, and Kevin M. Woods, Wake Forest University (950-20-1174)

2:30PM  Alternating Knots on Surfaces. Preliminary report.
   Tom R. Fleming*, Williams College, Michael Levin, Harvard University, and Ari Turner, Princeton University (950-57-508)

3:00PM  Close Encounters with Curves of the Spherical Kind.
   Preliminary report.
   Michael R. Munn, University of Notre Dame (950-53-632)

3:30PM  Explicit Representation Theory of the Quantum Weyl Algebra at Roots of 1.
   J. Boyette, M. Leyk, Texas A&M University, T. Plunkett*, University of Illinois at Urbana-Champaign, K. Sipe, Houston, TX, and J. Talley, Texas A&M University (950-16-554)

4:00PM  The Search For Tri-Operate Fields.
   Preliminary report.
   T. White, James Madison University (950-12-667)

4:30PM  Characterization of Completions of Reduced Noetherian Local Rings.

AMS Special Session on Philosophies in Mathematics Education, II

1:00PM - 4:00PM

Organizer: Seymour Lipschutz, Temple University

1:00PM  How Set Theoretic Thinking Affects Teaching.
   Harold M. Edwards, New York Univ. (950-98-431)

1:30PM  Following Descartes' advice and teaching to the gut.
   J. J. Uhl, Univ of Illinois at Urbana-Champaign (950-98-685)

2:00PM  On teaching linear algebra.
   James Milgram, Stanford (950-98-433)

2:30PM  An abstract framework in teaching linear algebra.
   Seymour Lipschutz, Temple University (950-98-427)

3:00PM  Linear algebra in the new decade.
   Seymour Lipschutz*, Temple University, Harold M. Edwards*, NYU/Courant, James Milgram*, Stanford University, and J. J. Uhl*, University of Illinois at Urbana-Champaign (950-98-487)

MAA Minicourse #11: Part B

1:00PM - 3:00PM

Discrete dynamical systems: Mathematics, methods, and models.

Organizers: David C. Arney, U. S. Military Academy
   John S. Robertson, Georgia College and State University

MAA Minicourse #14: Part B

1:00PM - 3:00PM

Modern physics and the mathematical world.

Organizer: George DeRise, Thomas Nelson College

MAA Minicourse #5: Part B

1:00PM - 3:00PM

Exploring abstract algebra topics through interactive labs.

Organizers: Allen C. Hibbard, Central College
   Kenneth M. Levasseur, University of Massachusetts at Lowell

AMS Session on Statistics

1:00PM - 2:40PM

Comparison of operating characteristics of quality control plans.

Raymond N Greenwell*, Hofstra University, Stephen J Finch, State University of New York at Stony Brook, John Whitbread, Cytometrix International, and Ann Tucker, State University of New York at Stony Brook (950-62-231)

1:15PM  Distribution functions of copulas: A class of bivariate probability integral transforms.
   Roger B Nelsen*, Lewis & Clark College, Juan Quesada-Molina, Universidad de Cranada, José Antonio Rodriguez-Lallena and Manuel Úbeda-Flores, Universidad de Almeria (950-62-237)
1:30 PM  Estimating a transformation of the data in nonparametric regression. Preliminary report.  
William J Hooper, SUNY Binghamton (950-62-612)  
1:45 PM  A random effects model for multivariate survival analysis with applications to bone marrow transplants. Preliminary report.  
Mouchni Bhattacharya, Brigham Young University (950-62-657)  
2:00 PM  The limiting power of the Durbin-Watson test. Preliminary report.  
Jörg-Uwe Löbus* and Lutz Ritter, University of Jena (950-62-669)  
Benjamin Stein*, Joseph Horowitz and Donald Geman, University of Massachusetts at Amherst (950-62-948)  
William C Calhoun, Bloomsburg University (950-62-1087)  

AMS Session on Mathematics Education and History  
1:00 PM - 4:40 PM  
1:00 PM  The Texas/Moore Method and the NCTM Standards.  
William Donnell* and D. R Traylor, University of the Incarnate Word (950-97-84)  
1:15 PM  Transcendental Mediation: A Practical Method for Improving the Mathematical Achievement of Students.  
Catherine A Gorini, Maharishi University of Management (950-97-173)  
1:30 PM  Public Contests and Publications in an Algebra Enrichment Course for Teachers. Preliminary report.  
Matthew J Haines, New Jersey City University (950-01-948)  
1:45 PM  Historical and Classroom Snapshots: Adding Natural Color to the Black-and-White of Mathematical Representation.  
Marshall Gordon, The Park School (950-01-849)  
2:00 PM  Genesis of Universal Forms: The Four-Square Theorem and its Generalizations.  
Mark B Beintema*, University of Wisconsin-Fox Valley, and Azar N Khorasovani, University of Wisconsin-Oshkosh (950-01-1114)  
2:15 PM  Mystery surrounding the mathematical genius. Preliminary report.  
Baikunth P Ambasht*, Bokaro Steel City, India, Jamuna P Ambasht, Benedict College, and Sanjay Tiwari, Gaya, India (950-00-625)  
2:30 PM  Teaching Geometry On-line. Preliminary report.  
David A. Thomas, Montana State University (950-98-24)  
2:45 PM  Extension of Mathematics Education Reform to the University Level.  
D. R. Traylor*, University of the Incarnate Word, and Ellen Szecsy, Northeast ISD (950-98-80)  
3:00 PM  Cubic Equations Simply—Without Memorizing Long Formulas—Plus its Numerous Applications.  
Roberto Kreczner, University of Wisconsin (950-98-192)  
3:15 PM  Teaching Liberal Arts Mathematics Courses with an Interdisciplinary Paper/Project Requirement.  
Ann Robertson, Connecticut College (950-98-991)  
3:30 PM  Awakening Students with Java and Number Theory.  
John W Jones*, Arizona State University, and Jeffrey J Holt, University of Virginia (950-98-1093)  
3:45 PM  The ubiquitous geometric series.  
Rachelle C. Roper* and Joseph Wiener, University of Texas-Pan American (950-98-1185)  
4:00 PM  The role of physical models in teaching hyperbolic geometry.  
Dana Taimina*, University of Latvia, and David W Henderson, Cornell University (950-98-1228)  
4:15 PM  ‘SAAb’ Congruence, the Steiner-Lehmus Theorem, and Generalization(?). Preliminary report.  
David F Beran, Univ of Wisconsin-Superior (950-51-323)  
4:30 PM  Inscribed Circles.  
(1144) Saad M. Adnan, Larkspur Middle School (950-51-1284)  

AMS Session on Real Variables and Topological Groups  
1:00 PM - 3:40 PM  
1:00 PM  Linear Operations on $L^p$-spaces. Preliminary report.  
Nicole Dinculeanu, University of Florida (950-28-212)  
Shusen Ding, U. of Seattle, and Bing Liu*, College of St. Scholastica (950-28-719)  
1:30 PM  Fractal vector measures and Green’s Theorem for curves.  
Franklin Mendivil*, Georgia Tech, and Ed Vrscay, Applied Math, University of Waterloo (950-28-925)  
1:45 PM  On characterizations properties of an induced measure on a Wallman space. Preliminary report.  
Carmen D. Vladi, Pace University (950-28-1108)  
2:00 PM  General Weighted Optial Inequalities for Linear Differential Operators.  
George A. Anastassiou*, University of Memphis, and J. Pecaric, University of Zagreb (950-26-25)  
2:15 PM  Extensions of Grüss’ Inequality.  
Arlington M. Fink, Iowa State University (950-26-142)  
Nasser Dastrange, Buena Vista University (950-26-184)  
Andrzej A Szymanski, Slippery Rock University (950-26-807)  
3:00 PM  Application of a Result of Davies and Peterson to Obtain some Discrete Inequalities.  
Ram N Mohapatra* and Ratan Guha, University of Central Florida (950-26-1028)  
Jeff Connor*, Ohio University, and Karl Große-Erdmann, FernUniv. (950-40-801)  
3:30 PM  Theory of hypernumbers and Feynman integrals. Preliminary report.  
Mark Burgin, University of California at Los Angeles (950-28-47)  

AMS Session on Associative Rings and Algebras  
1:00 PM - 4:10 PM  
1:00 PM  A note on surjective inverse systems.  
Radoslav M. Dimitric, University of California, at Berkeley (950-16-217)  
1:15 PM  Polycyclic group rings whose principal ideals are projective.  
Antonio F Bein, University of Wisconsin-Madison (950-16-223)
WASHINGTON, DC, SATURDAY, JANUARY 22 – PROGRAM OF THE SESSIONS

MAA Session on Math and Math Sciences in
1:00PM - 4:55PM

What Should Graduates Know?, II

1:00PM - 4:55PM

Organizers: Herbert E. Kasube, Bradley University
Harriet Pollatsek, Mount Holyoke College

A process for deciding what our graduates should know. Preliminary report.
Paul Latiola*, Joyce O’Halloran and Marjorie Enneking, Portland State University (950-L1-1274)

The role of geometry in the 21st century curriculum.
Libby Kursel, The University of Montana - Missoula (950-L1-1095)

Knowledge and Reasoning: What Is the Relation?
Gary W Krahn* and Steven B Horton, United States Military Academy (950-L1-1075)

Can We Teach What Employers Really Want?
G. Daniel Callon, Franklin College (950-L1-915)

Some musings from a guy who finally got a real job after 31 years in college.
Mark A Smith, Miami University (950-L1-817)

Break.

Preston Dinkins, Southern University (950-L1-1289)

Matthew P Richey, St. Olaf College (950-L1-1266)

Kevin E Charlwood, Washburn University (950-L1-331)

A Profile of Mathematics in Michigan.
Frances B Lichtman*, Alma College, Mitzi Chaffer and Tom Miles, Central Michigan University (950-L1-1002)

Recruiting Mathematics Majors from Remedial Courses?
Janet P Ray, Seattle Central Community College (950-L1-1146)

A Preview of a Mathematician’s Life - The Expectations, the Rewards, and the Challenges.
Teresa D Edwards, Spelman College (950-L1-1271)

MAA Session on Research on the Use of Hand-Held Technology in Teaching Mathematics

1:00PM - 4:15PM

Organizers: Deborah A. Crocker, Appalachian State University
Penelope Dunham, Muhlenberg College

A Large-scale Study Clarifying the Roles of the TI-92 and Instructional Format on Student Success in Calculus. Preliminary report.
Brian A. Keller*, Iowa State University, Chris A. Russell, Marshalltown Community College, and Heather A. Thompson, Iowa State University (950-N1-348)

Integrating the TI-89 Handheld CAS into the United States Military Academy Curriculum. Preliminary report.
Mary Ann Connors* and Kathleen G. Snook, United States Military Academy (950-N1-618)

Calculus Students Use of the Graphing Calculator.
Vincent E Dimicelli, Oral Roberts University (950-N1-942)

Michael J Bosse* and N. R Nandakumar, Delaware State University (950-N1-681)

Laptops in the Classroom.
James A Glackin* and Joseph D Myers, United States Military Academy (950-N1-415)

Preservice Middle School Mathematics Teacher’s Visual Interpretation of Functions: The Effects of a Technology-based Capstone Mathematics Course.
Brandy S Jumper*, James A Epperson and Gary A Harris, Texas Tech University (950-N1-587)

Mercedes A McGowen, William Rainey Harper College (950-N1-1253)

The handheld CAS in developmental algebra for college students.
Laurie B Hopkins* and Amelia S. Kinard, Columbia College (950-N1-847)

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Program of the Sessions – Washington, DC, Saturday, January 22 (cont’d.)

3:40 PM The effect of using graphing calculators on students’ understanding functions and attitudes towards mathematics & graphing calculators in Korean high school advanced algebra class. Oh-Nam Kwon* and Minkyeeong Kim, Ewha Womans University (950-N1-470)

4:00 PM Computer algebra systems in the secondary mathematics curriculum. Preliminary report. Todd Edwards, Ohio State University/Upper Arlington High School (950-N1-1257)

MAA Open Discussion
1:00 PM – 3:00 PM
College algebra reform.
Organizer: Donald B. Small, U.S. Military Academy

MAA Panel Discussion
1:00 PM – 2:20 PM
If “less is more” in the K-12 curriculum, then which “less” do we choose?
Organizer: Richard D. Anderson, Louisiana State University
Panelists: Andrew M. Gleason, Harvard University
Hyman Bass, Columbia University

MAA Special Presentation
1:00 PM – 2:20 PM
School mathematics CDs from Singapore.
Organizer: Richard A. Askey, University of Wisconsin, Madison

AMS-MAA-NCTM Panel Discussion
1:00 PM – 2:20 PM
Shaping the principles and standards for school mathematics: The role of Association Review Groups from the mathematics community.
Organizer: Joan Ferrini-Mundy, Michigan State University
Panelists: Mary M. Lindquist, Columbus State University
W. Gary Martin, NCTM
Kenneth A. Ross, University of Oregon
John C. Polking, Rice University

ASL Invited Address
1:20 PM – 1:45 PM
Four solutions in search of a problem.
J. Karel Lambert, University of California, Irvine

ASL Invited Address
2:00 PM – 2:45 PM
The logic of hyperimaginaries.
Bradd Hart, McMaster University

AMS-MAA Special Session on in Memory of Gian-Carlo Rota, VI
2:00 PM – 4:20 PM
Organizers: Richard P. Stanley, MIT

Rodica Simion, The George Washington University
2:00 PM The Whitney Algebra of a Matroid.
William R Schmitt*, University of Memphis, and Henry H Crapo, CAMS, Paris, France (950-05-1203)

2:30 PM Size Functions of Subgeometry-Closed Classes of Representable Combinatorial Geometries.
Joseph E Bonin* and Hongxun Qin, The George Washington University (950-05-68)

3:00 PM Heilny-type theorems for matroid flats.
Daniel A Klaw, Georgia Institute of Technology (950-05-434)

3:00 PM Geometric identities in Linear Lattices. Preliminary report.
Catherine H Yan, Texas A&M University (950-05-580)

4:00 PM The polymatroid critical problem. Preliminary report.
Joseph Kung, University of North Texas, Denton, TX 76203-1430 (950-05-152)

AMS Special Session on Analytic Aspects of Jordan Theory, II
2:00 PM – 4:50 PM
Organizers: C. Martin Edwards, Oxford University
Kevin McCrimmon, University of Virginia
Bernard Russo, University of California, Irvine
Gottfried Ruetimann, University of Bern

2:00 PM A new approach to representations of the Lorentz group on spinors.
Yaakov Friedman, Jerusalem College of Technology, and Bernard Russo*, University of California, Irvine (950-17-265)

3:00 PM JB*-triples with many dual ball extreme points.
L. J. Bunce, University of Reading (950-46-590)

3:40 PM On the Zelmanovian classification of prime JB*-triples.
Antonio Moreno Galindo* and Angel Rodriguez Palacios, Universidad de Granada (950-46-666)

4:20 PM Spectrum Preserving Maps on JB*-triples.
Preliminary report.
Matthew P Neal, University of California, Irvine (950-17-273)

AMS Special Session on Complex Hyperbolic Geometry and Conformal Geometry of the Heisenberg Group, III
2:00 PM – 3:50 PM
Organizers: William M. Goldman, University of Maryland
Hanna M. Sandler, American University
Richard Schwartz, University of Maryland

2:00 PM A Loop Structure on the Complex Hyperbolic Plane.
Michael K Kinyon, Indiana University South Bend (950-20-51)

2:30 PM Complex hyperbolic surfaces with free fundamental groups.
Nikolai Gusevskii, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil (950-53-729)

3:00 PM Rigidity and flexibility of triangle groups in complex hyperbolic geometry.
Elisha Falbel, Universite Pierre et Marie Curie (950-22-256)
3:30PM  
AWM Presentations by Recent Women Ph.D.s, II

2:00PM - 3:50 PM

2:00PM  
*Construction of Orthonormal Wavelets in n Dimensions.*  
Jennifer Courter, The Colorado College

2:30PM  
*Pattern Recognition in Gene Expression.*  
Laurie J. Heyer, University of Southern California, Los Angeles

3:00PM  
*Uniqueness of Symmetric Vortex Solutions in the Ginzburg-Landau Model of Superconductivity.*  
Tiziana Giorgi, Towson University

3:30PM  
*A categorical approach to the study of self-dual codes.*  
Judy L. Walker, University of Nebraska, Lincoln

AMS Invited Address

2:15PM - 3:05 PM

(1209)  
*The Riemann-Hilbert Problem and integrable systems.* Preliminary report.  
Alexander R. Its, Indiana University-Purdue University Indianapolis (950-34-06)

Association for Research on Undergraduate Mathematics Education Contributed Papers, II

2:30PM - 4:30 PM

Organizers: Julie Clark, Emory and Henry College  
M. Kathleen Heid, Pennsylvania State University  
Rina Zazkis, Simon Fraser University

2:30PM  
*Proof Schemes of Above-Average Mathematics Students.* Preliminary report.  
Mary K Porter*, St. Mary’s College, Notre Dame, IN, and David L Housman, Goshen College (950-D1-1003)

2:45PM  
*The NCTM Standards from an Axiological Perspective.* Preliminary report.  
Michael J Bosse*, Delaware State University (950-D1-409)

3:00PM  
A case study of a small group’s dynamics during discussions and negotiations in an upper division discovery style spherical geometry class.  
Libby Krussell, The University of Montana - Missoula, MT (950-D1-816)

3:15PM  
*Using portfolio in modern geometry classroom.* Preliminary report.  
Draga Vidakovic, Georgia State University (950-D1-999)

3:30PM  
*A Study of Iconic Translation in Undergraduates’ Interpretation of Graphs.*  
Nell K. Rayburn*, Austin Peay State University, Margaret L. Morrow, Plattsburgh SUNY, and Rick Seaman, University of Regina (950-D1-1051)

3:45PM  
*Theoretical Considerations On Incorporating Technology Into Multivariable Calculus.*  
Karen D King, Michigan State University (950-D1-906)

4:00PM  
*A Study in Applying Covariational Reasoning While Modeling Dynamic Events.*  
Marilyn P. Carlson, Arizona State University (950-D1-1017)

4:15PM  
Students’ Understanding of Linear Modeling in a College Mathematical Modeling Course.  
Susie M Lanier, Georgia Southern University (950-D1-367)

MAA Special Event

2:30PM - 4:00 PM

Presentation for chairs of mathematics departments in comprehensive universities, four-year liberal arts, and two-year colleges.  
Organizer: Gerald L. Alexanderson, Santa Clara University

MAA Panel Discussion

2:30PM - 4:00 PM

Doctoral programs in mathematics education—Results from a national conference.  
Presenters: Robert Reys, University of Missouri  
James T. Fey, University of Maryland, College Park

MAA Panel Discussion

2:30PM - 4:00 PM

Mathematics across the curriculum projects.  
Organizer: Frank Giordano, COMAP, Inc.  
Presenters: Dorothy I. Wallace, Dartmouth College  
Dennis DeTurck, University of Pennsylvania  
Mark H. Holmes, Rensselaer Polytechnic Institute  
Alan C. Tucker, SUNY at Stony Brook  
Steven R. Dunbar, University of Nebraska  
Benny D. Evans, Oklahoma State University  
Daniel P. Maki, Indiana University  
Chris Arney, U.S. Military Academy  
James H. Lightbourne, NSF  
Elizabeth J. Teles, NSF  
Lee Zia, NSF

ASL Invited Address

3:00PM - 3:45 PM

(1218)  
*L. E. J. Brouwer: How mathematics is rooted in life.*  
Dirk van Dalen, Utrecht University

MAA Minicourse #6: Part B

3:15PM - 5:15PM

Teaching with web-based interactive modular materials.  
Organizers: David A. Smith, Duke University  
Lawrence C. Moore, Duke University

ASL Contributed Paper Session

4:10PM - 6:00PM

Bernard Russo  
AMS Associate Secretary  
Irvine, California

James J. Tattersall  
MAA Associate Secretary  
Providence, Rhode Island
Meetings and Conferences of the AMS

Associate Secretaries of the AMS

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Meetings and Conferences of the AMS 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 contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Information in this issue may be dated. Up-to-date meeting and conference information is available on the World Wide Web at www.ams.org/meetings/.

Meetings:

2000
January 19-22 Washington, DC Annual Meeting... p. 107
March 11-12 Santa Barbara, California... p. 109
April 1-2 Lowell, Massachusetts... p. 110
April 7-9 Notre Dame, Indiana... p. 111
April 14-16 Lafayette, Louisiana... p. 112
June 13-16 Odense, Denmark... p. 112
August 7-12 Los Angeles, California... p. 113
September 22-24 Toronto, Ontario, Canada... p. 114
October 21-22 San Francisco, California... p. 114
November 3-5 New York, New York... p. 114
November 10-12 Birmingham, Alabama... p. 115
December 13-17 Hong Kong, People's Republic of China... p. 115

2001
January 10-13 New Orleans, Louisiana Annual Meeting... p. 115
March 16-18 Columbia, South Carolina... p. 116
March 30-31 Lawrence, Kansas... p. 116
April 28-29 Hoboken, New Jersey... p. 116
July 17-20 Lyon, France... p. 116
October 13-14 Williamstown, MA... p. 116
2002
January 6-9 San Diego, California... p. 116
Annual Meeting

Important Information Regarding AMS Meetings
Potential organizers, speakers, and hosts should refer to page 106 in the January 2000 issue of the Notices for general information regarding participation in AMS meetings and conferences.

Abstracts
Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX or AMS-LaTeX may submit abstracts with such coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html or send mail to abs-submit@ams.org, typing help as the subject line, and descriptions and instructions on how to get the template of your choice will be emailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. There is a $20.00 processing fee for each paper abstract. There is no charge for electronic abstracts. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

2000:
January 17-18, 2000: Short Course on Quantum Computation: The Grand Mathematical Challenge for the Twenty-First Century and the Millennium; Short Course on Environmental Mathematics; Washington, DC. (See pages 1171-1176, October 1999 issue, for details.)
June 11-July 20, 2000: Joint Summer Research Conferences in the Mathematical Sciences, Mt. Holyoke College, South Hadley, MA. (See pages 1325-1330, November 1999 issue, for details.)
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