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Experimentation and Proof in Mathematics page 670

Can we make predictions with these initial conditions?
A. Lubotzky, Institute of EXPANDING GRAPHS AND University, Appendix by J.D. Rogawski

DISCRETE INVARIANT

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NEW! HOMOTOPY THEORY AND MODELS

M. Aubry, Université de Nice, France

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From the Editor

In the fall 1994 election fewer than 10 percent of the members returned ballots, which meant that the amendment to the Bylaws did not pass, since, according to the Bylaws, amendments can pass only when at least 10 percent of the members vote and two-thirds of those voting approve.

The point here is not the merits of the amendment but rather the lack of participation of the members in the governance of the Society. This lack of interest is exhibited elsewhere.

There are about 300 appointments to committees made by the president each year acting on recommendations made by a committee on committees. Each year I place full-page advertisements in the Notices asking for recommendations to be forwarded to the Committee on Committees. Chairs of existing committees and members of the Council are polled for suggestions to be forwarded to the Committee on Committees. The response to these requests is horrible. There were at most a handful of responses to these calls for suggestions.

There were fewer than five suggestions for nominations for elections to the Council. There were NO suggestions from the general membership for nominations for election to the Nominating Committee and the Editorial Boards Committee. A request from department chairs for recommendations did elicit about thirty responses. I can assure those chairs that all of their recommendations were considered, one by one. (The Committee on Committees meeting lasted for just over five hours. This face-to-face meeting is only a portion of the work involved in this activity.)

The Society belongs to the membership, and the membership should be involved in its governance. It is impossible for the president and her Committee on Committees to know all members of the Society and especially to know which members are willing to serve the Society in various capacities. Thus it is important that the members communicate with the leadership about all aspects of the Society business. This includes desires and wishes about meetings and conferences, publications, science policy, education policy, and issues of the profession.

There are three committees that make recommendations to the president and the Council for election to various leadership and governance positions in the Society. These are: the Nominating Committee, which recommends nominees for the contested elections to the Council; the Editorial Boards Committee, which recommends editors to the Council for election to the editorial boards and associate editors for appointment to these boards; and the Committee on Committees, which recommends individuals to the president for appointment to the many committees of the Society. The Nominating Committee and Editorial Boards Committee members are elected, in contested election, by the membership. The candidates are nominated by the president. All suggestions received by the secretary are forwarded to her. The Committee on Committees is appointed by the president as one of her first official duties.

Among the many committees to which the president makes appointments are the five so-called policy committees: the Committee on Education, the Committee on Meetings and Conferences, the Committee on the Profession, the Committee on Publications, and the Committee on Science Policy. These committees are responsible for recommending to the Council of the Society policy in their areas of responsibility. The president appoints members to these committees upon recommendation by the Committee on Committees. In order that these policy committees represent the opinions of the membership, it is vital that the Committee on Committees have a diverse and rich pool of members from which it can choose individuals to recommend to the president.

Communications from the members are always welcome by the officers and other members who volunteer their time to ensure that the Society is fulfilling its mission. The Notices regularly publishes electronic mail addresses for the various officers and committees. We still read regular mail. We still answer the phone. So please vote in the next election. Send in your suggestions for appointments and nominations. Tell your committees what is right and what is wrong.

Robert M. Fossum
To the Editor,

We are all familiar with Wiener jokes. They are funny, and it doesn’t even matter that many of them are also told about other famous men. They are told affectionately, but their continued repetition creates the impression that Wiener was a foolish man, eccentric and egotistical. These jokes allow one to dismiss him and simultaneously praise his scientific work while belittling his social pronouncements. Even Pest Masani’s adulatory, and generally excellent, biography of Wiener apologizes for his hero’s political acts.

Here are some of them. He resigned from the National Academy of Sciences. He declared, after World War II ended, that mathematicians should sever their ties to the military. He repeatedly tried to warn labor leaders about the effects of computers on jobs, recognizing the adversarial relationship between labor on the one hand and business and government on the other. He continued to criticize Harvard for the anti-Semitism he experienced there.

Certainly there is not enough room in a letter like this to explain why all these acts are political or how brave Wiener was to take up these issues and how his reputation has been damaged by his refusal to play ball. But perhaps this quote, the preface to his book Cybernetics, will give the reader an idea of the kind of man Wiener was:

“Those of us who have contributed to the new science of cybernetics thus stand in a moral position which is, to say the least, not very comfortable. We have contributed to the initiation of a new science which, as I have said, embraces technical developments with great possibilities for good and evil. We can only hand it over to the world that exists about us, and this is the world of Belsen and Hiroshima. We do not even have the choice of suppressing these new technical developments. They belong to the age, and the most any of us can do by suppression is to put the development of the subject into the hands of the most irresponsible and most venal of our engineers. The best we can do is to see that a large public understands the trend and the bearings of the present work and to confine our personal efforts to those fields, such as physiology and psychology, most remote from war and exploitation. As we have seen, there are those who hope that the good of a better understanding of man and society which is offered by this new field of work may anticipate and outweigh the in-
decidental contributions we are making to the concentration of power (which is always concentrated, by its very conditions of existence, in the hands of the most unscrupulous). I write in 1947, and I am compelled to say that it is a very slight hope."

Right after the war Wiener refused a request by a missile engineer for one of his papers. He published his letter to the engineer in the January 1947 issue of the Atlantic Monthly, asserting that a scientist was responsible for the uses of his work: "I do not expect to publish any future work of mine which may do damage in the hands of irresponsible militarists."

The idea of responsibility is central in both of these quotes, and he was right. The frenzied acquisition of tens of thousands of nuclear weapons has wasted our resources and has left us deeply in debt and plagued by mountains of dangerous bombs and nuclear waste. The computer revolution has led to immense wealth for a very slight mine which may do damage in the hands of irresponsible militarists."

I was made his assistant in a summer course he taught at UCLA on nonlinear problems in random theory. I was attracted to him by what little I understood then of his mathematics and even more by his writings, particularly the introduction to Cybernetics quoted above, which helped me eventually sever my ties to the RAND Corporation. I returned to MIT to continue my graduate studies in 1961 and for three years was his graduate assistant. My duties were mostly papergrading and proofreading. (When I was finally ready to begin my thesis, he was already semiretired and spending a semester in Sweden, where he died.) I got to know him well and was very fond of him. He was always warm and accessible, and he was always lucid. Once I was walking in the hall at MIT with him when someone came up to him and started speaking to him. He stared up in the air, as though he didn't even see the person, and we walked on. Since I had met this person with Wiener a week earlier, I said to Wiener, "You know, this is..." He replied, in a firm voice, "Of course I know." I came to view Wiener's "lapses" as a defense mechanism. Almost everyone who saw him tried to speak to him, just, I assume, to be able to say that they had spoken with Norbert Wiener. I think that often his helpless, absorbed attitude was an affection to gain some privacy.

Norbert Wiener's biographer, Masani, considers Wiener America's "second Liebniz", a profound philosopher and humanist. I think that he was also a man of great integrity and courage who used and risked his prestige to oppose militarism and the concentration of power in multinational corporations. Wiener wasn't the only great scientist of his time who spoke against the misuse of power. One thinks immediately of Robert Oppenheimer and Linus Pauling. It has only been thirty years since Wiener died. Where are the scientists today, aside from Noam Chomsky, who speak out for social responsibility?

Michael B. Marcus
City College and
CUNY Graduate Center
(Received January 30, 1995)
the cyclic group of order \( n \) an "\( n \)-dimensional torus"").

At "lower levels" of the continuum, these problems would completely swamp whatever useful information might be present. The lack of publication delay would only exacerbate the problem, since fear of posting something inane or plain wrong seems not to be a deterrent to the legions of crackpots who are currently excluded from publishing in respectable journals but who freely post to sci.math from commercial Internet servers. Essentially I agree with Quinn that the distinction between preprints and refereed articles should be absolutely clear. The convenience of having preprints made electronically accessible is obvious, but to make this the standard for mathematical literature in the future would be disastrous.

The security issues raised by having mathematical literature stored and transmitted entirely in electronic form are paramount, but I am not the person to address them. As an example, it seems that malicious computer hacking could make establishment of priority extremely difficult for electronic publications or could be used to alter their content. Libraries might, as policy, make hard copies for the sake of safety. This seems only prudent.

Drastic change in the future of mathematical publication is certain, but it is crucial to keep the present standards for acceptance and publication in journals. Technology now makes it possible to remove paper from the process; what should remain is the intellectual integrity of a refereed journal with the availability of a newsgroup.

Andrew D. Hwang
Osaka University, Japan
(Received March 7, 1995)

Forgive, But Don't Forget
Nobody demurred at holding an International Congress in Japan in 1990, and nobody should be reluctant to hold one in Germany in 1998. Nazism, World War II, and all that—just water under the bridge, right? Forgive and forget, right? Maybe.

The wake of the Nazi nightmare for Germans is partly the process of recovering self-respect as a nation, and a major power at that. They have my support in this effort, which is undoubtedly difficult.

We should be sympathetic to German mathematicians who survived the Nazi times. To collaborate with Nazism then, one did not have to advocate terror and racism. If one had the "right" ancestry, collaboration was made automatic. It was not advocacy of any politics. It was the path of least resistance, taken by the apolitical; it was the default option. And it was the path taken by most German mathematicians. We who were not there must understand this. Understanding it does not mean condoning Nazi philosophy and institutions.

I am uncomfortable about the Germans as hosts of our Congress, not because they claim respect as a people and as scientists, but because I see some of them equating this with a whitewash of the Nazi past. Nazism was and is wrong, not because its state lost a war, but because it was and is racist and anti-human. Germans should have full status in the international community as human beings, but that does not mean we should exonerate the many who denied the humanity of others or should pretend that they did not. Germans have every right to their glorious mathematical tradition, but one hopes they are proud to be heritors, not only of those like Ludwig Bieberbach who pleaded for Nazism and those like Helmut Hasse who went along with the tide but also of those like Emmy Noether who were forced to emigrate and those like Carl Ludwig Siegel who chose exile. (One who has this pride is Reinhold Remmert, Mathematical Intelligencer 17, no. 2.)

Reestablishing international amity means embracing the former enemy, but it does not mean embracing Nazism—rather, the reverse.

So let's attend the 1998 ICM in Berlin, but maybe it would be good to wear a T-shirt reading,

Forgive and forget?
I can forgive,
but I can't forgive you if you forget.

Chandler Davis
University of Toronto
(Received March 17, 1995)

Are Non-Ph.D.s Taking Jobs from Ph.D.s?
I am writing this letter anonymously because I am an untenured Ph.D. who might jeopardize employment prospects if it were published with my name on it.

Last year the Notices ran an article about the problem of too many Ph.D.s + too few jobs. A major source of the problem seems to get no attention: Many people with no Ph.D. occupy tenured positions at four-year institutions while Ph.D.s go without any job at all. Also, non-Ph.D. adjuncts fill enough courses to keep a large number of Ph.D.s unemployed. The purpose of this letter is to point out that this is a major source of the Ph.D. employment problem. Furthermore, I urge Ph.D.s, especially those with tenure, to stop cooperating with or granting acquiescence via silence to the practice of hiring non-Ph.D.s.

It is perennially claimed by the institution involved in the practice that the presence of non-Ph.D.s is only a legacy of the past, only a temporary measure, only related to remedial courses, etc. Then more non-Ph.D.s are hired, stay on forever, and end up teaching classes for college credit. It is fair to conjecture that the real motivation for hiring non-Ph.D.s is that they are cheap and disposable (until they get entrenched via longevity in the institution's political structure). Obviously, this motivation will always be strong. Therefore, we need to be vigilant.

There is a big difference between a high school teacher and a college professor—it is Ph.D. training that makes the difference. We know this,
but we tend to get hamstrung by the argument that it is hardly beyond reason that a non-Ph.D. could do a good job teaching, say, calculus. That argument could be taken a step further: It also is not beyond reason that some undergraduates could teach calculus well. But this misses the point: College students at every level deserve more than a good teacher—one who can clearly spell out the basic facts and skills. They deserve a high-level practitioner of the subject—one who has journeyed to and beyond the edge of knowledge. Hence the title Doctor of Philosophy, the intent of the doctoral thesis, and the rigor of its defense.

If we believe in the Ph.D. degree, then we should also believe that it is worth protecting. Note how the medical and legal professions protect their doctoral degrees. While it is certainly not beyond reason that an experienced registered nurse could diagnose and treat a variety of routine, minor injuries and decide which cases should have an M.D.'s attention, it is illegal for a registered nurse to diagnose or decide upon treatment for something as minor as a hangnail. While it is certainly not beyond reason that an experienced paralegal or legal secretary could handle minor, routine criminal and traffic violation problems and decide which cases should have a J.D.'s attention, no one but a J.D. can represent another in court. Why? Because the medical doctors and the lawyers don't want it. Why not? Let's not be naive: Doctors and lawyers know where their bread is buttered. We should take the isomorphic position in regard to our own doctoral degree as the J.D.s and M.D.s: namely, that a course taught by a Ph.D. in the respective discipline is a necessary condition for college credit to be given for passing that course.

Worked Hard for My Ph.D.  
(Received March 20, 1995)

Editor's Note: It is the policy of the Notices Editorial Board not to publish letters written anonymously unless the author can provide a compelling reason for the anonymity.

Shepp Replies to Vitulli et al.

This is in response to a letter of Professor Vitulli et al. titled "Some Misconceptions in Shepp Letter" in the Notices, March 1995.

Let me begin by saying that I agree with most of the policies of the AMS with respect to women. Specifically,

1. I agree that women are underrepresented in math and sciences as a result of (mostly subtle) pressure by society. This pressure is a remnant of the past, and it should not take place. Its elimination will benefit both women and mathematics as well as society as a whole.

2. I agree that sexual discrimination and harassment are unacceptable, including their subtle forms.

Now, here is where we disagree. Even though discrimination and harassment are shameful, you cannot eliminate them by redistributing rewards. Let me describe an analogous situation. I have spent many years fighting discrimination against the Jews in Russian mathematics. Suppose a Jewish mathematician, X, did not have the same opportunities and, as a result, did not achieve as much as his non-Jewish counterpart, Y. Let us further assume that if all conditions had been equal, X would have achieved more than Y.

Now, suppose both X and Y compete for the same reward, such as a faculty position or a grant, or both want to publish a book and there is only one slot. May we use the fact of the past discrimination against X to justify giving the reward to X rather than to Y, who is stronger than X due to his unfair advantage? Assume Y in particular is not guilty of any past discrimination.

My answer is no. It's two wrongs and no rights. I am sorry for X, but mathematics is mathematics. The same goes for hour speakers. By saying that the organizers should take extra steps to ensure that a potential woman speaker is not overlooked, the authors of the letter above imply that such extra steps should not be taken with respect to any potential hour speaker. Any other interpretation is a form of double talk.

JCW documents advocate such things as incentive funding for meetings in which there are women speakers as a "mechanism and incentive for 'them' [men] to also invite junior women" rather than the "obvious big names". This is getting ridiculous.

As an editor of a journal, as a member of a panel considering grant applications, or in any other capacity, I make decisions based on the quality of the manuscripts, proposals, work, or achievements.

Women do not need the patronizing attitude, whether we call it extra steps or incentive. They need the same opportunities as men have. AMS should work on making this a reality. But those who distribute the rewards should be gender-blind. If that means that I am against a JCW resolution or AMS policy, so be it.

Shepp Replies to Lorch

Let me respond to Professor Lorch's letter by first quoting this part of his letter:

"He [Shepp] makes a mountain out of the molehill on which the 1972 AMS resolution promises to 'include more women on (a) Society programs and panels, including invited speakers and section chairmen, (b) committees and governing boards.'"

Unlike Professor Lorch, I do not view the 1972 AMS resolution as a molehill. (See my criticism of that resolution in my response to the letter by Professor Vitulli et al. published in this issue [above].)

Professor Lorch brings up another issue that was not part of the 1972 resolution, namely, the issue of the underrepresentation of minorities in mathematics (here we apparently agree—why indeed does the 1972 resolution refer only to women?). My attitude towards this issue is basically the same as that for women: namely, mathematicians and the entire society should make more efforts to attract minorities to our profession. Right
now, many talented young blacks do not have a chance to get a quality education at high school. Depriving them of that chance hurts them, hurts mathematics, and hurts the whole society.

However, what Professor Lorch (and also Vitulli, et al.) advocates is tokenism as a way of solving real and serious problems. We should distinguish between creating equal opportunities and deciding who deserves to be considered best. Tokenism may relieve our guilty conscience but it will do nothing to solve the real problem, and it surely will corrupt our values. Lee Lorch and I see the world differently, although we are old friends: to him, there are many eminent black mathematicians who, due to discrimination against blacks, do not get elected to the AMS Council. To me, the issue is that there are not enough eminent black mathematicians due to the lack of opportunities for black children.

On my suggestion to suppress given names to make it harder to determine gender, I did mean it seriously even though one could argue that it would not be very effective except for a "casual" discriminator. But it couldn't hurt, and if a person was systematically discriminating, maybe he would be caught persistently asking for irrelevant information. Maybe thirty years ago mathematics was small enough that all the members of the AMS knew each other, but things have changed. I will admit that as the erstwhile chair of the Committee to Choose Eastern Hour Speakers, I did not know the skin color of most of the people that appeared on the list of nominees; and if first names had been suppressed, I would not have been able to guess their gender either. I don't work in all fields of mathematics, and I don't know everyone. Nor do I care to know gender, skin color, income level, membership or nonmembership in the proletariat, religion, ethnicity, or any other irrelevant data in judging a mathematician. I am happy and eager to have Lee Lorch or anyone else nominate women and minority candidates for invited speakers, and committees ought to have people like Lee Lorch on them to ensure that all classes are properly considered; but I believe the actual selection should be done on the basis of mathematical achievement alone. To help ensure this, I would propose something like the system I used: each member of a committee to choose speakers or other prizewinners would nominate candidates, suppressing both first names and items listed above as simply being irrelevant data. Each nominator instead should write a paragraph accurately describing the achievements of his/her nominee(s). The committee would then vote based on the descriptions. Some discriminators might know that some of the candidates are women and blacks and discriminate against them, but maybe others might discriminate against men and whites. The proposed method would avoid as much discrimination as possible, maybe(?).

Larry Shepp
AT&T Bell Labs
(Received March 21, 1995)

Communication, Not Just Publication

Readers of the April 1995 Notices may be interested to know that the "MSRI Workshop" discussed in A. Jackson's article of that title was known to its organizers (John Gage and Stu Loken at LBL), Andrew Odlyszko (Bell Labs), Dick Palais (Brandeis), and us), the participants, and those who helped fund it (including the NSF and DOE) as the conference on "The Future of Mathematical Communication". The emphasis was on communication and not just publication. Lots more information, links, and leads can be found on the Web pages for the conference: http://www.msri.org/fmc/fmc.html.

Joe Christy
David Hoffman
MSRI
Berkeley, CA
(Received April 4, 1995)
A Few Results and Open Problems Regarding Incompressible Fluids

Peter Constantin

Water in the oceans and air in the atmosphere are examples of incompressible fluids—fluids that do not change their volume while they flow. They display a truly amazing range of phenomena, from regular patterns to turbulence. Despite this complexity, incompressible fluids are described by only a few partial differential equations and two kinds of limits. In the first limit, time tends to infinity, and in the second limit, coefficients in the equation are varied. The two limits do not commute in general; they can also represent different physical and mathematical situations. I will try to illustrate these issues in an informal manner below.

Incompressible fluids: fluids that do not change their volume while they flow.

From Drops to Turbulence

The equations of motion of incompressible fluids are described as follows: Let \( x \in \mathbb{R}^n \) denote a point in space, \( n = 2 \) or 3, and let \( t > 0 \) denote time. One associates to the velocity \( u(x,t) \in \mathbb{R}^n \) a first-order differential operator, \( D_t \):

\[
D_t = \partial_t + u(x,t) \cdot \nabla.
\]

\( D_t \) is the so-called material derivative; its characteristics, solutions of the ODE

\[
\frac{dX}{dt} = u(x,t),
\]

are called particle trajectories. The Navier-Stokes equations are

\[
D_t u + \nabla p = \nu \Delta u + f,
\]

\[
\nabla \cdot u = 0.
\]

The number \( \nu > 0 \) is the kinematic viscosity of the fluid. If one sets \( \nu = 0 \) in the equation above, one obtains the Euler equations of ideal fluids. The scalar function \( p(x,t) \) represents pressure; its mathematical role is to maintain the constraint of incompressibility \( \nabla \cdot u = 0 \). The functions \( f \) represent body forces. The fluid occupies a region \( G \subset \mathbb{R}^n \), and appropriate boundary conditions are prescribed. A great variety of physical situations are described by the nature of body forces and boundary conditions.

A drop falling from a faucet is an example of a familiar phenomenon that is described using the Navier-Stokes equations. This is a free boundary problem: the shape of the boundary between water and air changes in time under the pull of gravity. The Navier-Stokes equations are supplemented by additional equations for the boundary. These are given by the Gibbs-Thompson law that expresses the role played by the surface tension and links the pressure to the mean curvature of the free boundary. At the time when the drop pinches off there is a singularity in the

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subject and efforts. The physical experiments were matched to high-accuracy numerical simulations of simplified equations. The equations are approximations (so-called lubrication approximations) of the full Navier-Stokes free boundary problem, and they were obtained both from physical principles and by systematic asymptotic expansion. The singularity shape is believed to be universal and stable; this is why the drastic (but not arbitrary) simplifications of the Navier-Stokes equations are able to capture it. A spectacular succession of self-similar events preceding the pinchoff has been observed experimentally and explained using the simplified equations. These results are of high scientific quality; physical experiment, physical theory, and numerical experiments match each other. The ability of fluids to form drops in nonturbulent regimes is of obvious scientific and technological importance. There are some rigorous results, but to my knowledge the mathematical treatment of this problem is far from being complete.

I will turn now to questions related to turbulence. Two examples, Taylor-Couette and Rayleigh-Benard turbulence, can serve as a guide to posing questions regarding turbulence.

In the Taylor-Couette setting fluid is placed in the space between two concentric vertical cylinders; then one of the cylinders is rotated, entraining the fluid. In the Rayleigh-Benard setting fluid is placed in a closed container and heated from below. The external conditions are encoded in nondimensional parameters: Reynolds number, Rayleigh number. They represent a measure of the strength of the externally supplied energy (determined, for instance, by how fast the cylinders are rotated or how much the fluid is heated). The term **nondimensional** refers to scale invariance. The experimenters prepare an experiment at given values of the control parameters. The experiment is allowed to run for a sufficiently long time in order to make sure that one registers the time asymptotic regime. The information is recorded and processed, taking time averages. New values of the control parameters are selected and the process is repeated. This is possible because the experimentally controlled external forces are deterministic and the systems are assumed to be free of other external influences. In other words, the systems are assumed to be closed and controlled.

As the nondimensional control parameters are increased the behavior of the fluid changes, very roughly speaking, from simple to complex. At the high end of the parameter scale we find incompressible turbulence. The appropriate mathematical turbulence problem is thus: study the long-time behavior of solutions to Navier-Stokes equations at a fixed Reynolds number (fixed $\nu > 0$, boundary conditions and body forces $f$). Record it using appropriate measures or averages. Then increase the Reynolds number (for instance, decrease viscosity, keeping all other conditions the same) and study the large Reynolds number limit.

The order in which the limits are taken is crucial. In general the infinite Reynolds number and infinite time limits do not commute. The appropriate order for closed systems is taking the infinite time limit first, but taking the infinite Reynolds number limit before the infinite time limit might be appropriate for systems in which the forcing fluctuates rapidly in time.

I will call the case in which the infinite time limit is taken first the "temporal limit" and the case in which one takes the control parameter to infinity first the "inviscid limit".

**The Temporal Limit**

The finite-dimensional dynamical system paradigm [28] has great merit for the study of transition to turbulence [18]. Mathematically and numerically motivated originally, it was later verified in a number of physical experiments. Consider for simplicity the case of two-dimensional, spatially periodic Navier-Stokes equations with time-independent forces. At a fixed Reynolds number the Navier-Stokes equations are solved by a nonlinear semigroup $S(t)$ in a Hilbert space $H$, the space of divergence-free square integrable velocities. The norm $| \cdot |_H$ is the square root of the total kinetic energy, and $S(t)u_0$ represents the velocity at time $t$. The semigroup is dissipative: there exists a compact set in $H$ such that all trajectories $S(t)u_0$ belong to it for large enough $t$. The semigroup has a global attractor $A$: a compact invariant ($S(t)A = A$) set that contains all omega limit
sets. This set has finite fractal dimension [19]. The dimension is related to the Reynolds number [11], as predicted by the argument of Landau [24] concerning the number of degrees of freedom of turbulence. All Borel measures which are invariant under $S(t)$ are supported in $\mathcal{A}$. Consider the set of global solutions

$$\mathcal{G} = \{u_0 \in H; S(t)u_0 \text{ extends to } t \in \mathbb{R}\}.$$  

The global attractor can be described by

$$\mathcal{A} = \{u_0 \in \mathcal{G}; S(t)u_0 \text{ is bounded for } t \in \mathbb{R}\}.$$  

Consider now the set of those global solutions that grow at most exponentially backward in time

$$\mathcal{M} = \left\{u_0 \in \mathcal{G}; \lim_{t \to -\infty} \sup_{|t|} \log |S(t)u_0|_H < \infty\right\}.$$  

One can prove [12] that $\mathcal{M}$ is weakly dense in $H$. The dynamics on $\mathcal{M} \setminus \mathcal{A}$ can be related to the inviscid Eulerian dynamics: rescaling appropriately velocity and time, one obtains the Euler equations as the infinite negative time limit. Thus, for velocities selected from the rich invariant set $\mathcal{M} \setminus \mathcal{A}$, quasi-Eulerian dynamics is the past and finite dimensional dynamics on the Navier-Stokes attractor $\mathcal{A}$, the future.

One of the most common ways to analyze temporal data, such as the temperature $\theta(t)$ recorded at a given location in the Rayleigh-Benard convection experiment, is to compute the power spectrum,

$$P(\omega) = \lim_{T \to \infty} \frac{1}{T} \left| \int_0^T e^{-i\omega t} \theta(t) dt \right|^2.$$  

This is a well-defined and even automated procedure; its mathematical justification stems from classic work on stochastic signals, going back to Wiener, Khintchin and Kolmogorov. At finite Rayleigh and Reynolds numbers, though, the signal is not a random process, rather it is the output of a finite dynamical system. Using the properties of solutions of Navier-Stokes equations, one can still make mathematical sense of the procedure. Moreover, one can prove that the power spectrum must decay at least exponentially at high frequencies [2]. Specifically, the power spectrum of the temporal data obtained by evaluating a solution at some fixed location is a well-defined positive Borel measure $P(\omega)$ and satisfies

$$\int_{-\infty}^{\infty} e^{\tau |\omega|} P(\omega) < \infty.$$  

The positive constant $\tau = \tau(\mathcal{A})$ depends only on the attractor, in other words, only on the control parameters. Thus, slower than exponential decay—found by numerical treatment of experimental Rayleigh-Benard convection data—is not asymptotically correct in the high temporal frequency limit at fixed Rayleigh number. The reason why the numerical calculation led to an incorrect prediction is perhaps that numerical calculation may have used time series of experimental data sampled with too-long delays between successive measurements.

The temporal power spectrum of wind tunnel data provides strong experimental verification of one of the beacons in the subject of turbulence, the Kolmogorov theory [23]. Grounded in dimensional analysis, this theory proposes the existence of universal scaling behavior in fully developed turbulence. According to the Kolmogorov dissipation law, the energy dissipation rate

$$\varepsilon = \nu \left(\langle |\nabla u(x,t)|^2 \rangle\right)$$  

is a positive constant that is bounded independently of viscosity. The braces $\langle \cdots \rangle$ represent ensemble average (functional integration). Kolmogorov assumed homogeneity and isotropy (invariance with respect to translations and rotations of the underlying probability distributions). In addition, the Kolmogorov theory assumes that there exists an interval, the so-called inertial range, which extends from a small length (the Kolmogorov dissipation scale $\eta$) to a large one (the integral scale $\rho$), such that, for $r \in [\eta, \rho]$, the variation

$$s(r) = \left(\langle |u(x+y) - u(x)|^2 \rangle\right)^{\frac{3}{2}}$$  

of velocity across a distance $r = |y|$ can be determined from dimensional analysis:

$$s(r)^2 = (cr)^{\frac{3}{2}}.$$  

This is the Kolmogorov two-thirds law. It is one of the most important predictions of this theory. It implies that the energy spectrum behaves approximately like a $-\frac{5}{3}$ power in a range of wave numbers (Fourier variables).

Some modest progress on the mathematical aspects [5] of the issue of scaling can be summarized as follows. One considers a concrete averaging procedure in which the temporal limit has to be taken before ensemble average. There are no special assumptions regarding the ensemble average; in particular, no assumptions of homogeneity and isotropy are needed. One defines the structure function $s(y)$ (because of lack of isotropy $s$ is not assumed to be radially
symmetric) and dissipation $\epsilon$ as above. One considers ensembles $\mathcal{E}$ of solutions of the Navier-Stokes equations in $\mathbb{R}^3$ satisfying the following three assumptions: uniformly bounded velocities, uniformly bounded forces, and a mild technical assumption regarding $s$. Based on these three assumptions alone, one can prove that $\epsilon$ remains bounded uniformly as $\nu \to 0$. Moreover, the Kolmogorov two-thirds law holds as an upper bound:
\[
(s(y))^2 \leq (\epsilon |y|)^{\frac{3}{5}}
\]
for $|y|$ in an interval at the bottom of the inertial range. The Kolmogorov dissipation scale has a natural definition, so the statement is meaningful even if scaling has not been proved.

Proving a positive lower bound for $\epsilon$ that is uniform for arbitrarily large Reynolds numbers is a fundamental open problem.

There are few rigorous results concerning fully developed turbulence (i.e. the large Reynolds number asymptotics) in realistic models of closed systems driven at the boundary. The most reliable and reproducible quantities measured in high-quality experiments are bulk dissipation quantities. In the Taylor-Couette flow the bulk dissipation quantity is the total torque; in the Rayleigh-Benard case it is the Nusselt number, a measure of heat flux. These quantities obey empirical laws: they are given by certain functions of Reynolds or Rayleigh number.

A method to estimate rigorously the asymptotic behavior of these functions for large Reynolds or Rayleigh numbers for systems driven at the boundary has been developed [6] in recent years. In addition to providing good agreement to experimental results, the method leads to new variational problems with spectral side conditions.

**The Inviscid Limit**

Here we consider the inviscid limit: that is, we fix time and let the control parameter tend to infinity. Let us focus on the Navier-Stokes equation. The first question is: what are the limiting equations? In realistic closed systems where the boundary effects are important, unstable boundary layers drive the system: the limit is not well understood. In the case of no boundaries (periodic solutions or solutions decaying at infinity) the issue becomes one of smoothness and rates of convergence. Indeed in $n=2$, if the initial data are very smooth, then the limit is the Euler equation and the difference between Navier-Stokes solutions and corresponding Euler solutions is optimally small ($O(\nu^{1/3})$). However, if the initial data are not that smooth, for instance in the case of vortex patches, then the situation changes. Vortex patches are solutions whose vorticity (antisymmetric part of the gradient) is a step function. They are the building blocks for the phase space of an important statistical theory [26, 27]. When one leaves the realm of smooth initial data, the inviscid limit becomes more complicated: internal transition layers form because the smoothing effect present in the Navier-Stokes solution is absent in the Eulerian solution. In the case of vortex patches with smooth boundaries, the inviscid limit is still the Euler equations, but there is a definite price to pay for rougher data: the difference between solutions (in $L^2$) is only $O(\sqrt{\nu})$ [13]. This drop in rate of convergence actually occurs—there exist exact solutions providing lower bounds. The question of the inviscid limit for the whole phase space of the statistical theory of [26] and [27] is open. If the initial data are more singular, then even the classic notion of weak solutions for the Euler equations might need revision [15], except when the vorticity is of one sign [14].

In the case of three spatial dimensions and smooth initial data, the inviscid limit is the Euler equation as long as the corresponding solution to the Euler equation is smooth [20, 7]. This might be a true limitation because of the possibility of finite time blowup. The blowup problem for the Euler ($\nu = 0$) equations is the following: do smooth data (for instance, $f = 0$, and smooth, rapidly decaying initial velocity) guarantee smooth solutions for all time? The answer is known to be yes only for $n = 2$, not known for $n = 3$. The main difference between the two-dimensional and the three-dimensional cases can be explained as follows. The Euler equations are equivalent to the requirement that a first-order differential operator $\Omega$ commute with $D_t$:
\[
[D_t, \Omega] = 0.
\]
$\Omega$ is associated to a divergence-free function $\omega = \omega(x, t) \in \mathbb{R}^n$, $\nabla \cdot \omega = 0$:
\[
\Omega = \omega(x, t) \cdot \nabla.
\]

The vanishing of the commutator can be expressed as an evolution equation for the coefficients $\omega$. The equation is nonlinear because $u$ and $\omega$ are coupled:
\[
u = \mathcal{K} \ast \omega.
\]
A difference between $n = 2$ and $n = 3$ lies in the nature of the coupling matrix $\mathcal{K}$. For $n = 2$
\[
\mathcal{K}^{(2E)}_{ij}(\gamma) = \delta_{ij} \log(|\gamma|),
\]

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where $\delta_{ij}$ is the Kronecker delta. In three dimensions

$$K_{ij}^{[3E]}(y) = \epsilon_{ijk} \frac{\hat{y}_k}{|y|^2},$$

where $\hat{y} = y / |y|$, $\epsilon_{ijk}$ is the signature of the permutation $(1, 2, 3) \rightarrow (i, j, k)$ and repeated indices are summed. Note that the strength of the singularity of $K^{[3E]}$ at the origin is of the order $2 = n - 1$, whereas the strength of the singularity of $K^{[2E]}$ is merely logarithmic. This is a crucial difference. Moreover, if $n = 2$, the equation $[D_t, \Omega] = 0$ is equivalent to an active scalar equation

$$D_t \theta = 0,$$

irrespective of the nature of $K$. The natural analogue of the three-dimensional coupling in a two-dimensional model is

$$K_{ij}^{[2OE]} = \delta_{ij} \frac{1}{|y|}.$$  

This coupling has the correct singularity strength $1 = n - 1$. It turns out that this is a physically significant model: the scalar $\theta$ represents temperature in a quasi-geostrophic (Coriolis forces balance pressure gradients) approximation of atmospheric flow. Recent numerical and analytic [8, 9, 10] results suggest that there are important geometric effects that can prevent blowup, both in the quasi-geostrophic active scalar and in the three-dimensional Euler equations. Namely, one can prove that in regions where the normalized direction field

$$\xi = \frac{\omega}{|\omega|}$$

is regularly directed there cannot be blowup. Regularly directed is a technical term: roughly speaking, it means that the direction $\pm \xi$ has Lipschitz extensions in regions of high $|\omega|$. A valid blowup scenario requires therefore the formation of a singular object in physical space. Such an object might be as simple as conical “elbows” in a pair of vortex tubes, and such structures might have been observed in numerical simulations [22].

**Concluding Remarks**

Among the most physically significant mathematical problems in the theory of incompressible fluids is the problem of singularities. The stable finite time singularities which develop in nonturbulent situations, such as the drops forming under the combined effects of gravity and surface tension, are an example. Another example arises in connection to turbulence theory. The correct limit for closed system turbulence is the infinite time limit. The important mathematical problem of finite time blowup for the Navier-Stokes equations belongs here. There is, however, no evidence that this problem has physical significance; blowup of solutions of the Navier-Stokes requires infinite momentum, that is, breakdown of the model. Rather, the physically important problem is posed by the Kolmogorov theory. A successful link of this theory to Navier-Stokes dynamics will have to produce a lower positive bound for the product of viscosity and average square of the gradients. This clearly requires large gradients in the limit of zero viscosity, suggesting finite time blowup in the Euler equations as the physically important problem. However, in general the temporal limit and the inviscid limit do not commute. The inviscid limit may be complicated, even in the absence of boundary effects, in the case of nonsmooth data. The question of blowup for the Euler equation is relevant in this context.

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Mathematical Work of Norbert Wiener

V. Mandrekar

The Norbert Wiener Centenary Congress was held at Michigan State University, November 27-December 3, 1994. The Congress was cosponsored by the American Mathematical Society, the International Association of Cybernetics, and the World Organization of Systems and Cybernetics.

The aim of the Congress was to reveal the depth and strong coherence of thought that runs through Wiener's legacy and to exhibit its influence on current research. The Congress drew fifty-eight participants, including thirteen from Europe, two from Asia, one from Mexico, and two from Canada. There were twenty-nine addresses, sixteen contributed papers, and one round table discussion. The Congress ended with the award of the Norbert Wiener Centenary Medal to Claude E. Shannon (Shannon's wife accepted the medal on his behalf. See photo above.).

The following article, written by one of the co-organizers of the Congress, describes some of Wiener's work explored at the Congress and discusses its impact on contemporary research.

—Allyn Jackson

Norbert Wiener began his mathematical life in logic and foundations. He went to England to work with B. Russell. His contact with G. H. Hardy and others expanded the spectrum of his work to include analysis, engineering, statistics, and physics. He is known to the general public as a founder of cybernetics, but to mathematicians he is known for his fundamental contributions in analysis and for his use of randomness to expand the vision and applications of mathematics.

We shall explore this aspect of his work. His interest in randomness begins with his work on realizing Brownian motion in a function space. The insight gained raised further questions and issues which naturally led him to generalized harmonic analysis, Tauberian theorems, and later Paley-Wiener theory, which was then used to study problems involving randomness in signal analysis. In addition, Wiener introduced fundamental ideas and techniques in potential theory and homogeneous chaos, which to this day are finding applications to emerging fields in mathematics at the hands of other researchers.

In order to refer systematically to Wiener's works, we shall refer to his Collected works [NW1] with double brackets. For example, [[34a]] shall mean reference 34a in [NW1]. We also bring at-
tention to the biographical article by P. Masani [NW2], written at the time of Wiener's death.

We shall begin our look at Wiener's work first by examining his construction of the measure $W$ on the space $C_0[0, 1]$ of real-valued continuous functions $x$ on $[0, 1]$ with $x(0) = 0$ as a model for paths traversed by a particle following Brownian motion. This is contained in five papers from 1920–1924. First, we describe the measure space for $W$ (Wiener measure). Let $\{t_{n,i}\}$ be a doubly indexed set of points in $[0, 1]$ with these properties:

a. for each $n$, $0 < t_{n,1} < t_{n,2} < \cdots < t_{n,k_n} < 1$;

b. for each $n$ the set $\{t_{n,i}\}$ is a subset of $\{t_{n-1,i}\}$;

c. the set of all $\{t_{n,i}\}$ is dense in $[0, 1]$.

For each $n$, introduce the set $\pi_n$ of subsets of $C_0[0, 1]$: an element of $\pi_n$ is of the form

$I = \{x \in C_0[0, 1]: a_i < x(t_{n,i}) < b_i, i = 1, 2, \ldots, k_n\}$.

Notice that, because of b) $\pi_n \subset \pi_{n+1}$. The Wiener measure of $I$, $W(I)$ is

$$
W(I) = \int_{a_{i-1}}^{b_i} \cdots \int_{a_{n-1}}^{b_n} p(t_1, y_1) p(t_2 - t_1, y_2 - y_1) \cdots \cdot p(t_n - t_{n-1}, y_n - y_{n-1}) dy_1 \cdots dy_n
$$

where

$$
p(t, y) = (2\pi t)^{-1/2} \exp(-\frac{y^2}{2t}), y \in \mathbb{R}.
$$

$\cup \pi_n$ is the basis for a topology on $C_0[0, 1]$, and $W$ defines a Borel measure on this space. To show this, Wiener follows the Daniell approach to measure theory: starting with a positive functional on a (sufficiently large) linear space of Baire functions, satisfying the monotone convergence theorem of Lebesgue, Daniell extends this function as an integral on all Baire functions. Here we take the functions space to be $L$, the set of simple functions based on $\cup \pi_n$; the functional is $\int f dW$ on $L$: for $f = \sum \gamma_i X_i$, $\int f dW = \sum \gamma_i W(I_i)$. The crucial point is to prove continuity of $W$ from above at 0: For $\{f_n\}$ a non-increasing sequence in $L$ converging to 0, Wiener succeeds in showing that $\int f_n dW \to 0$. For this he constructs (for each integer $m$) a compact set $K_m \subset C_0[0, 1]$ of Hölder continuous functions of order $< 1/2$, with Wiener measure greater than $1 - 1/m$. From this it follows that $W$ is a Borel measure on $C_0[0, 1]$ and that Hölder continuous paths with finite quadratic variation exist almost everywhere in Wiener space. These paths in particular are nowhere differentiable. Thus Wiener uses the topological structure of $C[0, 1]$ to construct Brownian motion. In the work of A. N. Kolmogorov (see [10]) in 1933 for probability measures on $R^T$ (T arbitrary), regularity in the finite-dimensional case is used to produce the compact sets, and the topological structure of $R^T$ is exploited to produce a function of Baire Class two.

Before we go to Wiener's contribution to potential theory in the twenties, we want to examine a trail of ideas starting from the above construction to his major work of the thirties on generalized harmonic analysis.

Immediately after his paper [[24d]], Wiener gave a Fourier series representation for Brownian motion ([[24e]], p. 570), in terms of independent identically distributed (i. i. d.) standard normal random variables $\{a_n\}$ (see also [[34a]], p. 21). In [[27a]] Wiener gives the definition of the spectrum of a sequence of complex numbers $\{f_n\}$ satisfying

$$
\lim_{N \to \infty} \sum_{n=-N}^{N} f_{n+k} f_n = 0.
$$

The above-mentioned sequence $a_n$ satisfies Wiener's condition a. e., and from the representation in [[34a]], one gets

$$
a_n = \int_{0}^{2\pi} e^{imu} dB(u)
$$

where $B$ is the Brownian motion and the integral is in the sense of Wiener as given in [[23a]] using integration by parts. Thus Wiener seems to have been aware of the harmonic analysis of a sequence where the "spectral measure" $B$ may not be a measure. In recent years one defines the spectrum in the generalized sense [14] using the theory of generalized functions. The latter theory was unavailable to Wiener in a systematic
way, although he was conceptually aware of it (see [20], p. 427). In the continuous parameter case, the relation to generalized function was noticed in [5] (see also [3]). Wiener instead chose the techniques of the Plancherel Theorem. This had two advantages: first, it led to Tauberian theorems, and second, it found applications to electrical engineering, as Fourier theory was an established method for engineers.

In the mind of an analyst of the 1920s, a Tauberian theorem is one which deduces the convergence of an infinite series on the basis of the properties of the function it defines (via power series, Fourier series, or as coefficients in any standard expansion of a function) and any general term of the series from converging to the properties of the function it defines (via the techniques of the Plancherel Theorem). This is conditioned on the convergence of the Fourier series. For these reasons, I feel that it would be far more appropriate to term these theorems Hardy-Littlewood theorems, were it not that usage has sanctioned the other appellation.

Wiener’s central Tauberian theorem is an analogous theorem about indefinite integrals. It goes like this. Let \( f \) be a bounded measurable function on the real line \( f \in L^1 \), and let \( K \) be an \( L^1 \) function (that is, \( \int_{-\infty}^{\infty} |K(\xi)|d\xi < \infty \)). What is at issue is the limit of \( f \ast K(x) \) as \( x \to -\infty \):

\[
\lim_{x \to -\infty} \int_{-\infty}^{\infty} f(\xi)K(\xi - x)d\xi.
\]

The hope is that this limit is \( A \int_{-\infty}^{\infty} K(\xi)d\xi \) for some number \( A \) independent of \( K \). The theorem of Wiener is that if this is true for some \( K \in L^1 \) whose Fourier transform never vanishes, then it is true for all \( K \in L^1 \).

Using the Tauberian theorems, Wiener gave a proof in this paper of the Prime Number Theorem. His proof reduces it to the convergence of a certain definite integral (derived from the Riemann zeta function) based on function-theoretic information about the function the indefinite integral defines.

Wiener’s Tauberian theorems followed from two results which themselves have had great impact on the development of modern analysis.

I. Suppose that \( f \) is a continuous function on the circle which has an absolutely convergent Fourier series. If \( f \) never vanishes on the unit circle, then \( 1/f \) also has an absolutely convergent Fourier series.

Wiener’s argument proceeds from a local statement to the global one, using some very technical convergence arguments. This result is a lemma on the way to proving:

II. Let \( f \) be an \( L^1 \) function on the real line. The linear span of the set of translates of \( f \) (functions of the form \( f(x+y) \)) is dense in \( L^1 \) if and only if the Fourier transform of \( f \) vanishes on a set of measure zero.

It is quite easy to establish the necessary condition, for if \( F \) represents the Fourier transform of \( f \), then the Fourier transform \( S \) of the span of all translates of \( f \) is the linear span of the set of all functions of the form \( e^{iy}\xi} F(\xi) \). Since the closure of the linear span of the exponentials \( e^{iy}\xi \) in the uniform norm on any compact set coincides with all continuous functions on that
compact set, all functions in $S$ will vanish on the intersection of that compact set with the zero set of $F$. If that set has positive measure, then there certainly are functions in $L^1$ whose Fourier transform is identically 1 there; such a function cannot be in the closure of the linear span of the translates of $f$. The real issue is the sufficiency.

The property of the Fourier transform, that it changes translation operators into multiplication operators, is fundamental to all the uses of the Fourier transform. What was apparently first understood by Wiener is that it changes geometric questions about function spaces on the circle or in $\mathbb{R}^n$ into algebraic questions about the ring of multiplication operators on the transformed space. This ultimately led to considerations of abstract normed rings and great generalizations and simplifications of these works of Wiener (first by the Uppsala school of analysts and completed by Gelfand).

Thus, starting from the construction of Brownian motion, Wiener was led to several significant contributions to analysis, harmonic analysis, almost periodic functions, and number theory. His generalized harmonic analysis has had major impact in signal analysis and time series ([NW2] and [H49g]), since in practical situations one can only observe precisely the correlation functions associated with a signal. Here one needs to analyze the spectrum. In all of Wiener's work, the concept of ergodicity, to which we shall come in a while, was implicit.

Wiener's work with Paley started with [[33a]], where they considered problems of random Fourier series with i.i.d. Gaussian random variables replacing Rademacher functions. In his work on differential space [[23d]], Wiener had given a definition of a stochastic integral. He considered the process

$$Y(t, \cdot) = \int_{-\infty}^{+\infty} \varphi(u - t)B(du, \cdot)$$

for $\varphi \in L^2(-\infty, +\infty)$. Using the Paley-Wiener result that there is a measure-preserving ergodic flow on $[0, 1]$ given by translations of Brownian motion, one can see that this is a stationary process. In fact, considering this representation of the signal, one can show that a correlation function exists a.e. and is constant. It has absolutely continuous spectrum with density $|\hat{\varphi}(\lambda)|^2$. To study causality, one needs to assume that $\varphi(u) = 0, u \geq 0$. In this context the following two basic results of Paley and Wiener are indispensable [[34d]].

1. $\varphi \in L^2(-\infty, +\infty)$ is the boundary value of a function $\varphi_+$ analytic in the upper half plane which is uniformly $L^2$ on every horizontal line (the Hardy class $H_2$) if the Fourier transform $\hat{\varphi}$ vanishes on $(0, \infty)$.

2. The necessary and sufficient condition that a nonnegative function $f$ on $(-\infty, \infty)$ and in $L^1(-\infty, \infty)$ is of the form $f = |\varphi|^2$ a.e. where $\varphi$ is as above is $\log f(\lambda)/(1 + \lambda^2) \in L^1(-\infty, \infty)$.

These also turned out to be important results in the study of one variable prediction theory and filtering problems. In his work on multivariate prediction theory with P. Masani and E. J. Aukowitz, Wiener took the approach of Kolmogorov [11]. Let us illustrate this in the one-variable case.

Let $\{X_n, n \in \mathbb{Z}\}$ be a sequence in the complex Hilbert space $H = L^2(\Omega, F, P)$ with $(\Omega, F, P)$ a probability space. Let $L(X : n)$ be the past of the process, namely, $\overline{\sigma}(X_k, k \leq n)$ where $\overline{\sigma}$ denotes the closure of the linear span. Under Wiener’s condition on ergodicity

$$EX_nX_0 = (X_n, X_0) = \int_{-\infty}^{+\infty} e^{inx} dS(\lambda)$$

where $S$ is the spectral measure. Thus $\overline{\sigma}(X_k, k \in \mathbb{Z})$ is isometric to $L^2([0, 2\pi], S)$, sending $X_n \to e^{inx}$. Following Wold, one says the process is nondeterministic if $\cap_n L(X : n) = \{0\}$ (there is no remote past) and deterministic if $L(X : n) = L(X : n + 1)$ for all $n$ (the remote past contains all the information of the present and the future). By projecting $X_n$ onto the remote past $L(X : -\infty) = \cap_n L(X : n)$ and its orthogonal complement in $L(L(X) = \vee_n L(X : n)$, one gets an orthogonal decomposition $X_n = X_n + Z_n$ where $\{Y_n\}$ is deterministic and $\{Z_n\}$ is purely nondeterministic, $Y_n$ is uninteresting for prediction theory. Let $\xi_n$ be the new part (innovation) of $Z_n$, the part of $Z_n$ which is orthogonal to $L(X : n - 1)$. Writing $\{Z_n\}$ in terms of $\{\xi_n\}$, one sees that the spectral measure of the process is absolutely continuous with respect to Lebesgue measure and its spectral density factors. Being geometric, this technique goes through in the multivariate case with minor changes. In terms of correlation, a process with factorable density is purely nondeterministic. The important result used here, (the Szegö Theorem) that $\int_0^{2\pi} k\varphi(x)dx = -\infty$ is equivalent to the factorization of $f$, requires ideas from Paley-Wiener theory. For a vector process, the spectral measure is matrix (or, in general, operator) valued. This method for factoring density survives in the full rank case. However, the Szegö Theorem gets delicate but can also be reduced to univariate case using a technique of Lowdenslager [13] and some geometric arguments. Because of the generality of these arguments, this has implications to the invariant subspace problem, scattering theory, and harmonic analysis [1].

Extension of the idea of expressing a (strictly) stationary process in terms of orthogonal (independent) innovations for nonlinear prediction problem was initiated in the work of Wiener with Kallianpur and was successfully carried out in special cases by M. Rosenblatt and D. Han-
son. Attempts to obtain computable expressions for the optimal nonlinear predictor were made in Wiener-Masani [59b]. Under rather restrictive assumptions, the best (nonlinear) predictor of \( X_n \) with lead \( h > 0 \) is given by 

\[
E(X_n | \mathcal{F}_0^n) = I_n^2 - \lim Q_n(X_0, X_1, ..., X_{-m_0})
\]

where (i) \( \mathcal{F}_0^n \) is the \( \sigma \)-algebra generated by \( \{X_m, M \leq 0\} \), (ii) \( m_n \geq 0 \) integer based on \( n \), (iii) \( Q_n \) is a polynomial in \( m_n \) + 1 variables. Here \( \{X_n, n \in \mathbb{Z}\} \) is a strictly stationary process \( \in L^\infty(\Omega, \mathcal{F}, \mathbb{P}) \). The most general result in this direction is due to Ito and Stein and is stated in Kallianpur [9].

However, synthesis of the black box is a delicate problem [19] and Wiener gave his thoughts on it in his monograph [58a] using the homogeneous chaos paper. Wiener also used this to study the continuous analogue of the nonlinear prediction problem. This is one of many of Wiener's papers in which his ideas were shown to be basic to the development of the foundations of the area. His first work of this type was in potential theory.

Almost simultaneously with his work on Brownian motion, Wiener undertook his fundamental work on potential theory. Interestingly, he again used the Daniell integral to attack the Dirichlet problem. Let \( D \) be a domain in the plane with boundary \( \Gamma \). For what continuous functions \( \varphi \) on \( \Gamma \) is there a function \( u^\varphi \) continuous on the closure of \( D \), equal to \( \varphi \) on \( \Gamma \), and satisfying Laplace's equation in \( D \)? If it had been known for some time that this question (Dirichlet's problem) can be solved for all continuous functions on \( \Gamma \) when \( D \) is a smoothly bounded domain. Now, for a general domain \( D \), Wiener selected an increasing sequence of smoothly bounded domains \( D_n \) filling out \( D \) from the interior. Now fix a point \( y \) in \( D \). For \( \varphi \) defined on \( \Gamma \), let \( I_y(\varphi) = \lim_{n \to \infty} u_{D_n}^\varphi \), where \( u_{D_n}^\varphi \) solves Dirichlet's problem on \( D_n \) for some continuous extension of the given \( f \) on \( \Gamma \). Wiener showed that \( I_y \) is well defined, is independent of the choices of the sequence \( D_n \) and the continuous extension of \( \varphi \), and meets all the conditions of the Daniell integral on \( C(\Gamma) \). This gives for each \( y \) a probability measure \( \mu_y \) such that 

\[
u^\varphi(y) = \int_{\partial D} \varphi(x) \mu_y(dx)
\]

is harmonic in \( D \). The probability measure \( \mu_y \) is called harmonic measure. Kakutani related it to the exit time of Brownian motion in 1944. A point \( x \) on the boundary is called regular if \( \nu^\varphi(y) = \varphi(x) \), as \( y \to x \) for all continuous functions \( \varphi \) on \( \partial D \). Wiener gave a necessary and sufficient condition for a boundary point to be regular in terms of capacity, a notion he adapted to this purpose based on physical intuition. The condition is strikingly geometric: Let \( x \) be a point of \( \Gamma \) and \( \kappa_n \) the capacity of the intersection of \( D \) with the disk of radius \( 2^{-n} \) centered at \( x \). Then \( x \) is regular if and only if \( \Sigma \kappa_n^2 \) diverges.

Thus, Wiener introduced the central concepts of the modern potential theory: harmonic measure, generalized solutions, capacity of sets, and regular points. At just about the same time (although the paper was published a year earlier than Wiener's), O. Perron found another method for solving the Dirichlet problem on an arbitrary domain. His condition for regularity at a point \( x \) was stated in terms of the local existence of a barrier function: a function subharmonic near \( x \) which, on the closure of \( D \), has a strict maximum at \( x \). In his paper [58a], Wiener showed that the two constructions and conditions for regularity are equivalent.

Let us now turn to Wiener's work on homogeneous chaos, motivated by his interest in turbulence and statistical mechanics. Wiener defines a Gaussian function for \( \alpha \) on \([0,1]\) whose values are set functions \( \{\xi(A, \alpha)\} \) on Borel sets in \( R^n \) of finite Lebesgue measure with this property:

\[
\int_0^1 \xi(A, \alpha) \xi(B, \alpha) d\alpha = \text{the Lebesgue measure of } A \cap B.
\]

This is called chaos and he then defines what can be called the multiple Wiener integral. It should be noted that if the chaos is constructed from Brownian motion, i.e., \( B(A) = \int_A dB(t) \) with \( n = 1 \), then

\[
\int_0^1 \cdots \int_0^1 A(x, x, \ldots, x) dA dB dB \cdots dB = B(A)^k
\]

This is different from the definition of K. Ito and I. Segal, where the above integral is \( H_k(B(A)) \), \( H_k \) being the Hermite polynomial of order \( k \). If one examines Wiener's later work [58a], one can see that he orthogonlizes his integral, relating it to the Ito multiple integral. What Wiener defines is called in current literature the Stratonowich multiple integral. The relation between the Wiener and Ito integrals is precisely the Hu-Meyer formula [6], a special case of which for \( k = 2 \) occurs in [58a]. It should be noted that coefficients in the Hu-Meyer formula are precisely those expressing polynomials through Hermite polynomials. Wiener's aim was to prove a multidimensional generalization of the Birkhoff Ergodic Theorem and apply it to larger classes of functions on chaos using approximations through his integral. Although Wiener was not able to attack the problem of statistical turbulence, the ideas of Wiener have influenced physics problems. This can be seen in the work of Segal [22] on quantum field theory and Hu-Meyer on the computation of Feynman integrals, justifying the work of Hida-Streit. An interesting consequence of this work on multiple integrals is the work of A. V. Skorokhod [23], which extends Ito's generalization of the Wiener integral. The latter integral can be used to study nonlinear filter theory. It should also be observed
that Segal introduced a finitely additive (cylindrical) measure in his work on quantum field theory. Countably additive extension of this measure led L. Gross to the study of abstract Wiener spaces—an algebraic generalization of Wiener's original idea on Brownian motion! Expansion of nonlinear functions of chaos has made it possible to create a calculus on the abstract Wiener space called Malliavin calculus (see [24]), which has proven useful in the study of statistical mechanics. The just-mentioned work studies "generalized functions" on abstract Wiener space, the analogue of which for Lebesgue measure was also in Wiener's work (see [20], p. 427). Although Wiener proved a generalization of Birkhoff's Ergodic Theorem for multiparameter flows, he ended up proving a very general Ergodic Theorem [3ga].

We are unable to cover the work of Wiener on foundations, cybernetics, prosthesis, and economic philosophy; the bases of these also have deep mathematical ideas. Excellent references for Wiener's complete work, of course, are [17] and [21].

I would like to thank Professor P. R. Masani for guiding me through the work of Wiener and Professor R. V. Ramamoorthi for the discussions about the style of presentation. In addition, I want to thank the editor for his untiring effort for the improvement of this work.

Bibliography


The English word "prove"—as its Old French and Latin ancestors—has two basic meanings: to try or test, and to establish beyond doubt. The first meaning is largely archaic, though it survives in technical expressions (printer's proofs) and adages (the exception proves the rule, the proof of the pudding). That these two meanings could have coexisted for so long may seem strange to us mathematicians today, accustomed as we are to thinking of "proof" as an unambiguous term. But it is in fact quite natural, because the most common way to establish something in everyday life is to examine it, test it, probe it, experiment with it.

As it turns out, much the same is true in mathematics as well. Most mathematicians spend a lot of time thinking about and analyzing particular examples. This motivates future development of theory and gives one a deeper understanding of existing theory. Gauss declared, and his notebooks attest to it, that his way of arriving at mathematical truths was "through systematic experimentation". It is probably the case that most significant advances in mathematics have arisen from experimentation with examples. For instance, the theory of dynamical systems arose from observations made on the stars and planets and, more generally, from the study of physically motivated differential equations. A nice modern example is the discovery of the tree structure of certain Julia sets by Douady and Hubbard; this was first observed by looking at pictures produced by computers and was then proved by formal arguments.

It is disturbing that such considerations are usually totally excluded from the published record. What one generally gets in print is a daunting logical cliff that only an experienced mountaineer might attempt to scale, and even then only with special equipment. Is this the best thing for the research community? Is it fair to graduate students? Should we give the impression that the best mathematics is some sort of magic conjured out of thin air by extraordinary people when it is actually the result of hard work and of intuition built on the study of many special cases? In our educational institutions, we spend too much time revealing these almost unscalable logical edifices instead of giving others

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the feeling that they too can participate in the work.

Partly in response to this lack, we founded in 1991 the quarterly *Experimental Mathematics*, whose mission is to present mathematics as a living entity, with examples, conjectures, and theory all interacting with and reinforcing each other. Now in its third volume, *Experimental Mathematics* has established a solid reputation as a first-rate research journal, but it definitely has a different flavor from most traditional journals. For one thing, its range is broad: among the fields represented so far are algebraic geometry, cellular automata, combinatorics, differential geometry, dynamical systems, geometric topology, group theory, harmonic analysis, number theory, optimal geometries, several complex variables, singularity theory, and wavelets. For another, each article is individually edited to ensure a high standard of exposition in an effort to reach as many readers as possible. But the main difference reflects the philosophy above: we are interested not only in theorems and proofs but also in the way in which they have been or can be reached.

Note that we do value proofs: experimentally inspired results that can be proved are more desirable than conjectural ones. However, we do publish significant conjectures or explorations in the hope of inspiring other, perhaps better-equipped researchers to carry on the investigation. The objective of *Experimental Mathematics* is to play a role in the discovery of formal proofs, not to displace them.

**Enter the Computer**

As we have argued, experimental mathematics has always been around, so the introduction of the computer into mathematics has made more of a quantitative than a qualitative difference. But in another sense it has been quite revolutionary, affecting profoundly, if subtly, the usually unexamined and unstated basic philosophy of professional mathematicians. Its deepest effect may also be the least frequently noted.

In terms of formal training, most mathematicians are brought up (brainwashed?) to believe in the standard von Neumann–Bernays–Gödel set theory. Even those who never study set theory have no option but to absorb basic dogmas like Zorn’s Lemma. Epstein remembers as a young researcher coming across the ideas of constructive mathematics, largely through the work of Dehn in the 1920s [2]. In the late 1950s Haken created his theory of normal surfaces [3], which has been used to solve some important decidability problems: for example, Hemion and Waldhausen [4] produced an algorithm that takes as its input two knot diagrams and outputs whether the two knots are equivalent. Another recent success

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1 More information about this journal and sample issues can be obtained over the World Wide Web at http://www.geom.umn.edu/locate/expmath or by sending e-mail to expmath@geom.umn.edu. Electronic subscriptions will soon be available. Low priced individual subscriptions are available for members of the AMS.
for the theory of normal surfaces is Rubinstein's algorithm (improved and simplified by Thompson) to detect whether a finite simplicial complex is homeomorphic to the three-sphere.

Unfortunately, the theory of normal surfaces does not lend itself to practical programs, and this work, though constructive, is usually not feasible. Attempts are currently being made to bring such computations into range, but this seems a long way off, even if the number of simplices is small.

In contrast, Jeff Weeks's program SnapPea, largely based on work of Bill Thurston, can quickly compute amazing facts about a three-dimensional manifold, such as its geometric structure. SnapPea has had many remarkable successes in helping forward the understanding of three-dimensional manifolds—we are aware of over thirty research articles describing work that used SnapPea in such journals as Topology, Journal of Differential Geometry, Proceedings of the AMS, and, naturally enough, Experimental Mathematics [5]. The fact that it has been possible to write such a program is a most remarkable achievement of the constructive approach to mathematics.

Another program that has had a substantial effect on theoretical developments is the Surface Evolver, by Ken Brakke [6], which computes surfaces with properties stated by the user. Among other successes, the Evolver can be credited with helping provide a counterexample to Lord Kelvin's longstanding conjecture about the least-area regular arrangement of membranes dividing three-space into cells of equal volume [7].

These and many other programs written daily in a variety of languages have shown us in a practical way what constructive mathematics means. We no longer need to think of constructivism in the abstract; instead, we can construct away to our heart's content, at least where we have good algorithms. The intuitionists' trichotomy "True, False, Don't know", so strange to the trained and rigorous mathematician raised on conventional set theory, is completely intuitive and obvious when the answer is to be provided by a machine.

There is a feedback loop: computers in mathematics enhance the importance of the constructivist point of view, and the constructivist point of view increases the use of computers.

Another consequence of computer experimentation we have observed is psychological—the theory achieves concreteness and immediacy. Have you ever had the feeling, while reading some abstract mathematical text, of being totally disconnected from reality? It is different when the theory interacts with examples. Even if the computer is only presenting to you lists of numbers and symbols, the fact that you have connected the theory with a physical object, a computing machine, can make you feel different about it. The effect is greatly heightened if you can induce the computer to draw pictures representing the mathematical objects in question; this is, of course, only possible in certain cases but is extremely rewarding.

Contact with data and examples helps to keep one on solid ground and helps to avoid the crass blunders to which we are nearly all prone when we adopt purely formal methods of reasoning. Multi-channel research is likely to be more successful than one-channel research, and mathematicians would do well to explore as many avenues as possible of mathematical (and nonmathematical) reality related to the concepts that are of interest to them.

**But How Do You Know the Computer Gave the Right Answer?**

The history of mathematics has witnessed a steady tightening of standards of rigor, in part from experience of previously accepted standards of argument going wrong. Mathematicians should be prepared to maintain their uncompromising support of rigor. Some of our colleagues worry that the computer culture will undermine the concept of proof.

Such worries seem to us misplaced and often stem from unmerited confidence in conventional proofs. Mistakes in the conventional mathematical literature sometimes survive for years without being noticed, a famous example being the original proof of Dehn's Lemma in three-manifold theory. Conversely, sometimes correct proofs are presented and mistakenly rejected. Haken's work on normal surfaces referred to above, although flawless from the formal point of view, took many years to penetrate the barrier of skepticism. It was "obvious" to mathematicians of the mid-1950s, who had just been exposed to the unsolvability of most problems in the theory of presentations of groups, that three-dimensional manifolds could not be treated algorithmically.

At a more humdrum level, almost every published mathematics paper we have read contains errors, and often these errors, although easy to correct once one understands the paper, can and do seriously mislead readers, particularly the inexperienced.

The danger of taking the results of a computer program on trust are not that different from taking a traditional result on trust. How many people who quote the resolution of singularities can vouch for the correctness of the proof? How many who quote the classification of finite simple groups are aware that gaps remain in the proof, even a decade after it was "established", not to mention that some details depend on
computer verifications? And these are two of the most famous successes of postwar mathematics. We are not advocating that one should take results on trust; we are merely pointing out inconsistencies in the approach of some mathematicians who are suspicious of computer proofs.

When an ordinary mathematical theorem is published, we do not require it to have a formal, mechanically verifiable proof. That would be too long and incomprehensible and may, in any case, be unattainable because of the world's limited amount of paper, brain cells, computer memory, whatever. Likewise, it is unreasonable to insist that a result that depends on computer calculations must come with a formal proof of correctness. What seems reasonable is to require a statement of the algorithm used and a publicly available implementation that can be independently checked. By "the algorithm" we mean, roughly, a list of steps, each of which is fairly easy to program correctly, and a proof (in the usual sense of a mathematics journal) that these steps would lead to the claimed performance.

Skeptics will retort that there is no such thing as a nontrivial task that is "fairly easy to program correctly", and they are right. Programs almost invariably fail to do exactly what they are designed to do. Indeed, the authors' understanding of the state of the art in formal program verification is that specifying "what the program is designed to do" in a way that lends itself to automated analysis is itself very hard. Another difficulty is that even if a program is proved correct, the result relies on the correctness of the infrastructure (e.g., the absence of compiler bugs), which is currently impossible to guarantee.

Still, computers are used every day to design bridges, keep track of inventory, and fly space shuttles. We must learn to assign degrees of reliability to mathematical results that depend on computer calculations, as we do (or should) to mathematical results that do not depend on computer calculations, or to experimental results in other sciences, or to everyday operations such as balancing a checkbook. One of the hopes of the editors of Experimental Mathematics is to help the establishment of standards for experimental mathematics.

There is no question that claims are made about particular results of computer work without adequate justification, but this does not mean that every computer calculation that has not been formally verified is useless. Theorems survive by the creation of different and independent proofs, by being tested against examples, and, of course, by direct checking of the logic of the proof. This also applies to results that involve computer calculations.

A researcher who announces a computer result should start by opening the program to public scrutiny, as we have said. If the result is verified independently by other investigators using different programs, its reliability is established. If not, the level of reliability depends on many factors: whether the code (program) is documented so its logic can be checked by other workers, how many people have done the checking, what language the program is written in, and so on.

(Regarding languages: other things being equal, one should consider more reliable a program written in a language of which well-established public implementations are available. But other things are seldom equal. A short program written in a language that does not satisfy this condition, such as Mathematica, may be more reliable than a longer C program that does the same job if it avoids the need to reimplement basic routines. Of course, it would certainly be better if details on Mathematica's algorithms and their implementation were more widely known, even if commercial reasons inhibit the manufacturers from complete disclosure. At the other extreme, we have been told by an expert on computer risks that some UK government contracts insist on programs in assembly language because the compilers have not been checked for correctness. Unfortunately only fairly small programs can be checked by machine, and who checks the checkers?)
Sometimes it is much simpler to validate a proof than to discover it. Recently, Nathaniel Thurston [8], following work of David Gabai and Rob Meyerhoff, wrote a program to prove the nonexistence of groups of hyperbolic isometries satisfying certain conditions. The program is complex, and it ran for weeks; but the resulting mass of data can be checked by another, much shorter program, and if this shorter program can be proved correct, then the result is proved, even if the longer program is incorrect. Sometimes in the same spirit, for some problems there are computationally expensive algorithms that always return the right answer, together with a proof, and cheaper algorithms that have not been proved correct but seem to perform well in practice. The Mathematica functions PrimeQCertificate (reliable) and PrimeQ (not proved reliable) are examples for primality testing. A researcher might use the careless algorithm for exploratory work and thus arrive at a new result that can then be proved using the careful mode (always modulo the correctness of the implementation).

Note that the algorithms for proof verification that we are talking about are very specialized: the "proofs" they work on consist of data with a certain interpretation, a kind of shorthand, and only constitute proofs because of a background of traditional results that holds things together. (As an illustration of such an encoded proof, here is Mathematica's proof that 1021 is prime:

\{1021, 10, \{2, \{3, 2, \{2\}\}, \{5, 2, \{2\}\}, \{17, 3, \{2\}\}\}\}\}

A user of Mathematica who does not know number theory probably would not be able to make any sense of this, but a specialist in primality who has never used Mathematica may.) Conceivably, computers could also help check the logic of more general, traditional proofs. This is the subject of important research. But most mathematicians who are familiar with computers, including us, are skeptical about this possibility, at least at any time soon.

**Conclusion**

The role of the computer in suggesting conjectures and enriching our understanding of abstract concepts by means of examples and visualization is a healthy and welcome development. There are caveats, but many of them also apply to the traditional procedures that have long been accepted by mathematicians.

We believe that, far from undermining rigor, the use of computers in mathematics research will enhance it in several ways. Firstly, mathematicians who write complicated computer programs soon realize that subjecting lines of code to the usual techniques of mathematical analysis and proof often reveals faults in the programs. Programming can enhance and extend to a larger population an appreciation of why mathematicians regard proof as important. Secondly, the use of computers gives mathematicians another view of mathematical reality and another tool for investigating the correctness of a piece of mathematics through examining examples. Thirdly, and most fundamentally, it will strengthen the trend towards constructivism, helping to recast mathematics on more solid foundations.

**References**


[8] This work will be part of Thurston's Ph.D. thesis. E-mail addresses for the authors named are njt@math.berkeley.edu (Thurston), gabai@math.caltech.edu, and Meyerhoff-MT@hermes.bc.edu.

Mathematicians have always struggled with the difficulty of describing to nonmathematicians what they do. This difficulty is said to account for all sorts of ills, such as meager federal funding for mathematics research, low student interest in mathematics, and lack of appreciation for mathematics as a force in human culture. The easiest way to deal with the difficulty is to describe applications of mathematics. The hardest way is to address mathematics head-on, in all its abstractions.

In his book *Poetry of the Universe: A Mathematical Exploration of the Cosmos*, Robert Osserman deftly combines these two approaches in a serious yet lively work. Most people have wondered from time to time about what the universe is like outside of what we can observe from Earth, though fewer have wondered why Euclidean space is flat and a sphere is curved. Osserman exploits readers' natural curiosity about the universe to take them on a remarkable journey through mathematical lands unfamiliar to most.

Along the way, Osserman weaves together diverse strands of cultural, scientific, and mathematical developments, each of which makes an important contribution to the exposition. The danger in this tightly organized approach is that the reader is expected to remember too many different things in order to understand the overall picture. By some sleight of hand of which the reader remains unaware, Osserman devotes to each strand just the right emphasis and just the right amount of revisiting so that the strands illuminate the story that emerges, rather than obscuring it. A number of times, when reading about a particular topic in the book, I felt as if I were following a path through a densely packed forest that, while interesting, was unrelated to the main thrust of the book. It was delightful to emerge from the path to an open vista and see that the topic had strong and important connections to ones discussed earlier.

The writing style is concise and elegant, unadorned with flashy tricks that a writer less sensitive to the beauty of the subject might be
tempted to throw in. Osserman does not beat
readers over the head with technicalities, nor
does he apologize for technical aspects when he
needs to introduce them. He takes it on faith that
readers will be just as enraptured by the subject
as he is, rather than moralizing about why they
should be enraptured. The simplicity of this ap­
proach works.

The book begins in an­
tiquity, with Greek and
Egyptian attempts to mea­
sure the size of the earth. At
that time, it was commonly
accepted that the earth is a
ball, not a flat surface; it
was only later, when much
of the knowledge of the
Egyptians and Greeks was
lost after the fall of ancient
civilizations, that the idea
of a flat earth took hold in
the West. Osserman points
out that by the time of
Columbus, the notion of a
round earth was once again
in favor. Columbus did not
set out on his voyage as­
suming that he would reach
the "edge" of the earth
(though he and his com­
temporaries did wonder if his
ships would fall off the
earth when they sailed
around the "bottom").

Throughout the ages
people wrestled with the
problem of making accurate
maps of the earth. Osser­
man describes Mercator's
projection and Gauss's
work on geodesy, and along the way describes
why a completely accurate two-dimensional map
of the earth is impossible. The notion of curva­
ture is explained at first with down-to-earth pic­
tures of what orchards of trees would look like
on differently curved surfaces. These pictures are
gradually replaced by more abstract ones of sur­
faces with positive, negative, and zero curva­
ture.

In the early 1800s, Lobachevsky and Bol­yai si­
multaneously introduced the intriguing notion
of noneuclidean geometry, asking what would
happen if one replaces Euclid's parallel postu­
late by different notions. (Actually, Osserman
points out that Johann Lambert, a contemporary
of Euler's, had explored these ideas earlier but
convinced himself that they would lead to a con­
tradiction and did not pursue the work further.)
Osserman's ingenious explanations of the oddi­
ties of hyperbolic space would be enormously
useful to a student who is exploring the subject
for the first time.

Once one admits the possibility that the uni­
verse might be a three-sphere, the problem of
how to make a useful "map" arises. At this point
Osserman draws on his earlier discussions of the
analogous problem of making maps of the two­sphere of the earth. And it
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Taking up where
Lobachevsky and Bol­yai left
off, Riemann further de­
veloped the ideas of non­
euclidean geometry. He
constructed a model in
which the universe is seen
as a three-sphere: the way
to visualize it is as two sepa­
rate three-balls in three­
space, with their bound­
aries identified. Looking at
this as an "egocentric map" of the universe, one
imagines Earth at the center of one of the balls
and its antipodal point at the center of the other.
If one crosses at any point the boundary of the
first ball, one enters the second. A geodesic path
starting at Earth passes through the antipodal
point in the other ball and closes up back at Earth
again. Even though such constructions are com­
monplace in mathematics today, the power of
Riemann's ideas remains awe inspiring. "[E]ven
today—a century and a half later—it stretches
our imaginations to the limit to encompass Rie­
mann's vision," writes Osserman.

Osserman notes Dante's description of the
universe in the Divine Comedy, which bears
striking resemblance to Riemann's three-sphere.
Dante pictured the universe as two balls, one
called the "Primum Mobile", which has the earth
at its center, and the other called the "Empyrean".
The surface of the Empyrean is inhabited by an­
gels, and the center is a light of blinding intensity. "[W]e are to think of the Empyrean as somehow both surrounding the visible universe and adjacent to it," Osserman writes. "If that is the case, then the universe according to Dante would coincide exactly with the universe according to Riemann; they would differ only in the labels."

There are infinitely many possibilities for the geometry of the universe, and in order to understand which ones might be correct, one must uncover clues hidden in astronomical observations. One of the central tools is Hubble's Law, which says that all stars and galaxies are moving away from Earth at a speed proportional to their distance from Earth. The notion that as we examine distant galaxies we are actually looking back in time is one that, for most readers who are not scientists, will take some getting used to.

The emphasis Osserman devotes to this important point pays off later on, when he describes Einstein’s work and adds time as the fourth dimension.

Having explained the model of the universe as a three-sphere, Osserman goes on to examine other manifolds that might be possible candidates for representing the shape of the universe. The three-sphere yields a model of the universe with constant positive curvature. By contrast, one could also consider a toroidal universe with a flat metric. In a mathematically precise yet nontechnical way, Osserman describes these objects and manages to convey not only their utility as models for the universe but also their innate fascination. Even if one cannot prove that the universe has this or that particular shape, there is great satisfaction to be had in contemplating the possibilities. In addition, these mind-expanding explorations illustrate the power of mathematics to explain subtle and important aspects of the physical world and to provide clues about where to look for new information.

The denouement of the book comes not on the last page, but in the seventh of the nine chapters. There Osserman discusses the 3-degree microwave background radiation that emanates from every point in the sky. This radiation is thought to be the oldest that can be detected, originating about 300,000 years after the Big Bang. This is as far back in time as human beings can see. As Osserman puts it, "A curtain suddenly drops, permanently blocking from view what lies beyond." This was foreshadowed in the prelude to the book, which includes a "picture" of this radiation, assembled from observations made by the Cosmic Background Explorer that was launched in 1989. Just as Mercator wrestled with the question of how best to draw a flat map of the earth, astronomers had to come up with a way of representing in a two-dimensional picture this background radiation. Essentially, the book is devoted to explaining just what that picture means.

Although it is aimed at those with little background in science and mathematics, mathematicians are sure to love this book. With no equations, few symbols, and no proofs, the book nevertheless is scrupulously faithful to the mathematics it describes. Those who work outside geometry and topology will gain new appreciation and intuition, and those who do work in these areas will value Osserman’s insights into familiar problems. The book would be an excellent antidote for the mathematics student ensnared in thickets of equations and definitions. Detailed notes at the end of the book point to sources for further reading.

But will this book appeal to the general public, to those with no background in science or mathematics? It seems unlikely that someone with no previous interest in the subject would pick up this book and read it from start to finish; but then, that is true of just about any book, particularly nonfiction works. The mind-stretching visualizations required to really understand the ideas in the book would tax the patience of many readers, especially those accustomed to instant visual recognition so common in today's world of television and video games. The book is engaging, lively, and well paced, but (to its credit) not what might be called "entertaining". The book’s overarching organization is a model of clarity, and it nimbly skirts technical jargon. However, some readers could be confused by small details, such as the interchangeable use of terms like "the parallel postulate", or "parallel postulate", or "circumference" of a circle and "length" of a circle.

Such minor quibbles aside, this book offers many mathematical riches to readers of any background. The "poetry" referred to in the title is a genre that too few are familiar with. This mathematically honest and highly readable account explores realms of beauty that deserve more attention.

—Allyn Jackson
Nathan Fine 1916-1994

George E. Andrews

Nathan (Nat) Fine, a member of the American Mathematical Society for 53 years and of the Mathematical Association of America for 52 years, died on November 18, 1994, in Deerfield Beach, Florida, at the age of 78. Fine was born on October 22, 1916, in Philadelphia. He obtained a B.S. from Temple University in 1936, an A.M. from the University of Pennsylvania in 1939, and a Ph.D. there in 1946. In 1947, he was appointed assistant professor of mathematics at Penn. Before that he had held a variety of mathematical jobs: junior high teacher, 1941-1942; instructor at Cornell, 1942; and Purdue 1942-1945; as well as research mathematician for the Naval Ordnance Plant (Indianapolis), 1944-1945, and for the Operations Evaluations Group (Washington, D.C.), 1946-1947.

He rose to full professor at Penn in 1956. In 1963, he moved to Penn State University, where he remained until his retirement as Emeritus Professor in 1978. In 1953-1954 he was an NSF Postdoctoral Fellow, and in 1958-1959 he held a Guggenheim Foundation Fellowship; in 1966 he was the M.A.A.'s Hedrick Memorial Lecturer, where he presented an introduction to the material in his subsequent book on basic hypergeometric functions. He also served on a number of national committees on mathematics and mathematics education. Fine had three Ph.D. students: Justin Price (Purdue), Anthony Hager (Wesleyan), and William Webb (Washington State).

In addition to mathematics, he enjoyed a variety of games, including Go, chess, bridge, billiards, and backgammon. He was a life master at bridge and played duplicate bridge until two days before he died.

While the above provides a quick outline of Fine's life and achievements, it tells nothing of his essential qualities as a mathematician. His contributions are sufficiently broad that a short article by only one of his many friends and students will convey a somewhat distorted view. Having said that, I would like to offer the following account of how Nathan Fine profoundly affected my life.

I first met Nat in 1961 when I began graduate school at the University of Pennsylvania. In 1962 I took his course "Basic Hypergeometric Functions" under the mistaken assumption that "basic" meant "elementary". This was perhaps the most fortunate mistake I ever made. Twenty-six years later, I wrote the foreword to his book Basic Hypergeometric Series and Applications. The following is an abridged version of what I said:

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"In 1948, Nathan Fine published a note in the *Proceedings of the National Academy of Sciences* announcing several elegant and intriguing partition theorems. These results were marked both by their simplicity of statement and by the depth of their proof. Fine was at that time engaged in his own special development of $q$-hypergeometric series, and as the years passed he kept adding to his results and polishing his presentation. Several times, both at Penn and Penn State, he presented courses on this material. I took the course twice, first in 1962–1963 at Penn and then in 1968–1969 at Penn State. As a graduate student at Penn, I wrote my thesis on mock theta functions under Rademacher’s direction. The material that Fine was lecturing about fit in perfectly with my thesis work and introduced me to many aspects of this extensive subject. The course was truly inspiring. As I look back at it, it is hard for me to decide whether the course material or Fine’s exquisite presentation of it impressed me most.

"Research on $q$-hypergeometric series is significantly more active now than when Fine began his researches. There are now major interactions with Lie algebras, combinatorics, special functions, and number theory."

Much more could be added about Fine’s "exquisite presentation". My fellow students and I viewed him as a mathematical juggernaut. He spoke deliberately and somewhat slowly (thank goodness). He smoked unfiltered Camel cigarettes which he Persian-inhaled throughout each lecture. I look back fondly on Nat, his beautiful mathematics, and his ever-present cigarettes. In each lecture, he was clearly having a whale of a good time, and so were we.

It is almost impossible to describe the impression I had of his intellect. I think I can come closest by relating a story about the first class I took from him, a first-year graduate course in algebra in 1962. Fine often assigned homework from the text and one day inadvertently included one of those extra challenging problems designed to humble even the most arrogant graduate student. Whenever you do this, it is, of course, wise to make sure you know how to do the problem before you get to class. Nat had failed to notice the jawbreaker in this otherwise innocuous mixture of soft candies. When he asked at our next meeting, "Are there any questions," a number of hands went up. "What about problem X?" Nat asked if anyone had done the problem. A number thought they had. Two things emerged as the hour progressed: (1) This problem was a killer. (2) Each of my fellow students who thought he had solved the problem hadn’t.

Fine put on a display like I had never seen previously; it was clear from what he said that he had not looked at the problem before. In his slow and deliberate manner he dismantled each of the incorrect solutions clearly pointing out each error. All the while one could sense that he was just buying time and devoting only a small fraction of his attention to these incorrect answers. With ten minutes left, you could sense his relief as he had clearly solved the problem, and his last ten minutes were devoted to his correct solution of it. I subsequently thought of him as a mathematical Sherman Tank, not terribly speedy but absolutely inexorable as he rolled over mathematical challenges. This image, while partially correct, fails to convey the elegance and charm of Fine’s discoveries. He was a grand mathematician, and we who knew him mourn his passing.

This is probably not the place to provide a detailed analysis of Fine’s mathematical work. However it is perhaps appropriate to mention that in the introduction to his book on basic hypergeometric series, he singled out

$$\prod_{n=1}^{\infty} \frac{(1-q^{2n})(1-q^{3n})(1-q^{8n})(1-q^{12n})}{(1-q^{n})(1-q^{24n})} = 1 + \sum_{N=1}^{\infty} E_{1,5,7,11}(N; 24) q^N$$

as a result that especially pleased him (where $E_{1,5,7,11}(N; 24)$ is the sum of the divisors of $N$ congruent to 1,5,7, and 11 mod 24 minus the sum of those congruent to -1,-5,-7, and -11). One sees here the sort of mathematical taste that typified Ramanujan.

Fine published nearly forty papers on a variety of topics including number theory, logic, combinatorics, group theory, linear algebra, partitions and functional and classical analysis. Perhaps the most enduring of his papers is his Ph.D. dissertation on Walsh functions written under the direction of A. Zygmund and inspired by earlier work of his friend, H. Radamacher. This paper, together with his further work on Walsh functions, eventually led to his invitation to prepare his article on Walsh functions for the *Encyclopedic Dictionary of Physics*. His work on rings of quotients of continuous functions with Len Gillman, as well as the book with Gillman and Lambe, has been of continuing interest in functional analysis.

Finally it should be noted that Nat was a devoted problem solver. In addition to contributing problems and their solutions to numerous journals, he was also one of the active faculty participants in the legendary Pro-Seminar at the University of Pennsylvania. When he moved to Penn State, he instituted a problems course there, and in his retirement in Florida he taught such a course at Broward Community College as in-service training for mathematics faculty.
AMS Redirects Centennial Fellowship to Young Mathematicians

Mary Beth Ruskai and Robert Zimmer

At its March meeting in Chicago, the AMS Council authorized the redirection of the Centennial Fellowship to young (in the sense of years from Ph.D.) mathematicians, beginning with the fall 1995 application process. Details of the new program are still being worked on by the AMS Committee on the Profession (CoProf). However, the Council voted to authorize the redirection so that solicitation of contributions from AMS members could begin with the summer 1995 dues notices.

TheAMS Research Fellowship began in 1974, during an earlier employment crisis, as a postdoctoral fellowship program for recent Ph.D.s. The NSF established postdoctoral fellowships in mathematics in 1979, and in 1984 the eligibility period for the AMS fellowship was shifted so as not to overlap with the NSF program. Eligibility rules were changed several times; since 1990 the program has been directed toward mathematicians 7–12 years from the Ph.D. who have not had more than two previous fellowship years. In 1987 the name was changed to AMS Centennial Fellowship, and the current practice of using a dues checkoff to facilitate contributions began.

Despite concern for the needs of young mathematicians, the decision to redirect the fellowship was not made lightly. The CoProf report to Council stated:

The environment in which a discussion of the Centennial Fellowships now takes place is one of declining resources for support of mathematics research. As a consequence, there are numerous directions that are underfunded and numerous potential programs that one can easily see as being worthwhile, aimed at providing needed resources in these various directions. While this point is at play in numerous issues regarding funding decisions, it has an inevitable strong presence in the discussions of the issue of what the Centennial Fellowships should be, by virtue of the unique nature of these Fellowships of being raised directly by the mathematics community for the mathematics community. An immediate example is provided by the issue of changing the Fellowships from their present form. We believe, and believe

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it is generally felt, that as presently constituted the Fellowships play a valuable role and that they have been a success in filling the role that has defined them in recent years. Rather, the thought of changing these Fellowships comes from a sense that there are other underfunded directions that should have a higher priority. This is a matter of judgement and setting priorities, and it is the sense of our committee that in fact a change to other directions, namely, providing support to younger mathematicians, should take place. Nevertheless, even within the context of moving support to younger mathematicians, there are numerous issues that arise which again concern setting priorities in a situation of scarcity.

Because of the availability of the NSF postdoctoral program, CoProf has been examining other ways of using the funds. While there are undoubtedly more young mathematicians who could benefit from an NSF style postdoc, successful research mathematicians do not always follow one standard career path. Therefore, CoProf is trying to develop a new program which will foster research excellence by targeting a different group of promising young mathematicians than those already well served by existing fellowship programs.

The term "young mathematicians" is not well defined, and the eligibility period is still under discussion. The redirected program will almost certainly target recent Ph.D.s at the pretenure stage. However, to minimize overlap with other programs, such as the NSF postdocs and the prestigious research instructorships at top mathematics departments, new Ph.D.s will not necessarily be eligible.

CoProf plans to submit a proposal to the ECBT for discussion at its May 1995 meeting and a final plan to the AMS Council for approval in August. The AMS Notices will keep members informed as further information becomes available. New application forms and procedures should be ready early in the fall of 1995.

However, all AMS members should be aware that contributions made with their AMS dues payment in the summer of 1995 will be applied to the new program. Proponents of the new plan hope that contributions will increase significantly so that more young mathematicians can benefit.
Gábor Szegő Centenary

Paul Nevai

Gábor Szegő was born one hundred years ago on January 20, 1895, in Kunhegyes, Hungary (and died on August 7, 1985, in Palo Alto, California).

To the mathematics community, Szegő is best known for his masterpiece Aufgaben und Lehrsätze aus der Analysis, vols. I and II (written with his mentor and friend, George (György) Pólya, Springer-Verlag, Berlin, 1924), which was used by generations of mathematics students (and their professors). Quoting Pólya: "It was a wonderful time; we worked with enthusiasm and concentration. We had similar backgrounds. We were both influenced, like all other young Hungarian mathematicians of that time, by Leopold (Lipót) Fejér. We were both readers of the same well-directed Hungarian Mathematical Journal for high school students that stressed problem solving. We were interested in the same kind of questions, in the same topics; but one of us knew more about one topic, and the other more about some other topic. It was a fine collaboration. The book Aufgaben und Lehrsätze aus der Analysis, the result of our cooperation, is my best work and also the best work of Gábor Szegő."

For analysts, Szegő is best known for Szegő’s extremal problem and his results on Töplitz matrices which led to the concept of the Szegő reproducing kernel and which were the starting point for the Szegő limit theorem and the strong Szegő limit theorem and for Szegő’s theory of Szegő’s orthogonal polynomials on the unit circle. These have been summarized in his books Orthogonal Polynomials (Colloquium Publications, vol. 23, American Mathematical Society, Providence, Rhode Island, 1939) and Toeplitz Forms and their applications (jointly with Ulf Grenander, University of California Press, Berkeley and Los Angeles, 1958). The former is one of the most successful books ever published by the American Mathematical Society (four editions and several reprints).

Several of his friends, collaborators, and students have corresponded on a plan for a memorial (most likely a bronze relief to be set up in Kunhegyes in front of the city library) dedicated to Gábor Szegő.

Kunhegyes is a small town situated approximately 150 km southeast of Budapest. Szegő was one of the (two or three) most prominent people born there, so it is very appropriate to have a memorial placed there, especially since the citizens of Kunhegyes are committed to maintain such a memorial for many years to come. One might justifiably argue that either Budapest or Stanford would also be a proper place for such a memorial. As a matter of fact, there is a discussion going on about placing copies of the Szegő memorial in either Budapest or Stanford or both.

It is expected that such a memorial will cost in the neighborhood of three to five thousand U.S. dollars. For information on how to participate in this project, please contact either Paul Nevai, Department of Mathematics, Ohio State University, Columbus, OH 43210-1174, USA. (e-mail: nevai@math.ohio-state.edu, telephone: 614-292-3317) or perhaps the other sponsors of this project: namely, Dick Askey, Paul Erdős, Samuel Karlin, Peter Lax, Lee Lorch, Gilbert Strang, and Harold Widom, or one of the children of Gábor Szegő.

Finally, additional information can be found on Szegő at http://www.math.ohio-state.edu/JAT/DATA/ATNET/szego.

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Coxeter Receives Joint CRM/Fields Prize

The first Joint Centre de Recherches Mathématiques/Fields Institute Prize has been awarded to Professor H.S.M. (DONALD) COXETER of the University of Toronto. Professor Coxeter is being honored for a long and remarkable record of accomplishment.

Although he has drawn inspiration from elementary geometry and the symmetries of Platonic solids, Professor Coxeter's work has permeated modern mathematics. He has worked in a range of areas, from groups acting on n-space and sphere packings in n-dimensions, to the structure and classification of Lie groups, to noneuclidean geometry. In addition to mathematicians, many others—including artists, architects, chemists, philosophers, and physicists—know of Coxeter and have been directly influenced by his writing and his unfailing sense of beauty in mathematics. His book *Regular Polytopes* has been a classic since the time it was written and has been and continues to be widely read. The recent advances in buckyballs, fullerenes, and quasicrystals have reemphasized that the regular and semiregular polytopes continue to play important roles in science and mathematics.

Harold Scott MacDonald Coxeter was born in London, England, on February 9, 1907. He received his bachelor's degree in 1929 and his Ph.D. in 1931, both from the University of Cambridge. He also holds honorary degrees from University of Alta (1957), Waterloo University (1969), Acadia University (1971), Trent University (1973), University of Toronto (1979), Carleton University (1984), and McMaster University (1988).

Professor Coxeter was a Fellow of Trinity College, Cambridge, from 1931 to 1935. Concurrently, he was a Rockefeller Foundation Fellow (1932-1933) and a Procter Fellow (1934-1935) at Princeton University. In 1936 he moved to the University of Toronto. Professor Coxeter has held numerous visiting positions at universities around the world. He was editor-in-chief of the *Canadian Journal of Mathematics* from 1949 to 1958. In 1974 he was president of the International Congress of Mathematicians when it was held in Vancouver.

Professor Coxeter received the Tory Medal in 1949. He is a fellow of the Royal Society, London, and of the Royal Society of Canada. He is a foreign member of the Royal Netherlands Academy of Arts and Sciences and a foreign honorary member of the American Academy of Arts and Sciences.

As part of the Joint CRM/Fields Institute Prize, Professor Coxeter will present lectures at The Fields Institute during the fall of 1995 and the Centre de Recherches Mathématiques during September 1995.

—Allyn Jackson
Fossum Elected to Norwegian Society

AMS Secretary ROBERT M. FOSSUM has been elected to the Royal Norwegian Society of Sciences and Letters, the oldest learned society in Norway. Membership in the natural sciences section, to which Fossum was elected, is limited to 200 people, fifty of whom may be nonresidents of Norway.

Fossum, a professor of mathematics at the University of Illinois at Urbana-Champaign, has been at that institution since 1964. He was a Fulbright Scholar at the University of Oslo in 1967 and has been a visiting professor at universities in Aarhus, Copenhagen, and Paris. The author of many scholarly papers and books, Fossum has served as editor of several research journals, including the Proceedings of the AMS from 1973 to 1977. He has been AMS secretary since 1989.

—from University of Illinois News Release

D. J. Lewis Named DMS Director

The Division of Mathematical Sciences at the National Science Foundation (NSF) has announced that D. J. LEWIS of the University of Michigan, Ann Arbor, has accepted the position of division director. He succeeds Frederic Y. M. Wan, who left the DMS in January to become vice-chancellor for research and dean of graduate studies at the University of California, Irvine.

"It is the task of the division director to make use of whatever options are provided by Congress to maximize the funding available for mathematics," Lewis says. "To do so will be one of the challenges of this position." The DMS has in recent years been able to take advantage of funding made available through various federal "strategic initiatives". Although some in the mathematical community have questioned the value of such initiatives, there is no doubt that they have benefited mathematics funding. "In my opinion, [the two previous DMS directors] Judy Sunley and Fred Wan did an excellent and very imaginative job in finding ways to use the various strategic initiatives to increase funding for all of mathematics," Lewis points out. "They did far better than any of the other core disciplines. Very few understand what they accomplished and where mathematics would be without those efforts." The funding picture Lewis will face might be quite different, as it appears that Congress may no longer support the initiatives, given the enormous pressure to balance the federal budget.

One of the oft-mentioned problems with mathematics research funding is that too few people receive funding. In recent years, various mechanisms, such as salary caps, have been proposed as ways to increase the number of mathematicians receiving NSF funding. However, the DMS is not fully autonomous in making such decisions, Lewis points out. They depend on the budget and on the policies set forth by the National Science Board, the policy-making body of the Foundation. In addition, he points out, "Sometimes fewer but better funded" makes sense, especially when the alternative is for all to be extremely underfunded." But, he notes, "It is probably time to ask if current funding strategies are the best way to use limited funding to advance mathematics. This will be especially important should funding be reduced." He intends to work with the mathematical community to map out alternative funding strategies and bring them before the National Science Board and the Directorate for Mathematical and Physical Sciences. As an example, he pointed to the new group infrastructure grants established this year by DMS in response to advice from the AMS Committee on Science Policy.

Lewis notes that the DMS director is not in a position to personally influence Congress; that task falls to the mathematical community, acting as individuals or through such groups as the Committee on Science Policy. "In making its case, the mathematics community may well need to examine whether it is serving the country as well as it might and rethink what its role should be," he remarks. "There is a lot of skepticism in the general public with regard to higher education, research, and even science... Just sitting back and doing good research will not, in this climate, produce additional funding."

A noted number theorist, D. J. Lewis received his Ph.D. from the University of Michigan in 1950. He was an NSF Fellow at the Institute for Advanced Study in Princeton (1952-1953), an NSF Senior Fellow (1959-1961), a Senior Visiting Fellow at Cambridge (1965, 1969), a Visiting Fellow at Oxford (1976), and a Humboldt Awardee (1980, 1983). He has served as organizer of a number of major research conferences in number theory. He presented an AMS Invited Address in Urbana, Illinois, in 1970 and a Mordell Lecture at Cambridge University in 1980. Active on a variety of AMS committees, Lewis has been on the Notices Editorial Committee (1989-1992), the Joint Committee on Women in the Mathematical Sciences (1992-1994), and the Committee on Processional Ethics (1992-). He served as Chair of the Mathematical Reviews Editorial
Committee (1975–1977) and of the AMS Employment Task Force (1991–1992). Lewis is currently on the AMS Board of Trustees. He was the chair of the Department of Mathematics at the University of Michigan from 1984 to 1994 and served twice on the NSF Advisory Committee for the Mathematical Sciences. In January 1995 he received the AMS Distinguished Public Service Award for his outstanding contributions to the profession.

—Allyn Jackson

Rollo Davidson Trust

The trustees of the Rollo Davidson Trust have awarded Rollo Davidson Prizes for 1995 to two individuals. PHILIPPE BIANE of the University of Paris VI was honored for his work on Brownian motion and quantum probability. YUVAL PERES of the University of California, Berkeley, was honored for his work on probability on trees and connections with Brownian motion.

—Trustees of the Rollo Davidson Trust

Albert Cohen Receives Popov Prize

ALBERT COHEN of the University of Paris-Dauphine and École Normale Supérieure des Techniques Avancées was awarded the first Vasil Popov Prize on January 9, 1995, at the Texas Conference on Approximation Theory. The prize, established in memory of Vasil Popov, is awarded to a young mathematician who has made outstanding research contributions in approximation theory and/or related areas. The prize will be awarded every three years in conjunction with the Texas conference.

The Popov Prize was presented to Cohen by Ronald DeVore of the University of South Carolina on behalf of the selection committee. The other members of the committee were Charles Chui, Paul Neval, Allan Pinkus, Pencho Petrushew, and Edward Saff. After the prize presentation, Cohen presented a plenary lecture entitled “Nonlinear wavelet approximation and image compression”.

Albert Cohen received his Ph.D. in 1990 from the University of Paris-Dauphine, under the direction of Yves Meyer. Cohen’s first research dealt with the relation between wavelet theory and filter banks used in signal processing. These investigations led to the design of certain filter banks (related to biorthogonal wavelets) that are widely used by engineers in image and signal processing. This work also provided a deeper understanding of multiresolution analysis and refinement equations. This research, done in collaboration with Ingrid Daubechies, has been extended to the multivariate setting. Cohen has also made significant contributions to the development of multiscale methods for Euclidean domains and to the construction of related numerical algorithms. His recent work has emphasized the connections between wavelet theory and approximation, especially in the context of nonlinear approximation.

—Ronald DeVore, University of South Carolina

Sloan Fellowships Announced

The Alfred P. Sloan Foundation has announced the names of 100 outstanding young scientists and economists selected to receive Sloan Research Fellowships. Among the awardees were twenty mathematical scientists.

Now in its fortieth year, the Sloan Research Fellowship Program provides grants of $30,000 per year for two years. Candidates for the fellowships are nominated by department chairs and other senior scholars. More than 400 nominations were reviewed for the 1995 awards. The committee choosing the awardees in mathematics consisted of Spencer J. Bloch of the University of Chicago, William P. Thurston of the Mathematical Sciences Research Institute, and Karen K. Uhlenbeck of the University of Texas at Austin.

The names of the mathematics grantees and their institutional affiliations are listed below.

ALEXANDER I. BARVINOK, University of Michigan; ANN ARBOR; ANDREA L. BERTOZZI, University of Chicago; LUCIA CAFORASO, Harvard University; EDWARD FRENKEL, Harvard University; SERGEI IVANOV, University of Illinois at Urbana-Champaign; TASSO J. KAPER, Boston University; BRUCE KLEINER, University of Pennsylvania; RUTH J. LAWRENCE, University of Michigan, Ann Arbor; JOHN S. LOWENGRUB, University of Minnesota; JEFFERY D. MCNEAL, Princeton University; YAIR MINSKY, State University of New York, Stony Brook; VICTOR NISTOR, Pennsylvania State University; YONGBIN RUAN, University of Utah; ANDRAS SZENES, Massachusetts Institute of Technology; DANIEL I. TATARU, Northwestern University; BURT TOTARO, University of Chicago; RICHARD WENT-
WORTH, University of California, Irvine; ILYA ZAKHAREVICH, Ohio State University; FANGYANG ZHENG, Duke University; and YUXI ZHENG, Indiana University.

—from Sloan Foundation News Release

NSF Young Investigator Awards Announced

In November 1994, the National Science Foundation (NSF) announced awards in the 1994 NSF Young Investigator program. This program serves to recognize outstanding young faculty and enhance their careers.

Each award provides up to a maximum of $100,000 per year of public and private funds for five years to advance the awardee’s teaching and research career. The NSF provides each year a $25,000 base grant and up to $37,500, dollar-for-dollar, funds from private or nonprofit sources.

Approximately 1,435 nominations were received and 200 awards were made in all areas of science and engineering. Seven went to scholars in the mathematical sciences. Their names, affiliations, and research areas are given below.

OSCAR P. BRUNO of the Georgia Institute of Technology received his doctorate in 1989 from the Courant Institute for Mathematical Sciences at New York University. He works in applied mathematics, numerical analysis, materials, electromagnetism, and plasma physics.

ANDREW E. GELMAN of the University of California, Berkeley, received his doctorate from Harvard University in 1990. He works in statistics.

IGOR KRUZ of the University of Michigan, Ann Arbor, received his doctorate from Charles University in Prague in 1988. He works in algebraic topology and algebraic geometry.

MARK A. LEWIS of the University of Utah received his doctorate from Oxford University in 1990. He works in mathematical biology, applied mathematics, and ecology.

VICTOR NISTOR of Pennsylvania State University received his doctorate in 1992 from the University of California, Berkeley. He works in operator algebras and noncommutative geometry.

YUAN WANG of Florida Atlantic University received his doctorate from Rutgers University in 1990. He works in applied mathematics and control theory.

JONATHAN WEITSMAN of Columbia University received his doctorate in 1988 from Harvard University. He works in geometry and mathematical physics.

—National Science Foundation

Deaths

ANDREJ V. BITSADZE, of the Steklov Institute of Mathematics in Moscow, Russia, died on September 6, 1994. Born on May 22, 1916, he was a member of the Society for 1 year.

BENEDITO CASTRUCI, of the University of Sao Paulo, Brazil, died in January 1995. Born on July 8, 1909, he was a member of the Society for 38 years.

AVRON DOUGLIS, Professor Emeritus of the University of Maryland, died on February 15, 1995. Born on March 14, 1918, he was a member of the Society for 37 years.

KUNIO GOMI of Tokyo, Japan, died in September 1993. Born on January 25, 1927, he was a member of the Society for 16 years.

R. T. MCLEAN, of Loyola University in New Orleans, LA, died on November 6, 1994. Born on July 18, 1922, he was a member of the Society for 38 years.

HAIM HANANI, Professor Emeritus of the Technion-Israel Institute of Technology, died in April 1991. Born on September 11, 1912, he was a member of the Society for 34 years.

ALEXANDER P. ROBERTSON of Nedlands, Australia, died on January 31, 1995. Born on June 16, 1925, he was a member of the Society for 35 years.

JOHN LIGHTON SYNGE, formerly director of the School of Theoretical Physics, D. I. A. S. in Dublin, Ireland; professor of mathematics at Carnegie Institute in Pittsburgh, PA; Ohio State University in Columbus, OH; and at the University of Toronto in Canada, died on March 30, 1995, in Blackrock, County Dublin, Ireland, at the age of 98. He was a member of the Society for 68 years.
Listed here are the National Science Foundation (NSF) Calculus Reform Workshops for the summer of 1995. All participant expenses, except for travel, are paid by the NSF. Those interested in attending workshops should call or write to the Local Contact persons for information.

Calculus Reform: Activities and Projects, May 28-June 2, 1995. Instructors: Don Small (U.S. Military Academy) and Willie Taylor (Texas Southern University). Local Contact: Della Bell, Department of Mathematics, Texas Southern University, Houston, TX 77004; telephone 713-527-7002.


Calculus in Context, June 11-16, 1995. Instructors: Harriet Pollatsek and Don O'Shea (Mount Holyoke College). Local Contact: David Ford, Department of Mathematics, Emory University, Atlanta, GA 30322-2390; telephone 404-727-7962.


St. Olaf Project, June 18-23, 1995. Instructors: Arnie Ostebee and Paul Zorn (St. Olaf College). Local Contact: Clayton Dodge, Department of Mathematics, University of Maine, Orono, ME 04469-5752; telephone 207-581-3908.


Calculus Resources, June 18-23, 1995. Instructor: Wayne Roberts (Macalester College) and Marcella Beacham (Daley College). Local Contact: James Wilson, Department of Mathematics, Daley College, 7500 So. Pulaski, Chicago, IL 60652; telephone 312-838-7635.

An Active Approach with Projects, July 9-14, 1995. Instructors: Steve Hilbert and Diane Schwartz (Ithaca College). Local Contact: Chris Christensen, Department of Mathematics, Northern Kentucky University, Highland Heights, KY 41076; telephone 606-572-6672.

—Don Small, Workshop Coordinator
The Council Meeting in San Francisco

The Council of the American Mathematical Society met at 9:00 a.m. on Saturday, 07 January 1995, in the San Francisco Hilton Hotel. About thirty members of the Council were present for portions of the meeting. President Graham presided. What follows is a report on the actions of the Council. The official minutes of the Council are on file with the secretary and the executive director. They are available in original LATEX source and .dvi files on the Web at URL http://odin.math.uiuc.edu.

The Council began in executive session to consider election of officers and members of editorial boards. It also discussed whether or not to participate in a meeting in the summer of 1996 with the Mathematical Association of America. The actions taken by the Council in executive session are reported below.

The Council rose from executive session at about 10:00 a.m.

It was noted that several members of the Council were either changing positions or leaving the Council. Ronald L. Graham became ex-president on 31 January as Cathleen Morawetz became president. Graham will remain on the Council and on the Executive Committee. Mathematical Surveys Editorial Committee Chair Marc Rieffel will retire from that position but will remain on the Council as a member of the Executive Committee. The terms of Vice-President Linda Keen; American Journal of Mathematics Editorial Committee Representative Henri Gillet; Bulletin Editorial Committee Chair Richard Palais; Journal of the AMS Editorial Committee Chair H. Blaine Lawson; Executive Committee member Arthur Jaffe; and Members-at-Large Ruth M. Charney, Carl C. Cowen, Jr., Rebecca Herb, and Elliott H. Lieb ended on 31 January 1995. This was their last meeting in their current positions. The secretary requested and received unanimous consent to send thanks on behalf of the Council to each of these individuals for sharing their wisdom with the Society and the Council and for their service to the mathematical community.

The president introduced John Ewing, Indiana University, who is the newly appointed executive director of the Society. He will succeed William H. Jaco in mid-summer 1995.

Just after the consideration of the minutes in open session, it was moved and seconded to place on the agenda for consideration and possible action by the Society a resolution passed by the Association of Women in Mathematics on 04 January 1995. Since this item was not on the original agenda, it was ruled by the chair that a two-thirds affirmative vote of the Council was required to place the item on the agenda, according to rules\(^1\) of the Council. The vote on the motion was recorded as eleven (11) votes in favor, ten (10) opposed, and three (3) abstentions. Therefore the item was not placed on the agenda. (It was the sense of the Council that the resolution would be referred to the Committee on the Profession for possible consideration at some future meeting.) The minutes of the August 1994 Council were distributed by mail. The secretary requested and received approval of the minutes as distributed.

The minutes of the Business by Mail consenting to the appointment of Executive Director John Ewing were approved.

\(^1\) These rules appear in the Manual for Officers and Trustees, a new version of which will be available soon.
The ECVT met in Providence, RI, in November 1994. The minutes from this meeting will be distributed and are considered a part of the minutes of the Council.

The Canadian Mathematical Society is celebrating its fiftieth anniversary in 1995. To recognize this, the Council adopted the following resolution:

The Canadian Mathematical Society, founded in 1945 as the Canadian Mathematical Congress to promote research in mathematics; to assist in improving the teaching of mathematics in Canadian universities, colleges and schools; and to encourage and assist in the development of mathematics and mathematics education, is celebrating its Fiftieth Anniversary in 1995.

The American Mathematical Society extends to its sister organization to the north warmest congratulations on this happy occasion. The Society looks forward to continued cooperation with the Canadian Mathematical Society in our common goals of promoting mathematical scholarship in North America and throughout the world.

The Council accepted the report of the teller, in which it was reported that Gian-Carlo Rota of MIT has been elected to a three-year term as vice-president and that David B. A. Epstein, University of Warwick; Cora Sadosky, Howard University; James M. Hyman, Los Alamos National Laboratory; Jerrold E. Marsden, University of California Berkeley; and Alice Silverberg, Ohio State University, were elected to three-year terms as members-at-large of the Council.

The individuals elected to the Council in 1994 took office on 01 February 1995. The secretary recommended that these newly elected members who were present at the Council meeting be granted privileges of the floor (but without voting privileges) at this Council meeting.

In other results from the election; Donald E. McClure, Brown University, was elected to a five-year term as trustee; Ingrid Daubechies, Princeton University, Susan G. Williams, University of South Alabama, and Jerry Bona, Penn State University, were elected to three-year terms on the Nominating Committee; and Rhonda Hughes, Bryn Mawr College, and Harold M. Stark, University of California San Diego, were elected to three-year terms on the Editorial Boards Committee.

The bylaws state that amendments must be approved by two-thirds of the members voting in an election in which at least ten percent of the members participated. There were only 2,833 valid ballots returned in this past election, which is fewer than 10 percent of the 29,340 members. Therefore the amendments to the bylaws were not approved. However, 1,958 members voted for them, while 95 voted against them.

The secretary requested that the Council ask its Committee on the Profession to examine the various methods of distributing the ballots and propose a method that insures a higher rate of returned ballots for future elections.

The Council referred this matter to the Committee on the Profession and the secretary for further consideration.

As mentioned, the Council sat in Executive Session to receive and consider recommendations from the Editorial Boards Committee.

The EBC recommended and the Council approved the election of Clark Robinson to a three-year term and the re-election of Peter Winkler to a three-year term on the Contemporary Mathematics Editorial Committee.

The EBC recommended and the Council approved the re-election of William Fulton for another term on the Journal of the American Mathematical Society Editorial Committee.

The EBC recommended the election of Lars Wahlbin as managing editor of Mathematics of Computation, with his term beginning on 01 February 1996 (at the expiration of the term of Walter Gautschi). This election was approved by the Council.

The EBC recommended the election of Shlomo Sternberg and Wolfgang M. Schmidt to three-year terms on the Colloquium Editorial Committee. These elections were approved by the Council.

The EBC recommended the appointment of Svetlana Katok as managing editor for the Electronic Research Announcements. This is a new position which required Council approval. The remaining members of the editorial board are appointed by the president after consultation with the EBC and the managing editor. The appointment of Katok was approved by the Council.

The Executive Committee and Board of Trustees recommended election of several officers of the Society. These elections were considered in executive session.

The EBC recommended the election of Susan Friedlander to a two-year term as associate secretary for the Central Section. The Council approved by electing Friedlander to this office. Her term will begin on 01 February 1996.

The EBC recommended the election of William Harris to a two-year term as associate secretary for the Western Section. The Council approved by electing Harris to this position. His term will begin on 01 February 1996.

The Executive Committee and Board of Trustees forwarded to the Council a recommendation that the Society not hold a summer meeting in 1996. This was done upon the recommendation of the Secretariat and the Committee on Meetings and Conferences (COMC). The motion not to hold a summer meeting in 1996 failed.

The MAA sent a message to the Council read by the president which stated:

We appreciate the Council’s action on the meeting for August 1996. Now we, like the AMS, can focus on the long-term changes in summer meetings without exhausting ourselves on the logistics of a single meeting in 1996.

The Council considered several amendments to the bylaws. These will be considered in a separate note published in this issue of the Notices.

The Executive Committee and Board of Trustees recommended that the Council adopt the Agenda for Business
Meetings below as a model. The Council's Committee on the Agenda for Business Meetings could make minor alterations to this agenda, for example, if one of the officers or the executive director does not have a report, then that item may be omitted, the reading of the minutes would usually be suspended, and other categories might not have any action items.

The Council adopted the following outline as a model for the agenda for business meetings of the Society.

**Agenda for Business Meetings of the Society**

1. Introductions
2. Minutes of last meeting (the reading of which is usually omitted, a pointer to the minutes in the Notices being sufficient)
3. Reports
   a. Secretary
   b. Treasurer
   c. Executive Director
   d. President
4. Business proposed by Council and BT
5. Business proposed by previous business meeting (check to see if a quorum is present)
6. New business for referral to future business meeting (and placed on agenda by the Committee on the Agenda for Business Meetings)
7. Standard resolutions
8. Adjournment

Some committees of the Society have appointed subcommittees in order to handle some of the tasks assigned to the committee. The Council operates under Sturgis's *Standard Code of Parliamentary Procedure*, 3rd Edition, New and Revised. According to Sturgis:

A committee has the right to appoint subcommittees of its own members to which it may delegate authority and which are directly responsible to the committee. Subcommittees report only to the committee that created them.

It has been assumed that for the purposes of Society business, subcommittees of committees can have members who are not on the parent committee. The Executive Committee and Board of Trustees recommended adopting a modification of Sturgis’s policy that would allow subcommittees to have members that are not members of the parent committee. The Council adopted the following modification:

A committee has the right to appoint subcommittees which are directly responsible to it. Normally the chair of a subcommittee would be a member of the parent committee but members of subcommittees need not, in general, be members of the parent committee. While subcommittees can exchange information with other committees, they report only to the committee that created them.

The Council filed many reports from committees. The Committee on the Profession recommended the following resolution that was adopted by the Council:

**On Graduate Programs in Mathematics**

The current employment situation in mathematics has led to difficult questions concerning the size and structure of graduate programs in this country. The Council of the AMS feels that the Society must take a leading role in addressing these questions. However, as past experience has shown, the Society cannot reliably predict future trends in education and employment prospects for mathematicians. Further, the Society is not in a position to dictate policies to universities. The Council thus concludes:

It is not the Society's role to attempt to regulate the size of graduate programs in mathematics. However, we urge individual departments to reexamine the content, focus, and size of their programs and consider possible restructuring or reallocation of resources to better serve their needs and the needs of their students and graduates. In some cases this may involve shifting resources from graduate programs to postdoctoral programs or from Ph.D. programs to master's programs. It may also involve broadening the training of graduate students to prepare them for nonacademic as well as academic careers.

In its leadership role, the Society is in a unique position to collect and disseminate information, organize efforts, and provide assistance on the employment situation. In this regard, the Society is actively pursuing many of the recommendations made by its Task Force on Employment. Much more remains to be done. Thus:

Addressing the interlinked questions of graduate education and employment of mathematicians is and will remain a high priority for the American Mathematical Society. The Council pledges to continue to commit Society resources and efforts to help enhance career opportunities for its members.

The Committee on the Profession and the Committee on Meetings and Conferences proposed the resolution that follows regarding choice of meeting sites which was adopted by the Council.

The Council of the American Mathematical Society wishes to reaffirm the commitment of the Society to the human rights of mathematicians. The Society bears a particular responsibility to
provide the participants at meetings of the Society with an environment which is supportive of these rights.

Therefore, the Council resolves that the AMS will make every reasonable effort to schedule its meetings in localities which respect the participants' human rights, including freedom from discrimination based on race, gender, national origin, religion, age, sexual orientation, or disability.

The Council agreed to a recommendation from its Committee on Publications that the publisher of the Society be made an ex-officio member of the Committee.

It is noted that the current members on the Committee on Publications consist of three Council members (chosen from the vice-presidents and members-at-large), a member of the Editorial Boards Committee, a member of the Board of Trustees, the president, four to six at-large members, and now the publisher. The secretary and the executive director serve as nonvoting members. Furthermore, the Committee on Publications and the Mathematical Reviews Editorial Committee have agreed, with Council approval, to exchange visitors at each meeting of the respective committees.

The Committee on Electronic Products and Services is a standing committee of the Society. The Executive Committee, upon the advice of the Committee on Publications and CEPS, recommended that this committee be discharged with thanks and that its duties be assigned to the Committee on Publications. The Council approved this recommendation.

The Council agreed with a recommendation of the Executive Committee and the Board of Trustees that an editor for e-MATH be appointed for a three-year term. This editor will be responsible for the mathematical resources and informational items of interest to the mathematical community which are posted on e-MATH. The editor will operate from her/his home institution.

The Council formally recommended that a task force of the president on Participation for Underrepresented Minorities be appointed in cooperation with the Committee on the Profession.

The Council agreed to enlarge the Mathematical Reviews Editorial Committee to six members, with two members appointed from outside of North America.

The Council adopted as policy for the Notices Editorial Board that:

The Notices should publish brief reports annually. We have decided to do that in each February issue.

Currently the Colloquium Editorial Committee is responsible for recommending Colloquium Lectures to the Executive Committee. The tradition was that the Colloquium Lectures would result in a volume in the Colloquium Publication Series, for which the Colloquium Editorial Committee is responsible. For many years, the Colloquium Lectures have not resulted in such a volume, but the lecturer has been selected by the editorial committee nonetheless. At its November 1994 meeting, the Executive Committee agreed to recommend that the responsibility to select Colloquium Lecturers be assigned to a new committee, the Colloquium Lecture Committee, and that the Colloquium Editorial Committee be responsible only for the Colloquium Publications Series. The Council agreed by charging the Colloquium Editorial Committee as an editorial committee for the Colloquium Publications Series. Further, it created a new standing committee of the Society, the Colloquium Lecture Committee, to recommend Colloquium Lectures for the Society.

The AMS-ASA-AWM-IMS-MAA-NCTM-SIAM Joint Committee on Women in the Mathematical Sciences reported to the Society. The Council acted on items the committee proposed as follows:

The AMS-ASA-AWM-IMS-MAA-NCTM-SIAM Joint Committee on Women in the Mathematical Sciences resolution

AMS guidelines for organizers of special sessions should include the following:

Successful sessions include both well-known senior people and junior people who are starting to contribute to an area. Organizers are expected to reach out to junior mathematicians who have new results but have not yet established reputations. At a minimum, leading researchers and centers in a field should be contacted for suggestions of junior people whose work the organizers may not yet be familiar with.

If the preliminary list of special session invitees has few women, the organizers should consult others, particularly senior women in related fields, to insure that they have not inadvertently overlooked some.

One purpose of special sessions is to provide an opportunity for junior people to meet others in their field and become part of the mathematical research community. To facilitate this, organizers are encouraged to arrange an informal dinner, lunch, or social event for participants and attendees at their session. Whenever possible, social events and talks of junior people should be scheduled relatively early in the
session to enable people to benefit from new contacts.

In addition, the AMS should monitor the effectiveness of these guidelines and other strategies by collecting and reporting data on the number of women speakers in special sessions, including correlation with gender of organizers, to JCW, COMC, and CPROF in a very timely manner.

was tabled by a vote of twelve in favor to table and seven opposed.

The AMS-ASA-AWM-IMS-MAA-NCTM-SIAM Joint Committee on Women in the Mathematical Sciences resolution that

The AMS should include women on the organizing committees of all future major symposia which it co-sponsors.

was replaced by the resolution

The AMS should make every reasonable effort to see that women are included on the organizing committees of major symposia which it co-sponsors.

and then adopted by the Council.

The Council received the report of the Special Advisory Committee on Professional Ethics. The committee presented ethical guidelines for adoption by the Council. The question whether the Council wished to "speak in the name of the Society" on this issue was also raised. The Council voted to adopt these guidelines on behalf of the Council (by a vote that was unanimous save for one abstention) and to take a vote in thirty days to adopt them in the name of the Society. (Subsequently the Council has adopted these guidelines in the name of the Society. A separate report is found immediately following the Amendments to the Bylaws report.) The Council thanked the committee for its work and discharged it.

The Women in Probability Conference was co-sponsored by the Society. President-elect Morawetz attended as the official representative of the Society. Her report was attached to the agenda.

During 1993, a special committee of the Council considered when and where the Council should meet. The final report, as adopted by the April 1993 Council, stated that Council meetings at Annual Meetings should be held on the Saturday closest to the end of the meeting. This has presented scheduling problems for the meeting. The Council agreed and put the question of dates, time, and sites for future meetings into the hands of the Secretariat.

Several items of information were presented to the Council.

It was announced that the president has issued one decree since the last meeting of the Council. Professor D. J. Struik was 100 years old on September 30, 1994.

American Mathematical Society
Presidential Decree

WHEREAS:
Dirk J. Struik is celebrating his One Hundredth Birthday;
AND
Dirk J. Struik has been a member of the Society since January 1, 1927;

NOW THEREFORE,
I, the undersigned Ronald L. Graham, President of the American Mathematical Society, issue the following presidential decree:

Be it decreed that congratulations from the Society are extended to Dirk J. Struik on the occasion of his Hundredth Birthday and that in appreciation for his services to mathematics and the Society he be granted Distinguished Lifetime Membership in the Society, with all benefits of normal membership accruing thereto. The Society extends its heartiest congratulations to him and its best wishes on this very special occasion.

Signed this, the thirtieth day of September, Nineteen Hundred Ninety Four.

Ronald L. Graham
President, American Mathematical Society

The Council was informed that the Board of Trustees adopted the budget for 1995 as presented at the meeting of the BT on 20 November 1994.

President Graham announced that Mrs. Brennie Morgan had contributed generously to the Society in order to endow the joint AMS-MAA-SIAM prize for Outstanding Research in Mathematics by an Undergraduate Student. The regulations for the prize have been published in the Notices.

The Council recognized President Ronald Graham for his two years of tolerance and patience as president of the Council and thanked him warmly, by a round of applause, for his service to the Society.

The Council adjourned at 6:20 p.m.

Robert M. Fossum
Secretary
Urbana, IL

Proposed Amendments to the Bylaws

The Council has approved several amendments to the bylaws for ratification by the membership in the election this fall (October 1995). These amendments will be printed in the election material that will be sent to all members of
the Society in September 1995. They will also appear in the election announcement that will be printed in the September issue of the Notices. The purpose of this note is to alert the membership of these proposed amendments so they can familiarize themselves with the issues involved. The full text of the bylaws of the Society appears in the November issue of the Notices in odd-numbered years. The most recent copy, that of November 1993, was also amended in the 1993 election to reflect changes in the membership of the Council. The amendments approved in that November election are not reflected in the printed version of the bylaws.

There are three sets of amendments reported below. The first amendment, approved by the Council in August 1994, removes from the bylaws any mention of the Editorial Committee for the American Journal of Mathematics, a journal published by the Johns Hopkins University Press. This reflects the fact that the Editorial Board of the American Journal of Mathematics and the Society have terminated the relationship between the two organizations, so there is no representative of the Society appointed to that editorial board.

The second set of amendments, approved by the January 1994 Council but rejected by the membership in the 1994 election due to voter apathy (not enough members voted), modifies slightly the definition of the duties of the executive director and the relationship between the executive director and the Board of Trustees. It enlarges the so-called liaison committee to include the chair of the Board of Trustees, and it makes clear that the performance of the executive director is evaluated by the Board of Trustees. This set of amendments was approved again by the January 1995 Council for ratification by the membership in the upcoming election.

The third set of amendments concerns the Business Meeting of the Society. It was approved by the January 1995 Council for ratification by the members in the next election. The amendment attempts to resolve several problems with regard to Business Meetings.

It provides that a Business Meeting should be held only at the Annual Meeting of the Society, usually held in January. So there will no longer be Business Meetings at summer meetings, if the amendment passes. Furthermore, it addresses the question as to how items for action can reach a Business Meeting. The amendment would allow two methods for action items to come to a Business Meeting. An action item would reach a Business Meeting if it is recommended for action by both the Council of the Society and the Board of Trustees of the Society. Or an action item could reach a Business Meeting if a previous Business Meeting moves such an item on to the next Business Meeting. In order that an item put on the agenda for action by a previous Business Meeting can be approved, it must receive a majority of the votes of those who vote at a meeting where at least 400 members are present.

Amending the bylaws of the Society is usually a simple process. The Council recommends amendments for ratification by the membership. Approval by the membership consists of an affirmative vote by two-thirds of the members present at a Business Meeting or of two-thirds of the members voting in a mail ballot in which at least ten percent of the members vote. The alternative is designated by the Council when it recommends amendments for approval. In recent times, the Council has always designated approval by mail ballot, since attendance at Business Meetings has been rather sparse of late.

[The amendments are indicated by stating the OLD version and the the NEW proposed version.]

Amendment Concerning the American Journal of Mathematics
Editorial Committee of the AMS

Article III Committees

OLD Section 1. There shall be nine editorial committees as follows: committees for the Bulletin, for the Proceedings, for the Colloquium Publications, for the Journal, for Mathematical Surveys and Monographs, for Mathematical Reviews; a joint committee for the Transactions and the Memoirs; a committee consisting of the representatives of the Society on the Board of Editors of the American Journal of Mathematics; and a committee for Mathematics of Computation.

NEW Section 1. There shall be eight editorial committees as follows: committees for the Bulletin, for the Proceedings, for the Colloquium Publications, for the Journal, for Mathematical Surveys and Monographs, for Mathematical Reviews; a joint committee for the Transactions and the Memoirs; and a committee for Mathematics of Computation.

Amendment Concerning the Executive Director

Article VI. Executive Director

OLD Section 1. There shall be an Executive Director who shall be a paid employee of the Society. The Executive Director shall have charge of the central office of the Society, and shall be responsible for the general administration of the affairs of the Society in accordance with the policies that are set by the Board of Trustees and by the Council.

NEW Section 1. There shall be an Executive Director who shall be a paid employee of the Society. The Executive Director shall have charge of the central office of the Society, except for the office of the secretary, and shall be responsible for the general administration of the affairs of the Society in accordance with the policies that are set by the Board of Trustees and by the Council.

OLD Section 2. The Executive Director shall be appointed by the Board of Trustees with the consent of the Council. The terms and conditions of employment shall be fixed by the Board of Trustees.

NEW Section 2. The Executive Director shall be appointed by the Board of Trustees with the consent of the Council. The terms and conditions of employment shall be fixed by the Board of Trustees, and the performance of the Executive Director will be reviewed regularly by the Board of Trustees.

OLD Section 3 (first part). The Executive Director shall work under the immediate direction of a committee consisting of the president, the secretary, and the treasurer, of which the president shall be chairman ex officio.
NEW Section 3. The Executive Director shall be responsible to and shall consult regularly with a liaison committee consisting of the president as chair, the secretary, the treasurer, and the chair of the Board of Trustees.

OLD Section 3 (second part). The Executive Director shall attend meetings of the Board of Trustees, the Council, and the Executive Committee, but shall not be a member of any of these bodies.

ADD Section 4. The Executive Director shall attend meetings of the Board of Trustees, the Council, and the Executive Committee, but shall not be a member of any of these bodies.

Amendment Concerning Meetings

Article X Meetings

OLD Section 1. The annual meeting of the Society shall be held between the fifteenth of December and the tenth of February next following. Notice of the time and place of this meeting shall be mailed by the secretary or an associate secretary to the last known post office address of each member of the Society. The times and places of the annual and other meetings of the Society shall be designated by the Council. There shall be a business meeting of the Society at the annual meeting and at the summer meeting. A business meeting of the Society shall take final action only on business accepted by unanimous consent, or business notified to the full membership of the Society in the call for the meeting, except that the business meetings held at either the annual meeting or the summer meeting may take final action on business which has been recommended for consideration by the Council and has been accepted by the vote of four-fifths of the Society present and voting at such a meeting. Such notification shall be made only when so directed by a previous business meeting of the Society or by the Council.

NEW Section 1. The annual meeting of the Society shall be held between the fifteenth of December and the tenth of February next following. Notice of the time and place of this meeting shall be mailed by the secretary or an associate secretary to the last known post office address of each member of the Society. The times and places of the annual and other meetings of the Society shall be designated by the Council.

NEW Section 2. There shall be a business meeting of the Society only at the annual meeting. The agenda for the business meeting shall be determined by the Council. A business meeting of the Society can take action only on items notified to the full membership of the Society in the call for the meeting. A business meeting can act on items recommended to it jointly by the Council and the Board of Trustees; a majority of members present and voting is required for passage of such an item. A business meeting of the Society can place action items on the agenda for a future business meeting. Final action on an item proposed by a previous business meeting can be taken only provided there is a quorum of 400 members, a majority of members at a business meeting with a quorum being required for passage of such an item.

The remaining sections in this article will be renumbered accordingly.

Ethical Guidelines for the Society

In January 1994 the Council received the report of its Special Advisory Committee on Professional Ethics. The committee, which consisted of Murray Gerstenhaber, Frank Gilfeather, Elliott Lieb, and Linda Keen (chair), presented ethical guidelines for adoption by the Council. Those draft guidelines were published twice in the Notices, with a request to the membership for responses and suggestions for changes or improvements. These were sent to the committee, which considered all suggestions. The committee then redrafted the guidelines, which were then presented to the January 1995 Council. At that meeting, the Council voted to adopt these guidelines on behalf of the Council (by a vote that was unanimous save for one abstention). Later, in Business by Mail and according to the bylaws, the Council approved the Guidelines in the name of the Society by a vote of twenty-five (25) in favor and three (3) opposed.

Ethical Guidelines of the American Mathematical Society

To assist in its chartered goal, "...the furtherance of the interests of mathematical scholarship and research...", and to help in the preservation of that atmosphere of mutual trust and ethical behavior required for science to prosper, the American Mathematical Society, through its Council, sets forth the following guidelines. While it speaks only for itself, these guidelines reflect its expectations of behavior both for its members and for all members of the wider mathematical community, including institutions engaged in the education or employment of mathematicians or in the publication of mathematics.

It is not intended that something not mentioned here is necessarily outside the scope of AMS interest. These guidelines are not a complete expression of the principles that underlie them but will, it is expected, be modified and amplified by events and experience. These are guidelines, not a collection of rigid rules.

The American Mathematical Society, through its Committee on Professional Ethics (COPE), may provide an avenue of redress for individual members injured in their capacity as mathematicians by violations of its ethical principles. COPE, in accordance with its procedures, will, in each case, determine the appropriate ways in which it can be helpful (including making recommendations to the Council of the Society). However, the AMS cannot enforce these guidelines, and it cannot substitute for individual responsibility or for the responsibility of the mathematical community at large.

I. Mathematical Research and its Presentation

The public reputation for honesty and integrity of the mathematical community and of the Society is its collective treasure, and its publication record is its legacy.

The correct attribution of mathematical results is essential, both as it encourages creativity, by benefiting the creator whose career may depend on the recognition of the work, and as it informs the community of when, where, and
sometimes how original ideas have entered into the chain of mathematical thought. To that end, mathematicians have certain responsibilities, which include the following:

To endeavor to be knowledgeable in their field, especially as regards related work;

To give proper credit (even to unpublished sources, because the knowledge that something is true or false is valuable, however it is obtained);

To use no language that suppresses or improperly detracts from the work of others;

To correct in a timely way or withdraw work that is erroneous or previously published.

A claim of independence may not be based on ignorance of well-disseminated results. Errors and oversights can occur, but it is the responsibility of the person making the error to set the record straight.

On appropriate occasions, it may be desirable to offer or accept joint authorship when independent researchers find that they have produced identical results. However, the authors listed for a paper must all have made a significant contribution to its content, and all who have made such a contribution must be offered the opportunity to be listed as an author. To claim a result in advance of its having been achieved with reasonable certainty injures the community by restraining those working toward the same goal. Publication of results that are announced must not be unreasonably delayed. Because the free exchange of ideas necessary to promote research is possible only when every individual's contribution is properly recognized, the Society will not knowingly publish anything that violates this principle, and it will seek to expose egregious violations anywhere in the mathematical community.

II. Social Responsibility of Mathematicians

The Society promotes mathematical research together with its unrestricted dissemination, and to that end encourages all and will strive to afford equal opportunity to all to engage in this endeavor. Mathematical ability must be respected wherever it is found, without regard to race, gender, ethnicity, age, sexual orientation, religious or political belief, or disability.

The growing importance of mathematics in society at large and of public funding of mathematics may increasingly place members of the mathematical community in conflicts of interest. The appearance of bias in reviewing, refereeing, or in funding decisions must be scrupulously avoided, particularly where decisions may affect one's own research, that of close colleagues, or of one's students; in extreme cases one must withdraw.

A reference or referee's report fully and accurately reflecting the writer's views is often given only on the understanding that it be confidential or that the name of the writer be withheld from certain interested parties; therefore, a request for a reference or report must be assumed, unless there is a statement to the contrary, to carry an implicit promise of confidentiality or anonymity which must be carefully kept unless negated by law. The writer of the reply must respond fairly and keep confidential any privileged information, personal or mathematical, that the writer receives. If the requesting individual, institution, agency or company becomes aware that confidentiality or anonymity cannot be maintained, that must immediately be communicated, and if known in advance, must be stated in the original request.

Where choices must be made and conflicts are unavoidable, as with editors or those who decide on appointments or promotions, it is essential to keep careful records which, even if held confidential at the time, would, when opened, demonstrate that the process was indeed fair.

Freedom to publish must sometimes yield to security concerns, but mathematicians should resist excessive secrecy demands, whether by government or private institutions.

When mathematical work may affect the public health, safety or general welfare, it is the responsibility of mathematicians to disclose the implications of their work to their employers and to the public, if necessary. Should this bring retaliation, the Society will examine the ways in which it may want to help the "whistle-blower", particularly when the disclosure has been made to the Society.

III. Education and Granting of Degrees

Holding a Ph.D. degree is virtually indispensable to an academic career in mathematics and is becoming increasingly important as a certificate of competence in the wider job market. An institution granting a degree in mathematics is certifying that competence and must take full responsibility for it by insuring the high level and originality of the thesis work and sufficient knowledge by the recipient of important branches of mathematics outside the scope of the thesis. The original results in a thesis should be publishable in a recognized journal. When there is evidence of plagiarism, it must be carefully investigated, even if it comes to light after granting the degree, and, if proven, the degree should be revoked.

Mathematicians and organizations involved in advising graduate students should honestly inform them about the employment prospects they may face upon completion of their degrees. No one should be exploited by the offer of a temporary position at a low salary and/or a heavy work load.

IV. Publications

The Society will not take part in the publishing, printing or promoting of any research journal where there is some acceptance criterion, stated or unstated, that conflicts with the principles of these guidelines. It will promote the quick refereeing and timely publication of articles accepted to its journals.

Editors are responsible for the timely refereeing of articles and must judge articles by the state of knowledge at the time of submission. Editors and referees should accept a paper for publication only if they are reasonably certain the paper is correct.

The contents of an unpublished and uncirculated paper should be regarded by a journal as privileged information. If the contents of a paper become known in advance of publication solely as a result of its submission to or handling by a journal, and if a later paper based on knowledge of the privileged information is received anywhere (by the same or another journal), then any editor aware of the facts must refuse or delay publication of the later paper.
until after publication of the first—unless the first author agrees to earlier publication of the later paper.

At the time a manuscript is submitted, editors should notify authors whenever a large backlog of accepted papers may produce inordinate delay in publication. A journal may not delay publication of a paper for reasons of an editor's self interest or of any interest other than the author's. The published article should bear the date on which the manuscript was originally submitted to the journal for publication, together with the dates of any revisions. Editors must be given and accept full scientific responsibility for their journals; when a demand is made by an outside agency for prior review or censorship of so-called "sensitive" articles, that demand must be resisted, and, in any event, knowledge of the demand must be made public.

All mathematical publishers, particularly those who draw without charge on the resources of the mathematical community through the use of unpaid editors and referees, must recognize that they have made a compact with the community to disseminate information, and that compact must be weighed in their business decisions.

Both editors and referees must respect the confidentiality of materials submitted to them unless these have previously been made public, and above all may not appropriate to themselves ideas in work submitted to them or do anything that would impair the rights of authors to the fruits of their labors. Editors must preserve the anonymity of referees unless there is a credible allegation of misuse.

These are ethical obligations of all persons or organizations controlling mathematical publications, whatever their designation.

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

A listing of contact names and addresses for some of the major math institutes was published in the March issue of the Notices. Provided here are two additions to that list:

**Center for Discrete Mathematics and Theoretical Computer Science (DIMACS)**
Andras Hajnal, Director
Core Building, Busch Campus
Rutgers University
Piscataway, NJ 08855-11799
Telephone: 908-445-5928
Fax: 908-445-5932
E-mail: center@dimacs.rutgers.edu
WWW: http://dimacs.rutgers.edu

**Centre de recherches mathématiques (CRM)**
Université de Montréal
C.P. 6128, Succ. Centre-ville
Montreal, Quebec, H3C 3J7, Canada
Telephone: 514-343-7501
Luc Vinet, Director
E-mail: vinet@crm.umontreal.ca
Martin Goldstein, Deputy Director
E-mail: goldstein@re.umontreal.ca
Ghislain Giroux-Dufort, Executive Manager
E-mail: girouxdg@crm.umontreal.ca
Louis Pelletier, Visitors and Workshops
e-mail: pelletl@crm.umontreal.ca

**Upcoming Deadlines**

**July 7, 1995** (Long-term only), **August 11, 1995** (Project Development only), and **December 29, 1995** (Project Development only): Grants for Collaboration with Colleagues in Central Europe and Eurasia.

Office for Central Europe and Eurasia, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-3680; fax 202-334-2614; e-mail ocee@nas.edu.

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

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


**Where to Find It**

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

**Advanced Research Projects Agency, program officers in math**
October 1994, p. 943

**Air Force Office of Scientific Research, program officers in math**
October 1994, p. 942

**AMS e-mail addresses**
October 1994, p. 935

**Army Research Office, program officers in math**
October 1994, p. 943

**Board on Mathematical Sciences, National Research Council**
February 1995, p. 277
.TRANSLATIONS OF MATHEMATICAL MONOGRAPHS

Methods for Analysis of Nonlinear Elliptic Boundary Value Problems
I.V. Skrypnik

This book investigates boundary value problems for nonlinear elliptic equations of arbitrary order. In addition to monotone operator methods, a broad range of applications of topological methods to nonlinear differential equations is presented: solvability, estimation of the number of solutions, and the branching of solutions of nonlinear equations. The book is suitable for use in graduate courses in differential equations and nonlinear functional analysis.

Individual Member $85, List Price $130, Institutional Member $104.
Ordering Code MMON0/139NA

Traveling Wave Solutions of Parabolic Systems
Aizik I. Volpert, Vitaly A. Volpert & Vladimir A. Volpert

This book presents a general picture of current results about wave solutions of parabolic systems, their existence, stability, and bifurcations. The main part of this book contains original approaches developed by the authors. With introductory material accessible to nonmathematicians and an extensive bibliography of about 500 references, this book is an excellent resource on the subject.

Individual Member $90, List Price $142, Institutional Member $114.
Ordering Code MMON0/141NA

Qualitative Theory of Control Systems
A. A. Davydov

This book analyzes control systems using results from singularity theory and the qualitative theory of ordinary differential equations. The main part of the book focuses on systems with two-dimensional phase space. This book is accessible to graduate students and researchers working in control theory, singularity theory, and various areas of differential equations, as well as in applications.

Individual Member $45, List Price $75, Institutional Member $60.
Ordering Code MMON0/141NA

All prices subject to change. Free shipment by surface; for air delivery, please add $6.50 per title. Prepayment required. Orders from American Mathematical Society, P.O. Box 5904, Boston, MA 02205-5904, or call 800-321-4AMS (inside the U.S. and Canada) to charge with VISA or MasterCard. Residents of Canada, please include 7% GST.

Reference

Board on Mathematical Sciences Staff
February 1995, p. 277

Mathematics Research Institutes
Contact Information: The Fields Institute, The Geometry Center, Institute for Advanced Study, Institute for Mathematics and its Applications, Mathematical Sciences Institute, Mathematical Sciences Research Institute

Department of Energy, program officers in math
October 1994, p. 943

Disciplinary Subcommittee for the Mathematical Sciences
February 1995, p. 277

February 1995, p. 278

Mathematical Sciences Education Board Staff
February 1995, p. 278

National Science Board of NSF, members
May 1995, p. 589

NSF, mathematical scientists on the Advisory Committee for the Mathematical and Physical Sciences Directorate
February 1995, p. 277

NSF, program officers in the Division of Mathematical Sciences and Education and Human Resources Directorate
October 1994, p. 942 and January 1995, p. 63

National Security Agency, program officers in math
October 1994, p. 943

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

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

May 1995


Sponsor: SIAM Activity Group on Dynamical Systems.
Organizers: J.D. Crawford, Univ. of Pittsburgh, and J.D. Meiss, Univ. of Colorado, Boulder.

Information: SIAM Conference Coordinator, 3600 University Science Ctr., Philadelphia, PA 19104-2688; tel: 215-382-9800; fax 215-386-7939; electronic mail: meetings@siam.org.


22–26 IMA Workshop on Quasiclassical Methods, Institute for Mathematics and Its Applications, University of Minnesota, Minneapolis, MN. (Mar. 1994, p. 252)

22–26 International Conference on Spectral and High Order Methods (ICOSAHOM'95), Houston, TX. (Nov./Dec. 1994, p. 1197)


22–June 2 Workshop on Dynamical Systems, Trieste, Italy. (Nov./Dec. 1994, p. 1198)

23–27 Fourth International Conference on Mathematical Population Dynamics, Rice University, Houston, TX. (Feb. 1995, p. 280)


28–31 First International Conference on Neural, Parallel & Scientific Computations, Atlanta, GA. (May/June 1994, p. 515)


29–June 1 Ninth Haifa Matrix Theory Conference, Haifa, Israel. (Apr. 1995, p. 480)

29–June 1 International Conference on Mathematical Modelling, Universiti Brunei Darussalam, Brunei Darussalam. (Feb. 1994, p. 146)


31–June 2 International Conference on

This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete listing of meetings of the Society, and of meetings sponsored by the Society, will be found on the first page of the Meetings and Conferences section.

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@math.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 published 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.)

June 1995 Notices of the AMS 699
Complex Analysis, Computations and Other Applications, Institute of Control Sciences, Russian Academy of Sciences, Moscow, Russia. (Jan. 1995, p. 76)


June 1995

Model Oriented Data Analysis, Spetses, Greece. (May/June 1994, p. 515)

1-5 Approximation Dynamics with Applications to Numerical Analysis, Univ. of Missouri, Columbia, MO. (Jan. 1995, p. 76)


3-5 Canadian Society for the History and Philosophy of Mathematics, University of Quebec at Montreal, Montreal, Canada. (Feb. 1995, p. 280)

4-8 Canadian Mathematical Society 50th Anniversary Summer Meeting, University of Toronto, Toronto, Ontario, Canada. (May 1995, p. 591)

4-10 Mathematical Models of Microstructure, Paseky, Czech Republic. (Jan. 1995, p. 76)

5-7 3rd International Applied Statistics in Industry Conference (Continuing Continuous Improvement), Dallas, TX. (Sept. 1994, p. 846)

5-8 International Conference on Optimization: Techniques and Applications (ICOTA '95), Chengdu University of Science and Technology, Chengdu, China. (May/June 1994, p. 515)


5-9 Complex Analysis and Geometry - XII, Levico, Italy. (Apr. 1995, p. 480)

5-9 International Conference on Spectral and High Order Methods (ICOSAHOM '95), Houston, TX. (Jan. 1995, p. 76)


5-10 Second International Conference on Commutative Ring Theory, Fès, Morocco. (Mar. 1995, p. 396)

6-10 Eurhomogenization Nice 1995, Nice, France. (Feb. 1995, p. 280)

7-8 IMA Tutorial on Multiparticle Quantum Scattering with Applications to Nuclear, Atomic, and Molecular Physics, Institute for Mathematics and its Applications, University of Minnesota, Minneapolis, MN. (Apr. 1994, p. 385)

7-10 Fifth International Conference of the International Society for Scientometrics and Informetrics, Rosary College Graduate School of Library and Information Science, River Forest, IL. (Feb. 1995, p. 280)

8-10 Seventh Geometry/Topology Conference, Lehigh University, Bethlehem, PA. (Apr. 1995, p. 480)

9-10 Special Functions and Related Topics in Analysis: A Conference in Honour of Lee Lorch, North York (Metropolitan Toronto), Canada.

Program: This conference, dedicated to Lee Lorch on the occasion of his forthcoming 80th birthday, will be devoted to those topics in analysis (Fourier analysis, summability theory, special functions, ordinary differential equations) to which he has made particular contributions. It will also honour his lifelong dedication to the struggle for civil rights and for equal educational opportunities for women and minority groups.

Invited speakers: W. Al-Salam (Alberta), M. Ashbaugh (Missouri), R. Askey (Wisconsin), C. Davis (Toronto), J. A. Donaldson (Howard Univ.) A. Elbert (Hungarian Academy of Sciences), M. Gray (American Univ.), M. Ismail (Univ. of South Florida), J.-P. Kahane (Paris-Orsay), L. Littlejohn (Utah State), A. Meir (York Univ.) A. McD. Mercer (Univ. of Guelph), A. Mingarelli (Carleton Univ.), M. Muldoon (York Univ.), D. J. Newman (Temple Univ.) C. Sadosky (Howard Univ.), W. Van Assche (Katholieke Universiteit Leuven).

Information: M. Muldoon, Dept. of Mathematics and Statistics, York Univ., North York, Ontario M3J 1P3; Canada. Information: p. 1198)

9-11 Distinguished Lecture Series, The Fields Institute, Waterloo, ON, Canada.

Subject: Hecke Algebras, Type III Factors and Phase Transition with Spontaneous Symmetry Breaking

Speaker: Alain Connes (College de France).

Information: e-mail: valeriots@fields. uwaterloo.ca.

9-13 23rd Canadian Operator Symposium, The Fields Institute, Waterloo, ON, Canada.

Information: e-mail: oasympt@fields. uwaterloo.ca.


12-16 NSF-CBMS Regional Conference in the Mathematical Sciences, University of San Francisco.

Subject: Numerical Linear Algebra on Parallel Processors

Principal Lecturer: J. Demmel (Univ. of California, Berkeley)

Information: P. Pacheco, Department of Mathematics, Univ. of San Francisco, 2130 Fulton Street, San Francisco, CA 94117; tel: 415-666-6630; fax: 415-666-2346; e-mail: peter@usfca.edu.

12-16 Brazil-USA Conference on Multidimensional Complex Analysis and Partial Differential Equations, Sao Carlos, SP, Brazil. (Sept. 1994, p. 847)

12-16 IMA Workshop on Multiparticle Quantum Scattering with Applications to Nuclear, Atomic, and Molecular Physics, Institute for Mathematics and its Applications, University of Minnesota, Minneapolis, MN. (Apr. 1994, p. 385)

12-17 Symmetry in Nonlinear Mathematical Physics, Kiev, Ukraine. (Nov./Dec. 1994, p. 1198)

12-20 Viscosity Solutions and Applications, Montecatini Terme (PT), Italy. (Mar. 1995, p. 367)

12-23 Special Functions, q-Series and Related Topics, Toronto, Canada.

Program: One-week mini-course lectures and one-week workshop.

Sponsor: The Fields Institute, Waterloo, ON, Canada.

Information: e-mail: spfunct@fields.uwaterloo.ca.

12-23 Partial Differential Equations and Their Applications, Toronto, Canada.

Sponsor: The Fields Institute, Waterloo, ON, Canada.

Information: e-mail: pdwks@fields.uwaterloo.ca.


13-17 CBMS Regional Conference on Nondestructive Evaluation and Inverse Problems, University of Kentucky. (Jan. 1995, p. 77)

14-18 Cyclic Cohomology and Noncommutative Geometry. The Fields Institute, Waterloo, ON, Canada.

Information: e-mail: cyclic@fields.uwaterloo.ca.


18-20 Twelfth Annual Workshop in Geometric Topology, University of Wisconsin-Milwaukee, Milwaukee, WI.

Principal Speaker: S. Weinberger.

Financial Support: This workshop being supported by UW-Milwaukee and NSF. Some funding is available to cover expenses of participants, including graduate students, who do not have other means of support.

Information: F. D. Ancel (ancel@csd.uwm.edu) or C. R. Guilbault (craig@csd.uwm.edu) at Dept. of Math. Sciences, Univ. of Wisconsin-Milwaukee, Milwaukee, W153201.

18-23 Probabilistic Aspects of Single Orbit Dynamics, California State Univ., Bak-
ersfield, CA. (Apr. 1995, p. 480)
19–22 Symposium on Inertial Manifolds, Approximate Inertial Manifolds, and Related Numerical Algorithms, Xi'an, China. Information: e-mail: q-groups@fields.

24-28 Workshop on Discretely Coupled Dynamical Systems, Santiago de Compostela, Spain. (Feb. 1995, p.280)
25–July 1 An International Conference on the Interaction between Order, Convexity, and Model Theory in Analysis (OCOCOM), North Ossetian State University, Vladikavkaz, Russia. (May 1995, p. 592)
25–July 1 The Third Slovenian Conference in Graph Theory, Bled, Slovenia. (Apr. 1995, p. 481)
27–29 Moving Boundaries 95 (Computational Modelling of Free and Moving Boundary Problems), Bled, Slovenia. (Sept. 1994, p. 847)

July 1995

3–5 European Conference on Symbolic and Quantitative Approaches to Reasoning and Uncertainty, University of Fribourg, Switzerland. (Jan. 1995, p. 78)
3–7 AMAST'95, Fourth International Conference on Algebraic Methodology and Software Technology, Concordia University, Montreal, Canada. (Jul./Aug. 1994, p. 678)
3–14 Poincaré Conjecture, Levico, Italy. (Apr. 1995, p. 481)
3–14 SMS-NATO ASI: Gauge Theory and Symplectic Geometry, Université de Montréal, Montréal, Canada. (Nov./Dec. 1994, p. 1199)
4–6 Tenth International Conference on Artificial Intelligence in Engineering (AIENG), Udine, Italy. (Nov./Dec. 1994, p. 1199)
4–14 Elliptic Cohomology, Centre de Recherche Mathématique, Campus of the Universitär Autónoma de Barcelona. (Apr. 1995, p. 481)
8–9 Mathematica in Mathematics Research and Education, University of Tasmania. (May/June 1994, p. 516)
8–16 Joint Annual Meeting of the Statistical Society of Canada and the Institute of Mathematical Statistics, Montreal, Quebec, Canada. (May 1995, p. 592)
9–12 International IMACS-GAMM Symposium on Numerical Methods and Error Bounds, University of Oldenburg, Germany.
9–15 International Category Theory Meeting (CT95), Dalhousie University, Halifax, Canada. (Mar. 1995, p. 368)
10–14 7th Biennial Conference of the Computational Mathematics Group at Melbourne (CTAC 95), Melbourne, Australia. (May/June 1994, p. 516)
10–21 Conference on Discrete Mathematics, Combinatorics, and Graph Theory, Univ. of Wyoming, Laramie, WY. (Jan. 1995, p. 78)
10–26 XXVème Ecole d’Eté de Calcul des Probabilités, Saint-Flour (Cantal). (May 1995, p. 592)
15–18 Nonlinear Dynamics and Time Series: A Bridge between the Physical and Statistical Sciences, Montreal, Canada. Sponsor: The Fields Institute, Waterloo, ON, Canada.
Information: e-mail: nonlinear@fields.

24-28 Quantum Groups and Their Connection with Quantized Functional Analysis, The Fields Institute, Waterloo, ON, Canada.
Information: e-mail: q-groups@fields.

3–14 Poincaré Conjecture, Levico, Italy. (Apr. 1995, p. 481)

17–19 BEM 17–17th International Conference on Boundary Element Methods, Madison, WI. (Sept. 1994, p. 847)

17–21 Calculus in a Real and Complex World, Univ. of Massachusetts at Amherst. (Mar. 1995, p. 368)


17–21 Symposium on Sieve Methods, Exponential Sums and Their Applications in Number Theory, Univ. of Wales College of Cardiff, Cardiff, Wales, UK. (Jan. 1995, p. 78)

17–21 Modelling and Optimization of Distributed Parameter Systems with Applications to Engineering, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland. (Oct. 1994, p. 1028)


17–23 Mathematics in the Mountains, Hampton Inn, Silverthorne, Summit County, CO. (May 1995, p. 592)


24–29 Esquife 95, Lisbon, Portugal. (May 1995, p. 593)


Note: Correct date for this conference is July 27–30, 1996.

30–August 2 International Conference on Critical Thinking and Educational Reform, Sonoma State University, Rohnert Park, CA. (Apr. 1995, p. 481)


August 1995


1–5 16th Rolf Nevanlinna Colloquium, University of Joensuu, Joensuu, Finland. (Sept. 1994, p. 847)


Program: The symposium will cover a number of topics which have been centrally important in the study of applied mathematics in recent years. The symposium will also honor the many significant and varied contributions of Professor Martin D. Kruskal.


Support: The organizers have applied for a limited amount of external support. Women and minorities are especially encouraged to apply.

Information: M. Laxham, Program in Applied Mathematics, Univ. of Colorado, Boulder, CO 80309-0262; tel: 303-492-5779; fax: 303-492-0466; e-mail: margy@boulder.colorado.edu.

6–8 MATHFEST, University of Vermont, Burlington, VT (including the summer meetings of the AMS, AWM, MAA, and PME). (Jun./Aug. 1994, p. 679)

9–18 Conference on Fermat’s Last Theorem, Boston University. (May 1995, p. 593)


10–17 Logic Colloquium 1995, Israel (Haifa or Jerusalem). (Jul./Aug. 1994, p. 679)

13–17 Fourth International Colloquium on Numerical Analysis, Plovdiv, Bulgaria. (Sept. 1994, p. 848)

13–17 Second International Colloquium on Oscillation Theory, Plovdiv, Bulgaria. (Sept. 1994, p. 848)


15–19 Index Theory, Coarse Geometry and Topology of Manifolds, University of Colorado at Boulder. (May 1995, p. 593)

16–19 Fifth Conference of the International Linear Algebra Society, Georgia State University, Atlanta, GA. (Nov./Dec. 1994, p. 1200)

* 17–19 Conference on Mathematical Modelling in Population Biology, Utah State University, Logan, UT.

Organizers: The Southwest Regional Institute of Mathematical Sciences, Department of Mathematics, Univ. of Arizona Tucson, AZ 85721, funded by the National Science Foundation.

Objectives: This conference will bring researchers together to discuss the mathematical modeling of population dynamics and related topics (dynamics of epidemics, natural resource modeling, genetics, etc.). A special contingent of faculty and students will be present to learn about and discuss how these research topics might be integrated into undergraduate and high school curricula. Main speakers to include A. Hastings (Univ. of California at Davis) and H. Smith (Univ. of Arizona).

Call for Papers: Deadline for contributed papers: June 30, 1995. Financial support (for lodging, meals, and reasonable travel expenses) will be provided to a limited number of contributing speakers and graduate students.

Information: J. M. Cushing, Dept. of Mathematics, Univ. of Arizona, Tucson, AZ 85721; tel: 602-621-8863; fax: 602-621-8322; e-mail: cuhing@math.arizona.edu or J. Powell, Dept. of Mathematics & Statistics, Utah State Univ., Logan, UT 84322-3900; e-mail: powell@unfse.math.usu.edu.

18–23 Sixth International Colloquium on Differential Equations, Plovdiv, Bulgaria. (Sept. 1994, p. 848)

19–25 The Tenth International Congress of Logic, Methodology and Philosophy of Science, Florence, Italy. (Mar. 1995, p. 369)


* 21–September 1 Mathematics of Long-Range Aperiodic Order Advanced Study Institute, The Fields Institute, Waterloo, ON, Canada.

Information: e-mail: aperiod@fields.uwaterloo.ca.

* 25 Distinguished Lecture Series, The Fields Institute, Waterloo, ON, Canada.

Title: Thoughts on Geometry, Computability and Tiling Problems.

Information: e-mail: valeriots@fields.uwaterloo.ca.

28–September 16th International Conference on Differential Geometry and Applications, Masaryk University, Brno, Czech Republic. (Apr. 1995, p. 481)
September 1995


3-10 Summer School on General Algebra and Ordered Sets, Blatná, Moravia. (May 1995, p. 594)

4-8 Linear Groups, Levico, Italy. (Apr. 1995, p. 481)

4-8 Conference on Algebraic K-Theory, Adam Mickiewicz Univ., Poznan, Poland. (Apr. 1995, p. 481)

4-9 Seventh Congress of European Women in Mathematics (EWM '95), Madrid, Spain. (Mar. 1995, p. 369)


5-8 IMA Tutorial on Microstructure, Weak Convergence and Atomic Forces, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., S.E., Minneapolis, MN 55455. (Mar. 1995, p. 370)


11-15 IMA Workshop on Mechanical Response of Materials from Angstroms to Meters, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., S.E., Minneapolis, MN 55455. (Mar. 1995, p. 370)


13-15 14th Symposium on Reliable Distributed Systems, Bad Neuenahr (near Bonn), Germany. (Mar. 1995, p. 370)


18-24 8th International Symposium on Classical Analysis, Kazimierz Dolny, Poland. (Feb. 1995, p. 282)


22-30 Complex Dynamics, Centre de Recerca Matemàtica, Campus of the Universitat Autònoma de Barcelona.


26-28 MICROSIM 95, Southampton, UK. (May 1995, p. 594)


October 1995

*6-8 Midwest Dynamical Systems Seminar, University of Cincinnati. Special Note: This is the silver anniversary meeting.

Information: K. Meyer, Dept. of Mathematics, Univ. of Cincinnati ML 25, Cincinnati, OH 45221-0025; e-mail: KEN.MEYER@UC.EDU.

7-8 Eastern Section, Northeastern University, Boston, MA.

Information: W. Drady, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: meet@math.ams.org.

13-14 Fifteenth Annual Meeting of the Southeastern-Atlantic Regional Conference on Differential Equations, North Carolina State University, Raleigh, NC.

Invited Speakers: C. I. Byrnes (Washington Univ.), M. G. Crandall (Univ. of California at Santa Barbara), and C. A. Shoemaker (Cornell Univ.).

Call for Papers: Deadline for submitting abstracts for twenty-minute talks is September 1, 1995.

Information: B. G. Fitzpatrick, Department of Mathematics, Box 8205, N.C. State Univ., Raleigh, NC 27695-8205; e-mail: search@math.ncsu.edu.


*19-23 New Directions in the Theory of Markets (Game Theory with Applications in the Social Sciences and Biology), The Fields Institute, Toronto, ON, Canada.

Information: electronicmail: game@fields.uwaterloo.ca.

*23-24 Distinguished Lectures Series, The Fields Institute, Toronto, ON, Canada.

Title: Modular Forms and Elliptic Curves.

Speaker: A. Wiles (Princeton Univ.).

Information: e-mail: valeri@fields.uwaterloo.ca.


*23-27 Arithmetic Algebraic Geometry Workshop, The Fields Institute, Toronto, ON, Canada.

Information: electronic mail: alggeom@fields.uwaterloo.ca.


Program: The purpose of this congress is to bring together different design specialists (such as industrial design, graphic design, acoustic design, light design, images design, landscape design, and so on) that use mathematical and/or informatic tools to solve their problems.

Invited Speakers: R. P. Gomez (Granada Univ., Spain), C. R. Garrido (Granada Univ., Spain), O. Piro (Univ. de les Illes Balears, Spain), D. R. Gonzalez (C.N.R. Bologna, Italy), M. S. Bienbengut (Blumenau Univ., Brazil), and R. Doberti (Buenos Aires Univ.).

23-27 IMA Period of Concentration on Microstructure and Turbulence, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., S.E., Minneapolis, MN 55455. (Mar. 1995, p. 370)

30-November 1 The Tenth International
Symposium on Computer and Information Sciences (ISCS IX), Ephesus, Izmir, Turkey. (May 1995, p. 594)

30-November 3 IEEE Visualization '95, Atlanta Airport Hilton and Towers. (May 1995, p. 594)

November 1995

3–4 Central Section, Kent State University, Kent, OH.

Information: C. Harkness, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: chh@math.ams.org.

5–11 4th Austrian Symposium on History of Mathematics, Neuhofen an der Ybbs, Lower Austria.

Subject: 999 Years in Austria: A History of Mathematics, Neuhofen an der Ybbs, Lower Austria.

Information: C. Binder, Institut fur Technik Mathematik, TU Vienna, Wiedner Hauptstrasse 8-10/1141, A-1040 Vienna, Austria; e-mail: cbinder@email.tuwien.ac.at.


8–10 IMA Tutorial on Disordered Media and Percolation in Materials Science, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., S.E., Minneapolis, MN 55455. (Mar. 1995, p. 370)

13–17 IMA Workshop on Disordered Materials, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., S.E., Minneapolis, MN 55455. (Mar. 1995, p. 370)

17–18 Southeastern Section, University of North Carolina, Greensboro, NC.

Information: C. Harkness, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: chh@math.ams.org.

19–22 International Conference on Pure and Applied Mathematics (ICPAM95), University of Bahrain, Bahrain. (Nov./Dec. 1994, p. 1201)


December 1995

18–21 1st Asian Technology Conference in Mathematics (ATCM), Singapore. (Oct. 1994, p. 1029)

18–22 International Conference on Harmonic Analysis, University of Delhi, Delhi, India. (May 1995, p. 595)


January 1996

8–12 Workshop on Particulate Flows: Processing and Rheology, University of Minnesota, 206 Church St., SE, Minneapolis, MN 55455. (Apr. 1995, p. 482)

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5–9 IMA Workshop on Interface and Thin-Films, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., SE, Minneapolis, MN 55455. (Apr. 1995, p. 482)

15–March 15 IMA Period of Concentration on Light Propagation in Optical Waveguiding Material, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., SE, Minneapolis, MN 55455. (Apr. 1995, p. 482)

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4–8 IMA Workshop on Nonlinear Optical Materials, Institute for Mathematics and its Applications, Univ. of Minnesota, 206 Church St., SE, Minneapolis, MN 55455. (Apr. 1995, p. 482)

April 1996

19–21 Southeastern Section, Baton Rouge, LA.

Information: C. Harkness, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: chh@math.ams.org.

28–May 4 Backlund and Darboux Transformations: Geometry and Modern Applications, The Fields Institute, Toronto, ON, Canada.

Information: e-mail: backlund@fields.utoronto.ca.

May 1996

9–11 International Conference on Nonlinear Problems in Aviation and Aerospace, Dayton Beach, FL. (Jan. 1995, p. 79)

29–June 1 International Conference on Dynamical Systems and Differential Equations, Southwest Missouri State University, Springfield, MO.

Objectives: The objective of the conference is to bring together experts from various branches in the fields of dynamical systems, differential equations, and related subjects, to discuss the trends and recent achievements and to exchange information and viewpoints relevant to theory and applications.

Format: The program will consist of the following: expository lectures on topics of current interest by invited speakers (one-hour talks); seminars organized by area of research (leaders of these sessions will be invited to select speakers who will give 45-minute talks); and 30-minute contributed talks.

Information: S. Hu, Conference, Dept. of Mathematics, Southwest Missouri State Univ., Springfield, MO 65804; tel: 417-836-5112; fax: 417-836-3671; e-mail: dynmcs@caas.smu.edu. To receive the second announcement, which will contain the information on the invited speakers, session organizers and their session topics, please send your name and address. Updated information may also be obtained via anonymous ftp to nic.amsu.edu (146.7.2.3) in the directory of /pub/math_conf.

June 1996

3–7 Eighth Quadrennial International Conference on Graph Theory, Combinatorics, Algorithms, and Applications, Western Michigan University, Kalamazoo, MI. (May 1995, p. 595)

17–20 4th International Conference on Integral Methods in Science and Engineering, Oulu, Finland.


Call for Papers: Authors of contributed papers are requested to submit before February 15, 1996, an abstract containing the topic of the talk, a summary (not exceeding 300 words), and the full institutional address, including the telephone and fax numbers and e-mail address.

Information: S. Seikkala, IMS/96, Division of Mathematics, Faculty of Technology, University of Oulu, 90570 Oulu, Finland, tel: 358 81 533 2656; fax: 358 81 2664; e-mail: Seppo.Seikkala@oulu.fi. The second announcement will be sent to all prospective participants who signify their interest before November 1, 1995.

July 1996

8–10 Heat Transfer 96 (Fourth International Conference on Advanced Computational Methods in Heat Transfer), Udine, Italy.

Sponsors: Wessex Institute of Technology, Southampton, UK, and International Centre for Mechanical Sciences, Udine, Italy.

Abstract Deadline: October 1996.

Final Paper Due: February 1996.

Information: L. Morton, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton S040 7AA, UK; tel: (44)(703) 293223; fax:(44)(703) 292853; e-mail: cam@ib.r1.ac.uk.
April 1996, Waseda University, Tokyo, Japan.

Program: The purpose of this conference and workshop is to review the recent progress in knot theory and to discuss its future. There will be 20 (45-minute) plenary talks and 50 (20-minute) contributed talks in parallel sessions. In the workshop, there will be 3 one-hour x 3-day lectures and some one-hour expository addresses.

Plenary Speakers (Tentative List): D. W. Sumners (Florida S. Univ.); L. H. Kauffman (Univ. Ill. Chicago); C. Gordon (Univ. Texas); G. Burde (Univ. Frankfurt and Main); T. D. Cochran (Rice Univ.); J. M. Montesinos (Univ. C. Madrid); K. Murasugi (Univ. Toronto); K. Taniyama (Tokyo W.C. Univ.); H.Murakami (Osaka C. Univ.)

Call for Papers: Contributed papers are welcome.

Information: S. Suzuki, Math. Dept., School of Education, Waseda Univ., Tokyo 169-50, Japan; fax: 81-3-5286-1308; e-mail: knot96@math.waseda.ac.jp.

8-12 Prague Mathematical Conference 1996, Prague, Czech Republic. (Apr. 1995, p. 482)

10-17 The Second World Congress of Nonlinear Analysis, Athens, Greece, or Istanbul or Ankara, Turkey. (Feb. 1995, p. 281)

14-19 The Seventh International Conference on Fibonacci Numbers and Their Applications, Technische Universität Graz. (Apr. 1995, p. 482)

14-21 ICME-8: 8th International Congress on Mathematical Education, Seville, Spain. (May 1995, p. 595)


August 1996

13-17 Fifth International Colloquium on Numerical Analysis, Plovdiv, Bulgaria. (Apr. 1995, p. 482)

14-17 International Linear Algebra Society Meeting, Chemnitz, Germany. (Jul./Aug. 1994, p. 679)

18-23 Seventh International Colloquium on Differential Equations, Plovdiv, Bulgaria. (Apr. 1995, p. 482)

November 1996

1-3 Central Section, University of Missouri at Columbia, Columbia, MO.
New Publications Offered by the AMS

American Mathematical Society Translations—Series 2
Proceedings of the St. Petersburg Mathematical Society Volume III
O. A. Ladyzhenskaya, Editor
Volume 166
Books in this series highlight some of the most interesting works presented at symposia sponsored by the St. Petersburg Mathematical Society. Aimed at researchers in number theory, field theory, and algebraic geometry, the present volume deals primarily with aspects of the theory of higher local fields and other types of complete discretely valued fields. Most of the papers require background in local class field theory and algebraic $K$-theory; however, two of them, “Unit Fractions” and “Collections of Multiple Sums”, would be accessible to undergraduates.

Contents
A. I. Madunts and I. B. Zhukov, Multidimensional complete fields: Topology and other basic constructions; V. A. Abrashkin, A ramification filtration of the Galois group of a local field; B. M. Bekker, Class field theory for multidimensional complete fields with quasi-finite residue fields; D. G. Benois, On $p$-adic representations arising from formal groups; S. V. Vostokov, The pairing on $K$-groups in fields of valuation of rank $n$; S. V. Vostokov, Artin-Hasse exponentials and Bernoulli numbers; S. V. Vostokov and I. B. Zhukov, Some approaches to the construction of abelian extensions for $p$-adic fields; I. B. Zhukov, Structure theorems for complete fields; O. Izhboldin and I. Kurlandchik, Unit fractions; D. V. Fomin and O. T. Izhboldin, Collections of multiple sums; A. I. Madunts, On convergence of series over local fields; A. Nenashev, On K"och's conjecture about shuffle products.

June 1995, 266 pages (hardcover), ISBN 0-8218-0387-5, ISSN 0065-9290
1991 Mathematics Subject Classification: 11Sxx
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Contemporary Mathematics
Recent Developments in the Inverse Galois Problem
Shreeram S. Abhyankar, Walter Feit, Michael D. Fried, Yasutaka Ihara, and Helmut Voelklein, Editors
Volume 186
This book contains the refereed proceedings of the AMS-IMS-SIAM Joint Summer Research Conference on Recent Developments in the Inverse Galois Problem, held in July 1993 at the University of Washington, Seattle. A new review of Serre's Topics in Galois Theory serves as a starting point. The book describes the latest research on explicit presentation of the absolute Galois group of the rationals. Containing the first appearance of generalizations of modular curves, the book presents applications that demonstrate the full scope of the Inverse Galois Problem. In particular, the papers collected here show the ubiquity of the applications of the Inverse Galois Problem and its compelling significance. The book will serve as a guide to progress on the Inverse Galois Problem and as an aid in using this work in other areas of mathematics. This includes coding theory and other finite field applications. Group theory and a first course in algebraic curves are sufficient for understanding many papers in the volume. Graduate students will find this an excellent reference to current research, as it contains a list of problems appropriate for thesis material in arithmetic geometry, algebraic number theory, and group theory.

Contents
Part A. Explicit quotients of $G_Q$ and $G_{PQ}$; T. Crespo, Explicit Galois realization of $C_{16}$-extensions of $A_1$ and $S_3$; M. D. Fried, Topics in Galois theory; B. H. Matzat, Parametric solutions of embedding problems; A. Reverter and N. Vila, Some projective linear groups over finite fields as Galois groups over $Q$; S. Liedahl and J. Sonn, $K$-Admissibility of metacyclic 2-groups; J. R. Swallow, Embedding problems and the $C_{16}$-$C_4$ obstruction; H. V"olklein, Cyclic covers of $P^1$ and Galois action on their division points; Part B. Moduli spaces and the structure of $G_Q$; M. D. Fried, Introduction to modular towers: Generalizing dihedral group-modular curve connections; Y. Ihara and M. Matsumoto, On Galois actions on profinite completions of braid groups; M. Matsumoto, On the Galois
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"A concise, excellent and well-written introduction to the elementary theory of functions of several complex variables, which is of importance not only in various branches of mathematics but also in theoretical physics."—Mathematical Reviews
Paper $22.00 184 pages

Intuitive Topology
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Deputy Director Search Committee  
Mathematical Sciences Research Institute  
1000 Centennial Drive  
Berkeley, CA 94720-5070

For further information call (510) 642-9238. This position will begin in September 1995.

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**CONTEMPORARY MATHEMATICS**

**Lie Algebras, Cohomology, and New Applications to Quantum Mechanics**  
Niky Kamran and Peter J. Olver, Editors

Volume 160

This volume is devoted to a range of important new ideas arising in the applications of Lie groups and Lie algebras to Schrödinger operators and associated quantum mechanical systems. In light of the rapid developments in this subject, a Special Session was organized at the AMS meeting at Southwest Missouri State University in March 1992 in order to bring together, perhaps for the first time, mathematicians and physicists working in closely related areas. The contributions to this volume cover Lie group methods, Lie algebras and Lie algebra cohomology, representation theory, orthogonal polynomials, q-series, conformal field theory, quantum groups, scattering theory, classical invariant theory, and other topics. This volume, which contains a good balance of research and survey papers, presents a look at some of the current developments in this extraordinarily rich and vibrant area.

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Ronald L. Graham, introducing Taubes’s lecture

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Meetings & Conferences of the AMS

The following pages give information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of 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. For some meetings the list may be incomplete.

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November 11-12  Los Angeles, California  p. 720
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1998
January 7-10  Baltimore, Maryland  p. 725
March 27-28  Manhattan, Kansas  p. 726

Conferences:

1995
July 9-29,  AMS Summer Institute on Algebraic Geometry, Santa Cruz, California. See November/December 1994.

Other Events Cosponsored by the Society

1995

Important Information Regarding AMS Meetings

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

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

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

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

**Deadlines**  
For organizers: Expired  
For consideration of contributed papers in Special Sessions: Expired  
For abstracts: May 18, 1995

**Reception**  
The IMU and the organizers of the meeting invite registered participants and their spouses to a reception at the Meyersdorf House on Mount Scopus on Thursday, May 25, at 7:30 p.m. The mayor of Jerusalem, Ehud Elmert, will officially greet participants at 8:00 p.m. Tickets for this reception are available for $16 each and may be purchased on site at the registration desk in Canada Hall on Wednesday, May 24, and Thursday, May 25.

Boston, Massachusetts  
*Northeastern University*  
October 7-8, 1995

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

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

**Invited Addresses**  
Kevin D. Corlette, University of Chicago, *Harmonic maps, harmonic forms, and locally symmetric spaces.*  
Daniel S. Freed, University of Texas at Austin, *Geometry and quantum field theory.*
Freydoon Shahidi, Purdue University, Automorphic L-functions and representation theory.

Andrei V. Zelevinsky, Northeastern University, Totally positive factorizations of unipotent matrices.

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

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

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

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

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

Geometry, topology, and quantum field theory, Daniel S. Freed.

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

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

Syzygies and geometry, Anthony A. Iarrobino, Jr., Alex Martinsonovskovsky, and Jerzy Wejman, Northeastern University.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Ginzburg-Landau systems, Peter J. Sternberg.

Kent, Ohio

Kent State University

November 3–4, 1995

Meeting #904
Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: September 1995
Program issue of Notices: November 1995
Issue of Abstracts: Fall 1995

Los Angeles, California

University of Southern California

November 11–12, 1995

Meeting #905
Western Section
Associate secretary: Lance W. Small
Announcement issue of Notices: September 1995
Meetings & Conferences

Greensboro, North Carolina

University of North Carolina at Greensboro

November 17–18, 1995

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

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

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

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

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

Guanajuato, Mexico

November 29–December 2, 1995

Meeting #907
Second joint meeting of the AMS and the Sociedad Matematica Mexicana.
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: None published

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

Invited Addresses
David Gabai, California Institute of Technology.
Meetings & Conferences

Orlando, Florida
January 10-13, 1996

Meeting #908
Joint Mathematics Meetings including the 102nd Annual Meeting of the AMS, 79th Annual Meeting of the Mathematical Association of America (MAA), and annual meetings of the Association for Symbolic Logic (ASL), the Association for Women in Mathematics (AWM), and the National Association of Mathematicians (NAM).
Associate secretary: Lance W. Small
Announcement issue of Notices: October 1995
Program issue of Notices: January 1996
Issue of Abstracts: Winter 1996

Deadlines
For organizers: April 12, 1995
For consideration of contributed papers in Special Sessions: September 10, 1995
For abstracts: October 2, 1995

Invited Addresses
Irving Kaplansky, Mathematical Sciences Research Institute, Rings and things (Retiring Presidential Address).
Janos Pach, Hungarian Academy of Science.
Peter W. Shor, AT&T Bell Laboratories.

Iowa City, Iowa
University of Iowa, Iowa City
March 22-23, 1996

Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1996

Deadlines
For organizers: June 22, 1995
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions
Moments and operators, Raúl E. Curto, Palle E.T. Jorgensen, and Paul S. Muhly, University of Iowa, Iowa City.
Arrangements of hyperplanes, Michael Falk and Richard C. Randell, University of Iowa, Iowa City.
Mostly finite geometries, Norman Johnson, University of Iowa, Iowa City.
Derivatives and financial mathematics, John F. Price, Maharishi International University.
Group representations and mathematical physics, Tuong Ton-That, University of Iowa, Iowa City.
New York, New York
Courant Institute of Mathematical Sciences, New York University
April 13–14, 1996
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1996

Deadlines
For organizers: July 13, 1995
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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

Special Sessions
Real algebraic geometry and ordered algebraic structures, Charles N. Delzell and James J. Madden, Louisiana State University, and Scott Woodward, Southern University.
Nonlinear partial differential equations, J. Robert Dorroh and Gisele Ruiz Goldstein, Louisiana State University.
Control theory, Guillermo Ferreyra and Peter R. Wolenski, Louisiana State University.
Low-dimensional topology, Patrick M. Gilmer, Rick Litherland, and Neal W. Stoltzfus, Louisiana State University.
Fluid dynamics, Jerome A. Goldstein and Michael M. Tom, Louisiana State University.
Number theory and quadratic forms, Jurgen Hurrelbrink, Jorge F. Morales, Robert V. Perlis, and Paul B. van Wamelen, Louisiana State University.
Stochastic analysis and its applications, Hui-Hsiung Kuo and Ambar N. Sengupta, Louisiana State University.
Transform theory and evolution equations, Frank Neubrander and Lutz Weis, Louisiana State University.

Antwerp, Belgium
May 22–24, 1996
First joint meeting of the AMS and the mathematical societies of the BENELUX countries (Belgium, the Netherlands, and Luxemburg).
Associate secretary: Robert J. Daverman
Announcement issue of Notices: January 1996
Program issue of 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
Lawrenceville, New Jersey
Rider University

October 5-6, 1996

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1996

Deadlines
For organizers: January 5, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions
Homotopy theory, Martin Bendersky, Hunter College, and Donald M. Davis, Lehigh University.
Mirror symmetry and toric varieties, Ciprian S. Borcea, Rider University, and Sylvain E. Cappell, New York University, Courant Institute.
Spectral theory of partial differential operators, Thomas P. Branson, University of Iowa, Iowa City.
Operads, Hopf algebras, and categories, Arthur M. DuPré, Rutgers University, and James D. Stasheff, University of North Carolina, Chapel Hill.
Elliptic surfaces, William L. Hoyt, Rutgers University, and Charles F. Schwartz, Rider University.
Geometric topology, Norman Levitt, Rutgers University, and Georgia Triantafillou, Temple University.
Radon transforms and tomography, Andrew G. Markoe, Rider University, and Eric Todd Quinto, Tufts University.
Invariants of smooth 4-manifolds, John Morgan, Columbia University, and Frank S. Quinn, Virginia Polytechnic Institute and State University.
Algebraic K-theory, Charles A. Weibel, Rutgers University.

Columbia, Missouri
University of Missouri

November 1-3, 1996
Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1996

Deadlines
For organizers: February 1, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions
Partial differential equations and mathematical physics, Mark S. Ashbaugh, University of Missouri, Columbia.
Harmonic analysis and probability, Nakhle Habib Asmar and Stephen J. Montgomery-Smith, University of Missouri, Columbia.
Differential geometry, John K. Beem and Adam D. Helfer, University of Missouri, Columbia.
Differential equations and dynamical systems, Carmen C. Chicone and Yuri Latushkin, University of Missouri, Columbia.
Commutative algebra, Steven Dale Cutkosky and Hema Srinivasan, University of Missouri, Columbia.
Gauge theory and its interaction with holomorphic and symplectic geometry, Stamatis A. Dostoglou, University of California at Santa Barbara, Jan Segert and Shuguang Wang, University of Missouri, Columbia.
Spectral theory and completely integrable systems, Fritz Gesztesy, University of Missouri, Columbia.

Chattanooga, Tennessee
University of Tennessee, Chattanooga

October 11-12, 1996
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Fall 1996

San Diego, California

January 8-11, 1997

Joint Mathematics Meetings including the 103rd Annual Meeting of the AMS, 80th Annual Meeting of the Mathematical Association of America (MAA), and annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: January 1997
Issue of Abstracts: Winter 1997

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

Memphis, Tennessee

University of Memphis

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

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

College Park, Maryland

University of Maryland, College Park

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

Deadlines
For organizers: July 12, 1996
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Detroit, Michigan

Wayne State University

May 2–4, 1997
Central Section
Associate secretary: Andy R. Magid
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: Spring 1997

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

Atlanta, Georgia

Georgia Institute of Technology

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

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

Milwaukee, Wisconsin

University of Wisconsin, Milwaukee

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

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

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

Baltimore, Maryland

January 7–10, 1998
Joint Mathematics Meetings including the 104th Annual Meeting of the AMS, 81st Annual Meeting of the Mathematical Association of America (MAA), and annual meet-
Meetings & Conferences

ings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: January 1998

Deadlines
For organizers: April 10, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

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

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

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THE EMERGENCE OF THE AMERICAN MATHEMATICAL RESEARCH COMMUNITY, 1876 — 1900: J. J. SYLVESTER, FELIX KLEIN, AND E. H. MOORE
Karen Hunger Parshall and David E. Rowe

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<tr>
<th>City</th>
<th>State</th>
<th>Zip/Country</th>
</tr>
</thead>
</table>

Primary Fields of Interest (choose five from the list at right)

Secondary Fields of Interest (choose from the list at right)

Address for all mail

Telephone number(s)

Electronic address

Signature

**Prepayment Methods and Mailing Addresses**

All payments must be in U.S. Funds.

Send checks, money orders, UNESCO coupons to American Mathematical Society, P.O. Box 5904, Boston, MA 02206-5904

To use VISA or MasterCard, fill in information requested and mail to American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248 or call (401) 455-4000 or 1-800-321-4AMS.

For Foreign Bank Transfers: The name and address of the AMS bank is State Street Bank and Trust Company, 225 Franklin St., ABA #011000028, Account #0128-262-3, Boston, MA 02110.

**VISA □ MasterCard □**

<table>
<thead>
<tr>
<th>Account number</th>
<th>Expiration date</th>
</tr>
</thead>
</table>

**Application for Membership 1995**

(January–December)

Date 19

**Fields of Interest**

If you wish to be on the mailing lists to receive information about publications in fields of mathematics in which you have an interest, please consult the list of major headings below. These categories will be added to your computer record so that you will be informed of new publications or special sales in the fields you have indicated.

<table>
<thead>
<tr>
<th>Field</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>General</td>
</tr>
<tr>
<td>01</td>
<td>History and biography</td>
</tr>
<tr>
<td>02</td>
<td>Mathematical logic and foundations</td>
</tr>
<tr>
<td>03</td>
<td>Set theory</td>
</tr>
<tr>
<td>05</td>
<td>Combinatorics</td>
</tr>
<tr>
<td>06</td>
<td>Order, lattices, ordered algebraic structures</td>
</tr>
<tr>
<td>08</td>
<td>General algebraic systems</td>
</tr>
<tr>
<td>11</td>
<td>Number theory</td>
</tr>
<tr>
<td>12</td>
<td>Field theory and polynomials</td>
</tr>
<tr>
<td>13</td>
<td>Commutative rings and algebras</td>
</tr>
<tr>
<td>14</td>
<td>Algebraic geometry</td>
</tr>
<tr>
<td>15</td>
<td>Linear and multilinear algebra; matrix theory</td>
</tr>
<tr>
<td>16</td>
<td>Associative rings and algebras</td>
</tr>
<tr>
<td>17</td>
<td>Nonassociative rings and algebras</td>
</tr>
<tr>
<td>18</td>
<td>Category theory; homological algebra</td>
</tr>
<tr>
<td>19</td>
<td>K-theory</td>
</tr>
<tr>
<td>20</td>
<td>Group theory and generalizations</td>
</tr>
<tr>
<td>21</td>
<td>Topological groups, Lie groups</td>
</tr>
<tr>
<td>26</td>
<td>Real functions</td>
</tr>
<tr>
<td>28</td>
<td>Measure and integration</td>
</tr>
<tr>
<td>30</td>
<td>Functions of a complex variable</td>
</tr>
<tr>
<td>31</td>
<td>Potential theory</td>
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<tr>
<td>32</td>
<td>Several complex variables and analytic spaces</td>
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<td>33</td>
<td>Special functions</td>
</tr>
<tr>
<td>34</td>
<td>Ordinary differential equations</td>
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<tr>
<td>35</td>
<td>Partial differential equations</td>
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<tr>
<td>39</td>
<td>Finite differences and functional equations</td>
</tr>
<tr>
<td>40</td>
<td>Sequences, series, summability</td>
</tr>
<tr>
<td>41</td>
<td>Approximations and expansions</td>
</tr>
<tr>
<td>42</td>
<td>Fourier analysis</td>
</tr>
<tr>
<td>43</td>
<td>Abstract harmonic analysis</td>
</tr>
<tr>
<td>44</td>
<td>Integral transforms, operational calculus</td>
</tr>
<tr>
<td>45</td>
<td>Integral equations</td>
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<tr>
<td>46</td>
<td>Functional analysis</td>
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<tr>
<td>47</td>
<td>Operator theory</td>
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<tr>
<td>49</td>
<td>Calculus of variations and optimal control; optimization</td>
</tr>
<tr>
<td>51</td>
<td>Geometry</td>
</tr>
<tr>
<td>52</td>
<td>Convex and discrete geometry</td>
</tr>
<tr>
<td>53</td>
<td>Differential geometry</td>
</tr>
<tr>
<td>54</td>
<td>General topology</td>
</tr>
<tr>
<td>55</td>
<td>Algebraic topology</td>
</tr>
<tr>
<td>57</td>
<td>Manifolds and cell complexes</td>
</tr>
<tr>
<td>58</td>
<td>Global analysis, analysis on manifolds</td>
</tr>
<tr>
<td>60</td>
<td>Probability theory and stochastic processes</td>
</tr>
<tr>
<td>62</td>
<td>Statistics</td>
</tr>
<tr>
<td>65</td>
<td>Numerical analysis</td>
</tr>
<tr>
<td>66</td>
<td>Computer science</td>
</tr>
<tr>
<td>70</td>
<td>Mechanics of particles and systems</td>
</tr>
<tr>
<td>73</td>
<td>Mechanics of solids</td>
</tr>
<tr>
<td>76</td>
<td>Fluid mechanics</td>
</tr>
<tr>
<td>78</td>
<td>Optics, electromagnetic theory</td>
</tr>
<tr>
<td>80</td>
<td>Classical thermodynamics, heat transfer</td>
</tr>
<tr>
<td>81</td>
<td>Quantum theory</td>
</tr>
<tr>
<td>82</td>
<td>Statistical mechanics, structure of matter</td>
</tr>
<tr>
<td>83</td>
<td>Relativity and gravitational theory</td>
</tr>
<tr>
<td>85</td>
<td>Astronomy and astrophysics</td>
</tr>
<tr>
<td>86</td>
<td>Geophysics</td>
</tr>
<tr>
<td>90</td>
<td>Economics, operations research, programming, games</td>
</tr>
<tr>
<td>92</td>
<td>Biology and other natural sciences, behavioral sciences</td>
</tr>
<tr>
<td>93</td>
<td>Systems theory; control</td>
</tr>
<tr>
<td>94</td>
<td>Information and communication, circuits</td>
</tr>
</tbody>
</table>
**Membership Categories**

Please read the following to determine what membership category you are eligible for, and then indicate below the category for which you are applying.

For **ordinary members** whose annual professional income is $45,000 or less, the dues are $87; for those whose annual professional income is $45,001 or more, the dues are $116.

The **CMS cooperative rate** applies to ordinary members of the AMS who are also members of the Canadian Mathematical Society and reside outside of the U.S. For members whose annual professional income is $45,001 or less, the dues are $74; for those whose annual professional income is above $45,000, the dues are $99.

For a **joint family membership**, one member pays ordinary dues, based on his or her income; the other pays ordinary dues based on his or her income, less $20. (Only the member paying full dues will receive the Notices and the Bulletin as a privilege of membership, but both members will be accorded all other privileges of membership.)

Minimum dues for **contributing members** are $174.

For either **students** or **unemployed individuals**, dues are $29, and annual verification is required.

The annual dues for **reciprocity members** who reside outside the U.S. and Canada are $58. To be eligible for this classification, members must belong to one of those foreign societies with which the AMS has established a reciprocity agreement, and annual verification is required. Reciprocity members who reside in the U.S. or Canada must pay ordinary member dues ($87 or $116).

The annual dues for **category-S members**, those who reside in developing countries, are $16. Members can choose only one privilege journal. Please indicate your choice below.

Members can purchase a **multi-year membership** by prepaying their current dues rate for either two, three, four or five years. This option is not available to category-S, unemployed, or student members.

**1995 Dues Schedule (January through December)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Ordinary member</th>
<th>CMS Cooperative rate</th>
<th>Joint family member (full rate)</th>
<th>Joint family member (reduced rate)</th>
<th>Contributing member (minimum $174)</th>
<th>Student member (please verify)</th>
<th>Unemployed member (please verify)</th>
<th>Reciprocity member (please verify)</th>
<th>Category-S member</th>
<th>Multi-year membership</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$87</td>
<td>$74</td>
<td>$87</td>
<td>$67</td>
<td>$174</td>
<td>$29</td>
<td>$29</td>
<td>$58 $87 $116</td>
<td>$16</td>
<td>for ........ years</td>
</tr>
</tbody>
</table>

1 **Student Verification** (sign below)

I am a full-time student at .............................................. currently working toward a degree.

2 **Unemployed Verification** (sign below) I am currently unemployed and actively seeking employment. My unemployment status is not a result of voluntary resignation or of retirement from my last position.

3 **Reciprocity Membership Verification** (sign below) I am currently a member of the society indicated on the right and am therefore eligible for reciprocity membership.

4 □ send NOTICES  □ send BULLETIN

**Reciprocating Societies**

- Allahabad Mathematical Society
- Asociacion Matematica Española
- Australian Mathematical Society
- Berliner Mathematische Gesellschaft e.V.
- Calcutta Mathematical Society
- Croatian Mathematical Society
- Dansk Matematikforbund
- Deutsche Mathematiker-Vereinigung e.V.
- Edinburgh Mathematical Society
- Egyptian Mathematical Society
- Gesellschaft für Angewandte Mathematik und Mechanik
- Glasgow Mathematical Association
- Hellenic Mathematical Society
- Indian Mathematical Society
- Iranian Mathematical Society
- Irish Mathematical Society
- Israel Mathematical Union
- Janos Bolyai Mathematical Society
- Korean Mathematical Society
- London Mathematical Society
- Malaysian Mathematical Society
- Mathematical Society of Japan
- Mathematical Society of the Philippines
- Mathematical Society of the Republic of China
- Mongolian Mathematical Society
- Nepal Mathematical Society
- New Zealand Mathematical Society
- Nigerian Mathematical Society
- Norsk Matematikk Forening
- Österreichische Mathematische Gesellschaft
- Polskie Towarzystwo Matematyczne
- Punjab Mathematical Society
- Ramanujan Mathematical Society
- Real Sociedad Matematica Española
- Saudi Association for Mathematical Sciences
- Sociedade Colombiana de Matematica
- Sociedad de Matematica de Chile
- Sociedad Matematica de la Republica Dominicana
- Sociedad Matematica Mexicana
- Sociedade Brasileira de Matematica
- Sociedad Brasileira de Matematica Aplicada e Computacional
- Sociedad Paranaense de Matematica
- Sociedade Portuguesa de Matematica
- Societat Catalana de Matematiques
- Societatea Matematicienilor din Romania
- Société de Mathématiques Appliquées et Industrielles
- Société Mathématique de Belgique
- Société Mathématique de France
- Société Mathématique Suisse
- Society of Associations of Mathematicians & Computer Science of Macedonia
- Society of Mathematicians, Physicists, and Astronomers of Slovenia
- South African Mathematical Society
- Southeast Asian Mathematical Society
- Suomen Matemattinen Yhdistys
- Svenska Matematikersamfundet
- Unión Matemática Argentina
- Unión de Matematicas de Chile
- Unión de Matematicas de la República Dominicana
- Unión de Matematicas de la República Mexicana
- Unione Matematica Italiana
- Vijnana Parishad of India
- Wiskundig Genootschap
Order Form

ORDERED BY

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>City</th>
<th>State</th>
<th>Zip</th>
<th>Country</th>
<th>Code</th>
<th>e-mail</th>
</tr>
</thead>
</table>

MAIL TO (IF DIFFERENT)

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>City</th>
<th>State</th>
<th>Zip</th>
<th>Country</th>
<th>Code</th>
<th>e-mail</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Code</th>
<th>Title</th>
<th>Price</th>
<th>Total</th>
</tr>
</thead>
</table>

Optional delivery by air to foreign addresses $6.50 per copy
Residents of Canada, please include 7% GST

PAYMENT METHOD

- □ MasterCard
- □ Visa
- □ Check or Money Order

Card Number ___________________ Expiration Date ____________
Signature _____________________

For orders with remittances
American Mathematical Society
P. O. Box 5904
Boston, MA
02206-5904
401.455.4000

For VISA or MasterCard orders
American Mathematical Society
P. O. Box 6248
Providence, Rhode Island
02940-6248
800.321.4AMS
(800.321.4267)
cust-serv@math.ams.org

Please send me information about AMS membership
- □ individual
- □ institutional
- □ corporate
- □ institutional associate

CHARGE BY PHONE IN US AND CANADA 800.321.4AMS

Publications, videotapes, and miscellaneous items are sent via UPS to U.S. residential addresses, RPS or UPS to U.S. business addresses, and as printed matter elsewhere unless another delivery method is requested. Charges for surface delivery are paid by the AMS. For air delivery outside the U.S., please include an additional $6.50 per item. Software is sent via UPS Second Day Air to U.S. addresses and via U.S. Postal Service air parcel post to addresses outside the United States. Add shipping and handling for software: $8 per order in the U.S. and Canada; outside the U.S. and Canada $35 per order ($15 per order for AMS-TeX and/or AMSFonts only). Journal back numbers, Mathematical Reviews indexes, and review volumes are sent via surface mail to any destination unless air delivery is requested. Postage for surface mail is paid by the AMS. Air delivery rates, which will be quoted upon request, must be paid by the purchaser.

Customers in these areas should request price information and order directly from the indicated distributors: EUROPE, MIDDLE EAST, AFRICA: Oxford University Press, Walton Street, Oxford OX2 6DP England. Tel: 0865 50707, Telefax 0865 50646, Telex 837330 OXPREC; exclusive distributor of AMS books. INDIA: International Book Agency, flat No. 2, Nirala Market, Nirala Nagar, Lucknow, 226-020, India. Tel: 70506, Fax Nos: 79079, 24206, 230376; exclusive distributor of AMS books. JAPAN: Maruzen Co. Ltd., P. O. Box 5090, Tokyo International 100-81, Japan. Tel: Tokyo 03-5172-7211, Telex: JZ5516; exclusive distributor of AMS books and journals.
Change of Address

Members of the Society who move or change positions are urged to notify the Providence Office as soon as possible.

Journal mailing lists must be printed four to six weeks before the issue date. Therefore, in order to avoid disruption of service, members are requested to provide the required notice well in advance.

Besides mailing addresses for members, the Society's records contain information about members' positions and their employers (for publication in the Combined Membership List). In addition, the AMS maintains records of members' honors, awards, and information on Society service.

When changing their addresses, members are urged to cooperate by supplying the requested information. The Society's records are of value only to the extent that they are current and accurate.

If your address has changed or will change within the next two or three months, please fill out this form, supply any other information appropriate for the AMS records, and mail it to:

Customer Services
AMS
P.O. Box 6248
Providence, RI 02940
or send the information on the form by e-mail to:
amsmem@math.ams.org or cust-serv@math.ams.org

Name _____________________________
Customer code ______________________
Change effective as of __________________

Old mailing address


New mailing address


New position _________________________
If mailing address is not that of your employer,
please supply the following informations:

New employer _________________________
Location of employer (city, state, zip code, country)

Telephone number _____________________
e-mail _________________________________
Recent honors and awards
Personal Information

Name _____________________________
Mailing Address ________________________________
Telephone ______________________ e-mail ____________

Membership □ all that apply
AMS □
CMS □
MAA □
PME □
AWM □

Badge Information
Affiliation ____________________________
(Please limit affiliation to 36 characters – one line only)
Name to appear on badge ______________________
Guest Badge ____________________________

If you do not wish your program and badge to be mailed to you on July 12, place a check in the box.

Registration Fees

<table>
<thead>
<tr>
<th>Event</th>
<th># Tix</th>
<th>Price Per</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member AMS, CMS, MAA, PME</td>
<td>$125</td>
<td>$183</td>
<td></td>
</tr>
<tr>
<td>Nonmember</td>
<td>$194</td>
<td>$252</td>
<td></td>
</tr>
<tr>
<td>Graduate Student</td>
<td>$35</td>
<td>$45</td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>$20</td>
<td>$26</td>
<td></td>
</tr>
<tr>
<td>High School Student</td>
<td>$2</td>
<td>$5</td>
<td></td>
</tr>
<tr>
<td>Unemployed</td>
<td>$35</td>
<td>$45</td>
<td></td>
</tr>
<tr>
<td>Temporarily Employed</td>
<td>$95</td>
<td>$120</td>
<td></td>
</tr>
<tr>
<td>Third World Fee</td>
<td>$35</td>
<td>$45</td>
<td></td>
</tr>
<tr>
<td>Ermentaus Member of AMS or MAA</td>
<td>$35</td>
<td>$45</td>
<td></td>
</tr>
<tr>
<td>High School Teacher</td>
<td>$35</td>
<td>$45</td>
<td></td>
</tr>
<tr>
<td>Librarian</td>
<td>$35</td>
<td>$45</td>
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</tr>
<tr>
<td>One-day Member</td>
<td>—</td>
<td>$39</td>
<td></td>
</tr>
<tr>
<td>One-day Nonmember</td>
<td>—</td>
<td>$139</td>
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Total Payment

<table>
<thead>
<tr>
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<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Registration Fee(s)</td>
<td>______</td>
</tr>
<tr>
<td>Event Tickets</td>
<td>______</td>
</tr>
<tr>
<td>Dorm Payment or Hotel Deposit</td>
<td>______</td>
</tr>
<tr>
<td>TOTAL Amount Due</td>
<td>______</td>
</tr>
</tbody>
</table>

Make checks payable to the AMS. Canadian checks must be marked “U.S. Funds”. You may charge this total to your VISA or MasterCard.

Card Number: ____________
Card Type: ____________ Expiration Date: ____________
Signature: ____________
Name on Card: ____________

Please complete this form and return it to:
Mathematical Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, Rhode Island 02940
U.S.A
401-455-4143 or 1-800-321-4267 x 4143

For Office Use Only
Codes: ____________
Options: ____________
Hotel: ____________
Dates: ____________
Dorm: ____________
Room Type: ____________
Hotel Deposit: ____________
Dorm Payment: ____________
TOTAL Amt. Paid: ____________
Room/Board Paid: $ ____________
Room/Board Due: $ ____________
Remarks: ____________

Event Tickets

<table>
<thead>
<tr>
<th>Event</th>
<th># Tix</th>
<th>Price Per</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Opening Banquet</td>
<td>—</td>
<td>$25</td>
<td>—</td>
</tr>
<tr>
<td>Regular</td>
<td>—</td>
<td>$25</td>
<td>—</td>
</tr>
<tr>
<td>Vegetarian</td>
<td>—</td>
<td>$25</td>
<td>—</td>
</tr>
<tr>
<td>Dinner and Cruise</td>
<td>—</td>
<td>$33</td>
<td>—</td>
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<tr>
<td>Adult</td>
<td>—</td>
<td>$33</td>
<td>—</td>
</tr>
<tr>
<td>Children 6-11 yrs</td>
<td>—</td>
<td>$11</td>
<td>—</td>
</tr>
<tr>
<td>PME Banquet</td>
<td>—</td>
<td>$10</td>
<td>—</td>
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<tr>
<td>Members and Families</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Nonmembers</td>
<td>—</td>
<td>$17</td>
<td>—</td>
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<tr>
<td>MAA 25-year Banquet</td>
<td>—</td>
<td>$25</td>
<td>—</td>
</tr>
<tr>
<td>Regular</td>
<td>—</td>
<td>$25</td>
<td>—</td>
</tr>
<tr>
<td>Vegetarian</td>
<td>—</td>
<td>$25</td>
<td>—</td>
</tr>
</tbody>
</table>

TOTAL for Event Tickets $ ______
See separate tour form in this issue.

Deadlines

Advance Registration/Residence Hall Reserv. June 15, 1995
Hotel changes/cancellation thru MMSB July 5, 1995
Final Advance Registration (no housing) July 14, 1995
90% Refund on Residence Hall Package July 25, 1995*
50% Refund on Events July 31, 1995*
50% Refund on Registration Cancellation August 4, 1995*

*no refunds after this date
General Information

Where applicable, please check off one of the following

☐ I will be making my own reservations. Name of hotel or motel: ____________________________

☐ I live in the area or will be staying privately with family or friends.

☐ I plan to share a room with ____________________________, who is making our reservations.

University Reservations

Full prepayment for room and board is required. Purchase of a room and board package (breakfast and lunch) is required, and it is included in the rates listed below. All rates are per person. Mathfest participants may occupy the residence halls from Saturday, August 5 to Wednesday, August 9 only.

Acknowledgment of your residence hall reservations will be sent to the address indicated on the reverse side of this application. Please mark applicable rates listed below and enter the totals where applicable. There is no children's rate, but sleeping bags are allowed.

<table>
<thead>
<tr>
<th>Description</th>
<th># Staying</th>
<th>At # of Days</th>
<th>Total</th>
<th>Please ✓ all that apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td></td>
<td>$36</td>
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<td>Male</td>
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<tr>
<td>Double</td>
<td></td>
<td>$32</td>
<td></td>
<td>Female</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>$_____</td>
<td></td>
<td>Smoker</td>
</tr>
</tbody>
</table>

Rates are per person.

Date and Time of Arrival: ____________________________

Date and Time of Departure: ____________________________

Names of Other Occupants

<table>
<thead>
<tr>
<th>Arrival Date</th>
<th>Departure Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Child? (give age)</td>
</tr>
<tr>
<td></td>
<td>Child? (give age)</td>
</tr>
<tr>
<td></td>
<td>Child? (give age)</td>
</tr>
</tbody>
</table>

Majority of rooms will be assigned in the Living/Learning Complex; Marsh/Austin/Tupper will be used for overflow.

Hotel Reservations

Please indicate type of room:

☐ Single $89

☐ Double $89

☐ Triple $89

☐ Quad $89

To guarantee a room, please include $89 by check or provide a credit card number.

☐ Deposit enclosed   ☐ Hold with my credit card   Card Number ____________________________ Exp. Date __________

Date and Time of Arrival: ____________________________

Date and Time of Departure: ____________________________

Names of Other Occupants

<table>
<thead>
<tr>
<th>Arrival Date</th>
<th>Departure Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Child? (give age)</td>
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<td></td>
<td>Child? (give age)</td>
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