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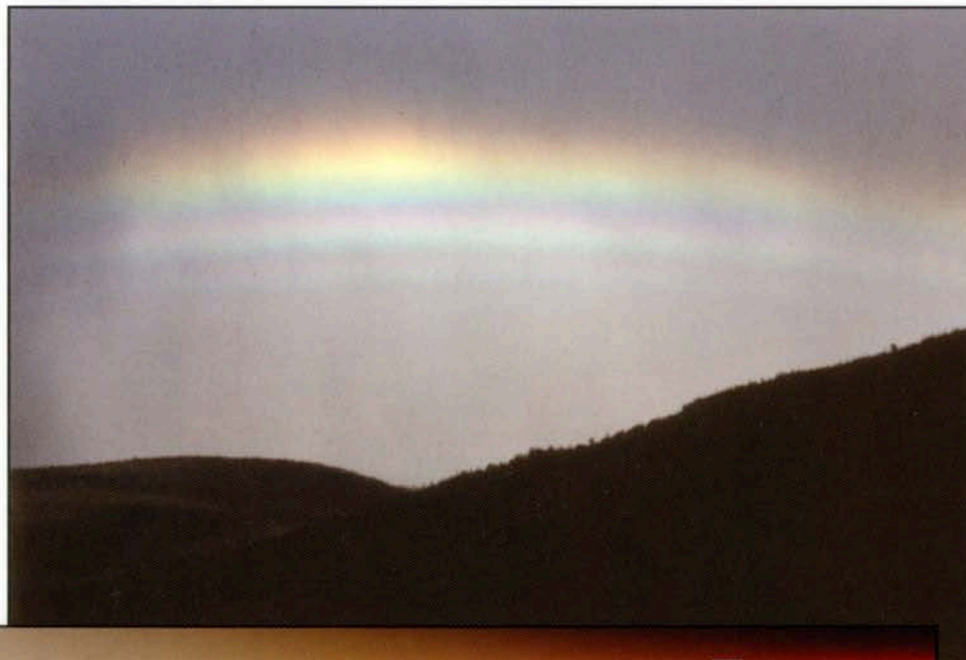

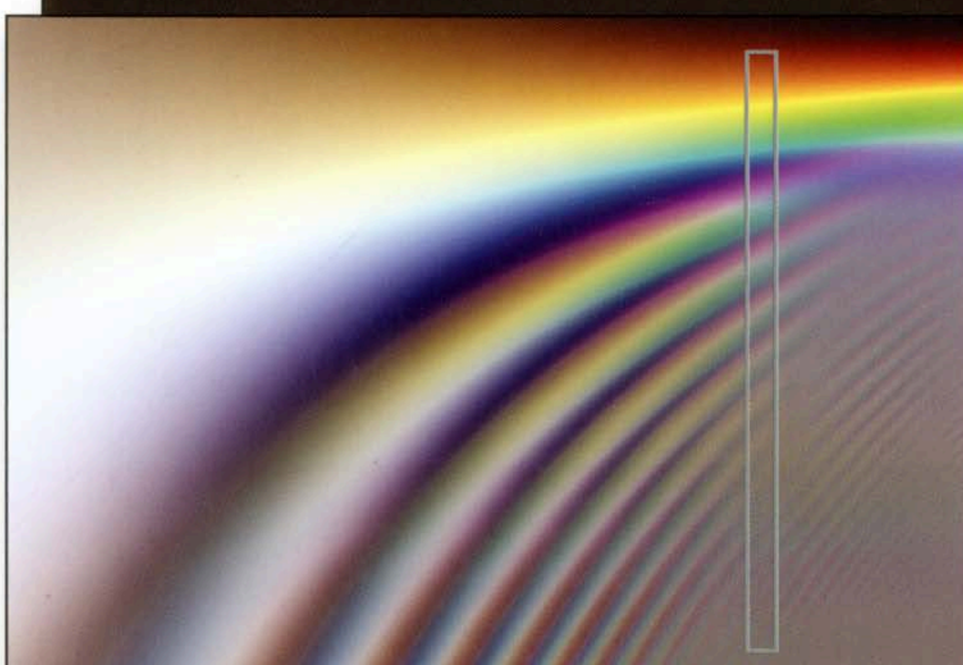

Supernumerary rainbows along with Airy's explanation (see page 1371)

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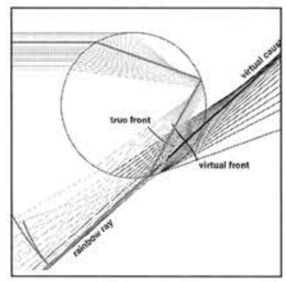
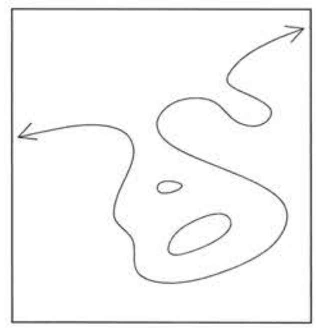
Feature Articles





Communications

Commentary

Notices

of the American Mathematical Society

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Departments

From the AMS Secretary

Graduate Student Seminars: Encouraging Student Participation and Developing Essential Research Skills Using Cookies, Doughnuts, and Mathematics

Technical seminars are an important part of graduate education in mathematics. However, graduate students are commonly "seen and not heard" in such seminars, as their voices typically are overwhelmed by those of faculty members. Doctoral programs should institute special seminar series aimed specifically at graduate students (and other young scientists).

Two years ago, while a graduate student in the Center for Applied Mathematics (CAM) at Cornell University, I revived a defunct series of talks by graduate students. The idea for reinventing what are now called the Mathematical Sciences Graduate Student Seminars arose during a conversation with some friends the previous spring. Although we were in the same program, most of us knew little about our colleagues' research beyond buzzwords (and perhaps general background information). We agreed it was worthwhile to learn more about each other's work through informal talks and discussions that were actually understandable, so I decided to pursue this idea.

The seminars in this series serve two primary purposes: (1) to foster interactions between graduate students in various disciplines both academically and socially, and (2) to allow students the opportunity to present their work and to discuss it with a broad group of their peers. Although polished presentations are neither demanded nor expected, the majority of the talks have been good and several were superb. These seminars offer a chance for students to get to know each other, practice their speaking skills, offer constructive criticism, etc. A typical seminar draws an audience of ten to fifteen students and one to three professors. The talks have covered diverse areas of applied mathematics, including genomics, coupled oscillators, polymers, pattern formation, ventricular fibrillation, hopping robots, hybrid dynamical systems, finite element methods, and quantum chaos. Additionally, some students have discussed research from internships, and others have led discussions on topics such as the experience of women in graduate school.

How does one actually initiate such a seminar series? My first step, during the summer of 2000, was to contact both Terry Fine, the director of graduate studies of Cornell's applied mathematics program, and Steve Strogatz, the director of Cornell's Integrative Graduate Education and Research Traineeship (IGERT) grant in nonlinear science, to see what kind of reaction my thoughts would elicit. Terry Fine supported my efforts, and Steve Strogatz was especially enthusiastic, offering not only encouragement but also money to purchase muffins and doughnuts.

The next step was to announce the seminar series and find enough speakers to be able to hold it either weekly or biweekly. To inform people of my plans, I sent email to Cornell's CAM and IGERT mailing lists. To acquire speakers, I contacted advanced graduate students both within and outside CAM and IGERT shortly after the fall 2000 semester began. Through this process, as well as by word of mouth, I was able to find enough speakers for the seminar series' first semester. Obtaining speakers has subsequently become easier, as this seminar series has become an established part of the academic landscape for Cornell's applied mathematics and nonlinear science programs. During the fall 2001 semester I started passing along the duties of running this seminar series to Suzanne Shontz, a fellow CAM graduate student. We determined together which students should be invited to speak, and she did the majority of the work during the spring 2002 semester. I expect that she will similarly find an apprentice for the future.

I utilized several media to announce individual talks. Every department in which CAM advertises its colloquia also received flyers about each talk, and the talks were included in weekly seminar listings distributed by the mathematics and physics departments. Additionally, I sent two emails every week—one on the day of the seminar and another two days before—to the CAM and IGERT colloquium mailing lists. Moreover, the CAM and IGERT webpages both contain links to the seminar series' webpage (`http://www.cam.cornell.edu/colloquia/mathsciences.html`).

An interdisciplinary environment assisted the establishment of this seminar series at Cornell. However, similar efforts should be able to flourish elsewhere. Indeed, my purpose here is not primarily to describe a single successful endeavor, but rather to invite others to replicate it. This requires effort on the part of both graduate students and established faculty. Indubitably, any seminar series involving primarily graduate students also requires active participation by graduate students in its organization and implementation. Nevertheless, the encouragement (and perhaps financial assistance) of established scientists is also an integral component in establishing seminar series such as the one I have described.

Ultimately, it would be ideal for every graduate program in the mathematical sciences, whether interdisciplinary or not, to include a medium for students to present their research to each other in a comfortable environment that also incorporates some of the canonical structures of scientific research.

—Mason A. Porter
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Letters to the Editor

Universities under Curfew

When some of us decided in early April to circulate a statement announcing our refusal to cooperate with official Israeli institutions in the wake of the ongoing Israeli military reoccupation of most of the Palestinian autonomous zones, we anticipated, and indeed hoped, that our initiative would provoke a substantial discussion of our reasons for taking such a difficult step, in the pages of the *Notices* or elsewhere. We did feel entitled to expect, however, that the discussion would be based on the text of our statement rather than on the thoroughly misleading interpretation presented in the letter entitled "A boycott by passport" published in the November 2002 issue. The letter quotes our statement briefly, leading the reader to believe that our intention was "essentially [to] bar all serious contact with Israeli nationals." This interpretation is so far-fetched that we have to assume that many of the signatories simply did not read our statement.

Certainly few of them can have read the explanatory material at `http://www.pjpo.org/`. Regarding the Mona Baker incident which occupies most of the text of "A boycott by passport", we do not believe that it is our role to comment on the decisions of individual signatories of our statement, and we decline to do so in this instance. Mona Baker herself did not consult us either before or after taking her action. Nevertheless, our own position is clear. A letter posted at `http://www.pjpo.org/letter_opposition.html` in response to a petition opposed to our initiative reaffirms this commitment and makes it more precise:

> The letter from Etingof states that "Targeting innocent fellow scientists is unacceptable." We agree. The final sentence of our statement affirms our intention to continue collaborating with, and hosting, Israeli scientists, and it goes without saying that this intention applies to all Israeli colleagues, regardless of their political perspectives. In particular we are aware of the "harm", in our opinion limited, our initiative may cause individual Israeli scientists, and are determined to do everything in our power to avoid doing harm, especially to younger colleagues whose resources are limited.

On the other hand, many individual scientists who signed our statement have been subjected to harassment by colleagues. Some of us, both junior and senior scientists, have received threatening messages, including threats to boycott scientific activities with which we are involved and journals on whose editorial boards we serve.

We also draw your attention to the following response, posted at `http://www.pjpo.org/faq.html`, to the question, "Is the boycott compatible with scientific responsibilities?"

> We signed the "Call for a boycott of Israeli scientific institutions" as individuals only. This means it remains subordinated to our duties and will in no way affect our conduct in any official capacity such as editor of a scientific journal, organizer of a scientific conference, director of a scientific group or institution, or officer of a university or a scientific society—or in any directly or indirectly related matter.

Given the original text and the above clarifications, it is hard to see how anyone can honestly construe our statement as a call for a "boycott by passport". We thus cannot consider the letter published in the *Notices* a contribution to a substantial discussion: it does not address our statement. For the same reasons, Peter Shalen's letter to the *Notices* is irrelevant to our petition.

The "boycott by passport" letter does, however, raise an important point. Of course we too "condemn all actions that deny academic freedom to individuals solely on the basis of their nationality." Palestinian universities were subjected to repeated closures from the beginning of the Israeli occupation to the creation of the Palestinian authority. With the current military reoccupation of the Palestinian autonomous zones, closure has again become a fact of daily life for Palestinian colleagues. To quote a recent statement signed by academics and others from around the world and published at `http://www.birzeit.edu/`, "Following Israel's military re-occupation of West Bank towns (including Ramallah) in mid-June 2002, all Palestinian educational life within the re-occupation zones has been brought to a grinding halt by a blanket curfew imposed on the civilian population."

Before the Oslo process, the Council of the AMS refused on several occasions to take a position against the closure of Palestinian universities. The—we hope temporary—opprobrium of the readers of the *Notices*, due to a misrepresentation of our objectives, would be a small price to pay if the AMS were to make known its intention henceforward to support academic freedom for Palestinians as well as for colleagues of other nationalities.

—Viviane Baladi
CNRS (Centre National de la Recherche Scientifique) and Institut de Mathématiques de Jussieu

—Ivar Ekeland,
Université Paris IX

—Michael Harris,
Université Paris 7

(Received September 13, 2002)

Editor's Note: The above letter was endorsed by twelve mathematicians, whose names are listed on the Web at `http://www.pjpo.org/AMS.html`.

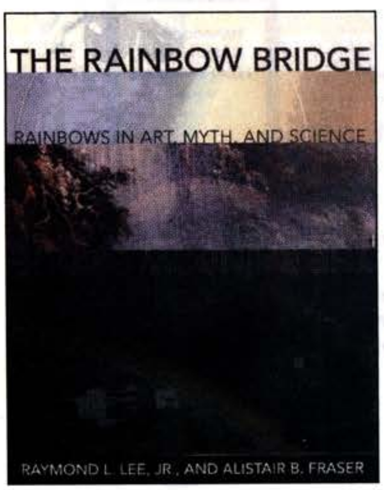
—Harold P. Boas

Like a Bridge over Colored Water: A Mathematical Review of *The Rainbow Bridge: Rainbows in Art, Myth, and Science*

Reviewed by John A. Adam

The Rainbow Bridge: Rainbows in Art, Myth, and Science
Raymond L. Lee Jr. and Alistair B. Fraser
Pennsylvania State University Press, 2001
393 pages, $65.00
ISBN 0-271-01977-8

This is a magnificent and scholarly book, exquisitely produced, and definitely not destined only for the coffee table. It is multifaceted in character, addressing rainbow-relevant aspects of mythology, religion, the history of art, art criticism, the history of optics, the theory of color, the philosophy of science, and advertising! The quality of the reproductions and photographs is superb. The authors are experts in meteorological optics, but their book draws on many other subdisciplines. It is a challenge, therefore, to write a review about a book that contains no equations or explicit mathematical themes for what is primarily a mathematical audience. However, while the mathematical description of the rainbow may be hidden in this book, it is nonetheless present. Clearly, such a review runs the risk of giving a distorted picture of what the book is about, both by "unfolding" the hidden mathematics and suppressing, to some extent, other important and explicit themes: the connections with mythology, art, and science. To a degree this is inevitable, if such a weighted metric is to be used. Lee and Fraser are intent on exploring bridges from the rainbow to all the places listed above, and in the opinion of this reviewer they have succeeded admirably. The serious reader will glean much of value, and mathematicians in particular may benefit from the tantalizing hints of mathematical structure hidden in the photographs and graphics. Following an account of several themes present in the book that I found particularly appealing, some of the mathematical structure underlying and supporting the bridge between the rainbow and its optical description will be emphasized in this review.



I have included several direct quotations to illustrate both the writing style and the features of the book that I found most intriguing. Frankly, I found some of the early chapters harder to appreciate than later ones. This is a reflection, no doubt, of my own educational deficiencies in the liberal arts; but upon completing the book, I was moved to suggest to the chair of the art department that it might be interesting to offer a team-taught graduate seminar in art, using this book as a text. He is now avidly reading my copy of the book.

The ten chapters combined trace the rainbow bridge to "the gods" as a sign and symbol ("emblem and enigma"); to the "growing tension between scientific and artistic images of the rainbow"; through the inconsistencies of the Aristotelian description and beyond, to those of Descartes and Newton, and the latter's theory of color; to claims of a new unity between the scientific and artistic

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enterprises; the evolution of scientific models of the rainbow to relatively recent times; and the exploitation and commercialization of the rainbow. All these bridges, the authors claim, are united by the human appreciation of the rainbow's compelling natural beauty. And who can disagree? An appendix is provided ("a field guide to the rainbow") comprising nineteen basic questions about the rainbow, with nontechnical (but scientifically accurate) answers for the interested observer. This is followed by a set of chapter notes and a bibliography, both of which are very comprehensive. The more technical scientific aspects of the distribution of light within a rainbow are scattered liberally throughout the latter half of the book; indeed, the reader more interested in the scientific aspects of the rainbow might wish to read the last five chapters in parallel with the first five (as did I). The technical aspects referred to are explained with great clarity.

But what *is* a rainbow? Towards the end of this review, several mutually inexclusive but complementary levels of explanation will be noted, reflecting the fact that there is a great deal of physics and mathematics behind one of nature's most awesome spectacles. At a more basic observational level, surely *everyone* can describe the colored arc of light we call a rainbow, we might suggest, certainly as far as the *primary* bow is concerned. In principle, whenever there is a primary rainbow, there is a larger and fainter *secondary* bow. The primary (formed by light being refracted twice and reflected once in raindrops) lies beneath a fainter secondary bow (formed by an additional reflection, and therefore fainter because of light loss) which is not always easily seen. There are several other things to look for: faint pastel fringes just below the top of the primary bow (supernumerary bows, of which more anon), the reversal of colors in the secondary bow, the dark region between the two bows, and the bright region below the primary bow. This observational description, however, is probably not one that is universally known; in some cultures it is considered unwise even to look at a rainbow. Indeed, in many parts of the world, it appears, merely pointing at a rainbow is considered to be a foolhardy act. Lee and Fraser state that "getting jaundice, losing an eye, being struck by lightning, or simply disappearing are among the unsavory aftermaths of rainbow pointing."

The historical descriptions are in places quite breathtaking; we are invited to look over the shoulders, as it were, of Descartes and Newton as they work through their respective accounts of the rainbow's position and colors. While the color theory of Descartes was flawed, his geometric theory was not. Commenting on the latter, the authors point out that "Descartes'[s] seventeenth-century analysis of the rainbow bears out Plato's great faith in observations simplified and clarified by the power of mathematics." Newton, on the other hand, eschews Descartes's cumbersome ray-tracing technique and "silently invokes his mathematical invention of the 1660s, differential calculus, to specify the minimum deviation rays of the primary and secondary rainbows." Later in the book Lee and Fraser remark that Aristotle and later scientists in antiquity "constructed theories that primarily *describe* natural phenomena in mathematical or geometric terms, with little or no concern for physical mechanisms that might *explain* them." This contrast goes to the heart of the difference between Aristotelian and mathematical modeling.

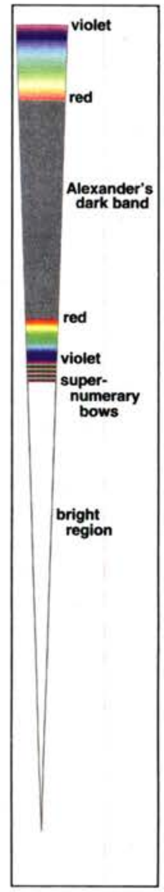


Figure 1. A sector illustrating the rainbow configuration, including both a primary bow (on the bottom) and a secondary bow (at the top). The bright region is not shown to scale.

I was pleasantly surprised to learn that the English painter John Constable was quite an avid amateur scientist: he was concerned that his paintings of clouds and rainbows should accurately reflect the science of the day, and he took great trouble to acquaint himself with Newton's theory of the rainbow (many other details can be found in pp. 80–7 of the book). In a similar vein, the writer John Ruskin was a detailed observer of nature, his goal being "that of transforming close observation into faithful depiction of a purposeful, divinely shaped nature." The poet John Keats implies in his *Lamia* that Newton's natural philosophy destroys the beauty of the rainbow ("There was an awful rainbow once in heaven: / We know her woof, her texture; she is given / In the dull catalog of common things. / Philosophy will clip an Angel's wings"). Keats's words reflected a continuing debate: did scientific knowledge facilitate or constrain poetic descriptions of nature? His contemporary William Wordsworth apparently held a different opinion, for he wrote, "The beauty in form of a plant or an animal is not made less but more apparent as a whole by more accurate insight into its constituent properties and powers."

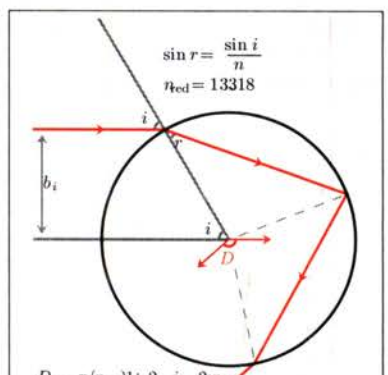


Figure 2. A typical path through a raindrop for a ray of light contributing to the primary rainbow, according to geometrical optics.

In a subsection of Chapter 4 entitled "The Inescapable (and Unapproachable) Bow", the authors address, amongst other things, some common misperceptions about rainbows. Just as occurs when we contemplate our visage in a mirror, what we see is not an *object*, but an *image*; near the end of the chapter this rainbow image is beautifully portrayed as "a mosaic of sunlit rain." Optically, the rainbow is located at infinity, even

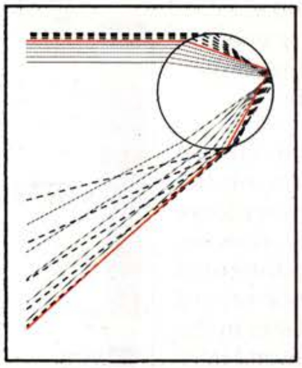


Figure 3. The paths of several rays of light impinging upon a raindrop with different angles of incidence. Such rays contribute to the primary rainbow. The ray of minimum deviation (the rainbow ray) is the darkest line.

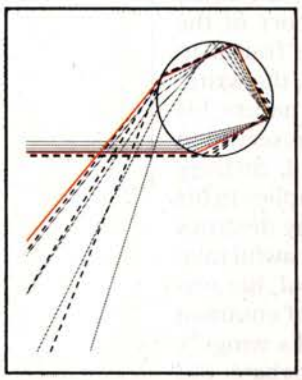


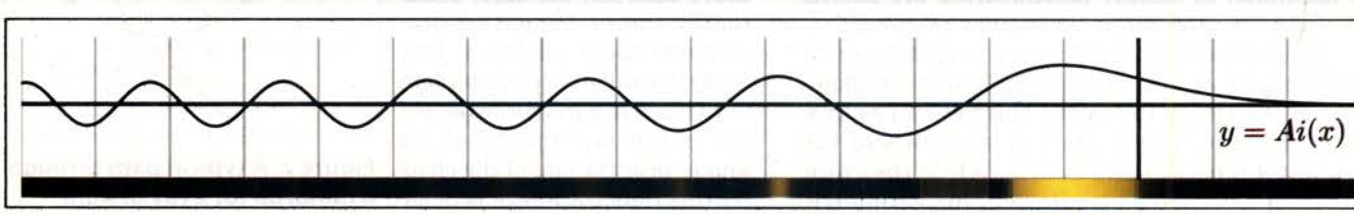
Figure 4. The ray paths for the secondary rainbow, similar to Figure 3 above. Again, the ray of minimum deviation is the darkest line.

though the raindrops or droplets sprayed from a garden hose are not. To place the rainbow in the sky, note that the *antisolar point* is 180° from the Sun on a line through the head of the observer. As will be noted below, rays of sunlight are deviated from this line (in a clockwise sense in Figure 2); the ray of minimum deviation (sometimes called the rainbow or Descartes ray) is deviated by about 138° for the primary bow. Therefore there is a concentration of deviated rays near this angle, and so for the observer the primary bow is an arc of a circle of radius 180° − 138° = 42° centered on the antisolar point. Thus the rainbow has a fixed angular radius of about 42° despite illusions (and allusions) to the contrary. The corresponding angle for the secondary bow is about 51°, though in each instance the angle varies a little depending on the wavelength of the light. Without this phenomenon of *dispersion* there would be only a "whitebow"!

It is perhaps an occupational hazard for professional scientists and mathematicians to be a little frustrated by incorrect depictions or explanations of observable phenomena and mathematical concepts in literature, art, the media, etc. From the point of view of an artist, however (Constable notwithstanding), scientific accuracy is not necessarily a prelude to artistic expression; indeed, to some it may be considered a hindrance. Nevertheless, we can identify perhaps with the authors, who, in commenting on the paintings of Frederic Church (in particular his *Rainy Season in the Tropics*), write, "Like Constable, he in places bends the unyielding rule that all shadows must be radii to the bow (that is, they must converge on the rainbow's center)." The same rule applies to sunbeams, should they be observable concurrently with a rainbow.

By the middle of the eighteenth century, the contributions of Descartes and Newton notwithstanding, observations of supernumerary bows were a persistent reminder of the inadequacy of current theories of the rainbow. As Lee and Fraser so pointedly remark, "One common reaction to being confronted with the unexplained is to label it inexplicable." This led to these troubling features being labeled spurious; hence the unfortunate addition of the adjective *supernumerary* to the rainbow phenomenon. Now it is known that such bows "are an integral part of the rainbow, not a vexing corruption of it"; an appropriate, though possibly unintended, mathematical pun (see below). By focusing attention on the light *wavefronts* incident on a spherical drop rather than on the rays normal to them, it is easier to appreciate the self-interference of such a wave as it becomes "folded" onto itself as a result of refraction and reflection within the drop. This is readily seen from Figures 8.7 and 8.9 in the book (see Figures 5 and 6 here), from which the true extent of the rainbow is revealed: the primary rainbow is in fact the *first interference maximum*, the second and third maxima being the first and second supernumerary bows respectively (and so on).

The angular spacing of these bands depends on the size of the droplets producing them. The width of individual bands and the spacing between them decreases as the drops get larger. If drops of many different sizes are present, these supernumerary arcs tend to overlap somewhat and smear out what would have been obvious interference bands for droplets of uniform size. This is why these pale blue or pink or green bands are then most noticeable near the top of the rainbow: it is the near-sphericity of the smaller drops that enable them to contribute to this part of the bow; larger drops are distorted from sphericity by the aerodynamic forces acting upon them. Nearer the horizon a wide range of drop size contributes to the bow, but at the same time it tends to blur the interference bands. In principle, similar interference effects also occur above the secondary rainbow, though they are very rare, for reasons discussed in the penultimate chapter. Lee and Fraser summarize the importance of spurious bows with typical metaphorical creativity: "Thus the supernumerary rainbows proved to be the



Graph of the Airy function $Ai(x)$, which is a solution of the differential equation $y'' + xy = 0$. Below, according to Airy's theory, illumination is proportional to $Ai(x)^2$, simulating a monochromatic bow along with several supernumerary bows.

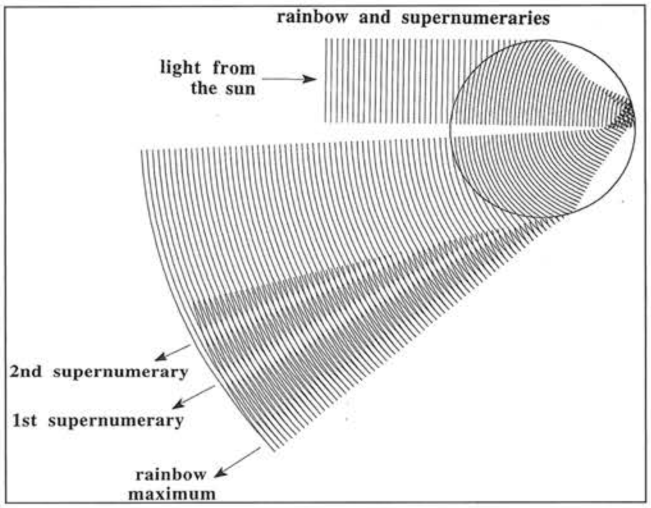


Figure 5. A wavefront version of Figure 3 illustrating the constructive and destructive interference patterns of the light as it interacts with a raindrop. The width of each band of color is relatively narrow, resulting in fairly pure rainbow colors. The primary rainbow and the first two supernumerary bows are identified here.

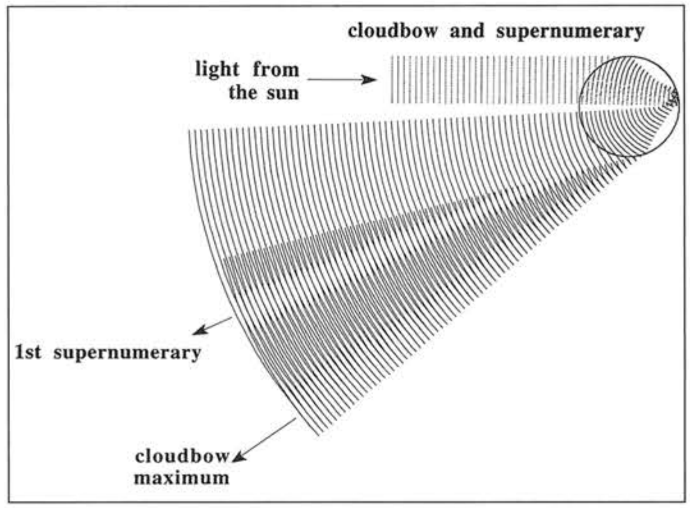


Figure 6. Similar to Figure 5, but for a much smaller cloud droplet. The resulting bands of color are so broad that additive color mixing produces a whitish "cloudbow".

midwife that delivered the wave theory of light to its place of dominance in the nineteenth century."

It is important to recognize that, not only were the Cartesian and Newtonian theories unable to account for the presence of supernumerary bows, but also they both predicted an *abrupt* transition between regions of illumination and shadow (as at the edges of Alexander's dark band, when only rays giving rise to the primary and secondary bows are considered). In the wave theory of light such sharp boundaries are softened by *diffraction*, which occurs when the normal interference pattern responsible for rectilinear propagation of light is distorted in some way. Diffraction effects are particularly prevalent in the vicinity of *caustics*. In 1835 Potter showed that the rainbow ray may be interpreted as a caustic, i.e., the envelope of the system of rays constituting the rainbow. The word *caustic* means burning, and caustics are associated with regions of high-intensity illumination (with geometrical optics predicting an infinite intensity there). Thus the rainbow problem is essentially that of determining the intensity of (scattered) light in the neighborhood of a caustic.

This was exactly what Airy attempted to do several years later in 1838. The principle behind Airy's approach was established by Huygens in the seventeenth century: Huygens's principle regards every point of a wavefront as a secondary source of waves, which in turn defines a new wavefront and hence determines the subsequent propagation of the wave. As pointed out by Nussenzveig [9], Airy reasoned that if one knew the amplitude distribution of the waves along any complete wavefront in a raindrop, the distribution at any other point could be determined by Huygens's principle. Airy chose as his starting point a wavefront surface inside the raindrop, the surface being orthogonal to all the rays that constitute the primary bow; this surface has a point of inflection wherever it intersects the ray of minimum deviation, the "rainbow ray". Using the standard assumptions of diffraction theory, he formulated the local intensity of scattered light in terms of a "rainbow integral", subsequently renamed the *Airy integral* in his honor; it is related to the now familiar Airy function. It is analogous to the Fresnel integrals which also arise in diffraction theory. There are several equivalent representations of the Airy integral in the literature; following the form used by Nussenzveig [10], we write it as

$$(1)\quad \mathrm{Ai}(C) = (3^{1/3}\pi^{-1}) \int_0^\infty \cos(t^3 + 3^{1/3}Ct)\, dt.$$

While the argument of the Airy function is arbitrary at this point, C refers to the set of control space parameters in the discussion below on diffraction catastrophes. In this case it represents the deviation or scattering angle coordinate. One severe limitation of the Airy theory for the optical rainbow is that the amplitude distribution along the initial wavefront is unknown: based on certain assumptions it has to be guessed. There is a natural and fundamental parameter, the *size parameter*, β, which is useful in determining the domain of validity of the Airy approximation; it is defined as the ratio of the droplet circumference to the wavelength η of light. In terms of the wavenumber k this is

$$\beta = \frac{2\pi a}{\eta} \equiv ka,$$

a being the droplet radius. Typically, for sizes ranging from fog droplets to large raindrops, β ranges from about one hundred to several thousand. Airy's approximation is a good one only for $\beta \gtrsim 5000$ and for angles sufficiently close to that of the rainbow ray. In light of these remarks it is perhaps surprising that an exact solution does exist for the rainbow problem, as indicated below.

In the epilogue to the final chapter of the book, one subsection is entitled "Airy's Rainbow Theory: The Incomplete 'Complete' Answer". This theory did go beyond the models of the day in that it quantified the dependence upon the raindrop size of (i) the rainbow's angular width, (ii) its angular radius, and (iii) the spacing of the supernumeraries. Also, unlike the models of Descartes and Newton, Airy's predicted a nonzero distribution of light intensity in Alexander's dark band and a finite intensity at the angle of minimum deviation (as noted above, the earlier theories predicted an infinite intensity there). However, spurred on by Maxwell's recognition that light is part of the electromagnetic spectrum and the subsequent publication of his mathematical treatise on electromagnetic waves, several mathematical physicists sought a more complete theory of scattering, because it had been demonstrated by then that the Airy theory failed to predict precisely the angular position of many laboratory-generated rainbows. Among them were the German physicist Gustav Mie,[1] who published a paper in 1908 on the scattering of light by homogeneous spheres in a homogeneous medium, and Peter Debye, who independently developed a similar theory for the scattering of electromagnetic waves by spheres. Mie's theory was intended to explain the colors exhibited by colloidally dispersed metal particles, whereas Debye's work, based on his 1908 thesis, dealt with the problem of light pressure on a spherical particle. The resulting body of knowledge is usually referred to as Mie theory, and typical computations based on it are formidable compared with those based on Airy theory, unless the drop size is sufficiently small. A similar (but nonelectromagnetic) formulation arises in the scattering of sound waves by an impenetrable sphere, studied by Lord Rayleigh and others in the nineteenth century [6].

Mie theory is based on the solution of Maxwell's equations of electromagnetic theory for a monochromatic plane wave from infinity incident upon a homogeneous isotropic sphere of radius a. The surrounding medium is transparent (as the sphere may be), homogeneous, and isotropic. The incident wave induces forced oscillations of both free and bound charges in synchrony with the applied field, and this induces a secondary electric and magnetic field, each of which has components inside and outside the sphere. Of crucial importance in the theory are the scattering amplitudes $(S_j(k,\theta), j = 1,2)$ for the two independent polarizations, θ being the angular variable; these amplitudes can be expressed as an infinite sum called a partial-wave expansion. Each term (or partial wave) in the expansion is defined in terms of combinations of Legendre functions of the first kind, Riccati-Bessel functions, and Riccati-Hankel functions (the latter two being rather simply related to spherical Bessel and Hankel functions respectively).

It is obviously of interest to determine under what conditions such an infinite set of terms can be truncated and what the resulting error may be by so doing. However, it turns out that the number of terms that must be retained is of the same order of magnitude as the size parameter β, i.e., up to several thousand for the rainbow problem. On the other hand, the "why is the sky blue?" scattering problem—*Rayleigh scattering*—requires only one term, because the scatterers are molecules much smaller than a wavelength of light, so the simplest truncation—retaining only the first term—is perfectly adequate. Although in principle the rainbow problem can be "solved" with enough computer time and resources, numerical solutions by themselves (as Nussenzveig points out [9]) offer little or no insight into the physics of the phenomenon.

The *Watson transform*, originally introduced by Watson in connection with the diffraction of radio waves around the Earth (and subsequently modified by Nussenzveig in his studies of the rainbow problem), is a method for transforming the slowly converging partial-wave series into a rapidly convergent expression involving an integral in the complex angular-momentum plane. The Watson transform is intimately related to the *Poisson summation formula*

$$(2)\quad \sum_{l=0}^{\infty} g(l+\frac{1}{2},x) = \sum_{m=-\infty}^{\infty} e^{-im\pi} \int_0^{\infty} g(\lambda,x) e^{2\pi i m\lambda}\, d\lambda$$

for an "interpolating function" $g(\lambda,x)$, where x denotes a set of parameters and $\lambda = l + \frac{1}{2}$ is now considered to be the complex angular momentum variable.

[1] *I am grateful to J. D. Jackson, who informed me that "Ludvig Lorenz, a Danish theorist, preceded Mie by about fifteen years in the treatment of the scattering of electromagnetic waves by spheres." His contributions to electromagnetic scattering theory and optics are rather overlooked, probably because his work was published in Danish (in 1890). Further details of his research, including his contributions to applied mathematics, may be found in reference [5] (the article immediately following that one on p. 4696 is about Gustav Mie). There is also a valuable historical account by Logan [6] of other contributions to this branch of (classical) mathematical physics.*

But why *angular momentum*? Although they possess zero rest mass, photons have energy $E = hc/\eta$ and momentum $E/c = h/\eta$, where h is Planck's constant and c is the speed of light in vacuo. Thus for a nonzero impact parameter b_i, a photon will carry an angular momentum $b_i h/\eta$ (b_i being the perpendicular distance of the incident ray from the axis of symmetry of the sun-raindrop system). Each of these discrete values can be identified with a term in the partial-wave series expansion. Furthermore, as the photon undergoes repeated internal reflections, it can be thought of as orbiting the center of the raindrop. Why *complex* angular momentum? This allows the above transformation to effectively "redistribute" the contributions to the partial wave series into a few points in the complex plane—specifically poles (called *Regge* poles in elementary particle physics) and saddle points. Such a decomposition means that angular momentum, instead of being identified with certain discrete real numbers, is now permitted to move continuously through complex values. However, despite this modification, the poles and saddle points have profound physical interpretations in the rainbow problem.

In the simplest Cartesian terms, on the illuminated side of the rainbow (in a limiting sense) there are two rays of light emerging in parallel directions: at the rainbow angle they coalesce into the ray of minimum deflection, and on the shadow side, according to geometrical optics, they vanish (this is actually a good definition of a caustic curve or surface). From a study of real and complex rays, it happens that, mathematically, in the context of the complex angular momentum plane, a rainbow is the *collision of two real saddle points*. But this is not all: this collision does not result in the mutual annihilation of these saddle points; instead, two complex saddle points are born, one corresponding to a complex ray on the shadow side of the caustic curve. This is directly associated with the diffracted light in Alexander's dark band.

Lee and Fraser point out that as far as most aspects of the optical rainbow are concerned, Mie theory is esoteric overkill; Airy theory is quite sufficient for describing the outdoor rainbow. I found particularly valuable the following comment by the authors; it has implications for mathematical modeling in general, not just for the optics of the rainbow. In their comparison of the less accurate Airy theory of the rainbow with the more general and powerful Mie theory, they write, "Our point here is not that the exact Mie theory describes the natural rainbow inadequately, but rather that the approximate Airy theory can describe it quite well. Thus the supposedly outmoded Airy theory generates a more natural-looking map of real rainbow colors than Mie theory does, even though Airy theory makes substantial errors in describing the scattering of monochromatic light by isolated small drops. *As in many hierarchies of scientific models, the virtues of a simpler theory can, under the right circumstances, outweigh its vices*" [emphasis added].

Earlier in this review the question, What is a rainbow? was answered at a basic descriptive level. But at an *explanatory* level a rainbow is much, much more than such an answer might imply. Amongst other things a rainbow is: (1) a concentration of light rays corresponding to a minimum (for the primary bow) of the deviation or scattering angle as a function of the angle of incidence; this minimum is identified as the Descartes or rainbow ray; (2) a caustic, separating a 2-ray region from a 0-ray (or shadow) region; (3) an integral superposition of waves over a (locally) cubic wavefront (the Airy approximation); (4) an interference problem (the origin of the supernumerary bows); (5) a coalescence of two real saddle points; (6) a result of scattering by an effective potential consisting of a square well and a centrifugal barrier (a surprising macroscopic quantum connection); (7) associated with tunneling in the so-called *edge domain* [4]; (8) a tangentially polarized circular arc; and (9) a *fold diffraction catastrophe*. These nine topics are very much interrelated, and the interested reader will find many references to them in [1], [4], [9], and [10]. The books by Grandy and Nussenzveig are excellent: they are primarily written by theoretical physicists for theoretical physicists and so do not possess the kind of rigor analysts seek (such as in the book by Pearson [11]); perhaps such a transition will be made in the future. But why not read *The Rainbow Bridge* first?

A Mathematical Appendix

Some descriptive material has been presented above concerning complementary explanations of the rainbow. It is of interest to put some mathematical flesh on those bones, so to that end a brief summary is provided of three aspects of the rainbow problem at the level of geometrical optics, as a scalar scattering problem, and as a diffraction catastrophe. These accounts touch on items (1)–(3), (5), (6) and (9) in particular, but as noted above it is difficult to separate them in a precise way.

A rainbow occurs when the the scattering angle D, as a function of the angle of incidence i, passes through an extremum (a minimum for the primary bow; see Figure 3). The "folding back" of the corresponding scattered or deviated ray takes place at this extremal scattering angle (the rainbow angle $D_{\min} \equiv \theta_R$; note that sometimes in the literature the rainbow angle is defined as the complement of the deviation, $\pi - D_{\min}$). Two rays scattered in the same direction with different angles of incidence on the illuminated side of the rainbow ($\theta > \theta_R$) fuse together at the rainbow angle and disappear as the dark side ($\theta < \theta_R$) is approached. This is one of the simplest physical examples of a *fold catastrophe* in the sense of Thom. As is noted below, rainbows of different orders are associated with so-called *Debye terms* of different orders; the primary and secondary bows correspond to $p = 2$ and $p = 3$ respectively. For $p - 1$ internal reflections, p being an integer greater than 1, the total deviation is, from elementary geometry,

$$D_{p-1}(i) = 2(i - pr) + (p - 1)\pi,$$

where by Snell's law the angle of refraction $r = r(i)$ is also a function of the angle of incidence. Thus for the primary rainbow ($p = 2$),

$$D_1(i) = \pi - 4r + 2i,$$

and for the secondary rainbow ($p = 3$),

$$D_2(i) = 2i - 6r$$

(modulo 2π). Removing the dependence on r, the angle through which a ray is deviated for $p = 2$ is

$$D_1(i) = \pi + 2i - 4\arcsin\left(\frac{\sin i}{n}\right),$$

where $n > 1$ is the refractive index of the raindrop. In general

$$D_{p-1}(i) = (p - 1)\pi + 2i - 2p\arcsin\left(\frac{\sin i}{n}\right).$$

The minimum deviation occurs for $p = 2$ when

$$i = i_c = \arccos\sqrt{\frac{n^2 - 1}{3}}$$

and in general when

$$i = i_c = \arccos\sqrt{\frac{n^2 - 1}{p^2 - 1}}.$$

For the primary rainbow $p = 2$, so $i_c \approx 59^\circ$, using an approximate value for water of $n = 4/3$; from this it follows that $D(i_c) = D_{\min} = \theta_R \approx 138^\circ$. For the secondary bow $p = 3$ and $i_c \approx 72^\circ$; now $D(i_c) = \theta_R \approx 231^\circ = -129^\circ$. The rainbows each lie on the surface of a cone, centered at the observer's eye, with axis the line from that point to the antisolar point (delineated by the shadow of the observer's head). The cone semiangles are about 42° and 51° respectively for the primary and secondary bows. For $p = 2$, in terms of n alone, $D(i_c) = \theta_R$ (the rainbow angle) is defined by

$$D(i_c) = \theta_R = 2\arccos\left[\frac{1}{n^2}\left(\frac{4 - n^2}{3}\right)^{3/2}\right].$$

This approach can be thought of as the elementary classical description. Surprising as it may seem, there is also a wave mechanical counterpart to the optical rainbow; indeed, such effects are well known in atomic, molecular, and nuclear physics [1], [10]. On the way to this, so to speak, there is a "semiclassical" description. In a primitive sense, the semiclassical approach is the "geometric mean" between classical and quantum mechanical descriptions of phenomena in which interference and diffraction effects enter the picture. The latter do so via the transition from geometrical optics to wave optics. A measure of the scattering (by raindrop or atom) that occurs is the differential scattering cross-section $d\sigma/d\Omega = |f(k,\theta)|^2$ (essentially the relative particle or wave "density" scattered per unit solid angle at a given angle θ in cylindrically symmetric geometry), where $f(k,\theta)$ is the *scattering amplitude* defined below; this in turn is expressible as a partial-wave expansion. The formal relationship between the latter and the classical differential cross-section is established using the WKB approximation, and the principle ofstationary phase is used to evaluate asymptotically a certain phase integral. A point of stationary phase can be identified with a classical trajectory, but if more than one such point is present (provided they are well separated and of the first order), the corresponding expression for $|f(k,\theta)|^2$ will contain interference terms. This is a distinguishing feature of the "primitive" semiclassical formulation. Indeed, the infinite intensities predicted by geometrical optics at focal points, lines, and caustics in general are breeding grounds for diffraction effects, as are light/shadow boundaries for which geometrical optics predicts finite discontinuities in intensity. Such effects are most significant when the wavelength is comparable with (or larger than) the typical length scale for variation of the physical property of interest (e.g., size of the scattering object). Thus a scattering object with a "sharp" boundary (relative to one wavelength) can give rise to *diffractive scattering* phenomena [10].

There are critical angular regions where this semiclassical approximation breaks down and diffraction effects cannot be ignored, although the angular ranges in which such critical effects become significant get narrower as the wavelength decreases. Early work in this field contained *transitional asymptotic approximations* to the scattering amplitude in these critical angular domains, but they have very narrow domains of validity and do not match smoothly with neighboring noncritical angular domains. It is therefore of considerable importance to seek *uniform asymptotic approximations* that by definition do not suffer from these failings. Fortunately, the problem of plane-wave scattering by a homogeneous sphere exhibits all of the critical scattering effects (and it can be solved exactly, in principle) and is therefore an ideal laboratory in which to test both the efficacy and accuracy of the various approximations. Furthermore, it has relevance to both quantum mechanics (as a square well or barrier problem) and optics (Mie scattering); indeed, it also serves as a model for the scattering of acoustic and elastic waves and, as noted earlier, was studied in the early twentieth century as a model for the diffraction of radio waves around the surface of the earth. Light waves obviously are electromagnetic in character, and so the full weight of that theory is necessary to explain features such as the polarization of the rainbow, but the essence of the approach is well captured by the scalar theory.

The essential mathematical problem for scalar waves can be thought of either in terms of classical mathematical physics, e.g., the scattering of sound waves, or in wave-mechanical terms, e.g., the nonrelativistic scattering of particles by a square potential well (or barrier) of radius a and depth (or height) V_0. In either case we can consider a scalar plane wave impinging in the direction $\theta = 0$ on a penetrable ("transparent") sphere of radius a. The wave function $\psi(r, \theta)$ satisfies the scalar Helmholtz equation

$$(3) \qquad \begin{aligned} \nabla^2\psi + n^2k^2\psi = 0 \qquad r \le a \\ \nabla^2\psi + k^2\psi = 0 \qquad r \ge a, \end{aligned}$$

where again k is the wavenumber and $n > 1$ is the refractive index of the sphere (a similar problem can be posed for gas bubbles in a liquid, for which $n < 1$). The boundary conditions are that $\psi(r, \theta)$ and $\psi'(r, \theta)$ are continuous at the surface. Furthermore, at large distances from the sphere ($r \gg a$) the wave field can be decomposed into an incident wave + scattered field, i.e.,

$$\psi \sim e^{ikr\cos\theta} + \frac{af(k, \theta)e^{ikr}}{r},$$

the dimensionless scattering amplitude being defined as

$$(4) \quad f(k, \theta) = \frac{1}{2ika}\sum_{l=0}^{\infty}(2l + 1)(S_l(k) - 1)P_l(\cos\theta),$$

where S_l is the scattering function for a given l and P_l is a Legendre polynomial of degree l. For a spherical square well or barrier,

$$S_l = -\frac{h_l^{(2)}(\beta)}{h_l^{(1)}(\beta)}\left\{\frac{\ln' h_l^{(2)}(\beta) - n\ln' j_l(\alpha)}{\ln' h_l^{(1)}(\beta) - n\ln' j_l(\alpha)}\right\},$$

where $\ln'$ represents the logarithmic derivative operator, j_l and h_l are spherical Bessel and Hankel functions respectively, the size parameter $\beta = ka$ plays the role of a dimensionless external wavenumber, and $\alpha = n\beta$ is the corresponding *internal* wavenumber. S_l may be equivalently expressed in terms of cylindrical Bessel and Hankel functions. The lth partial wave in the solution is associated

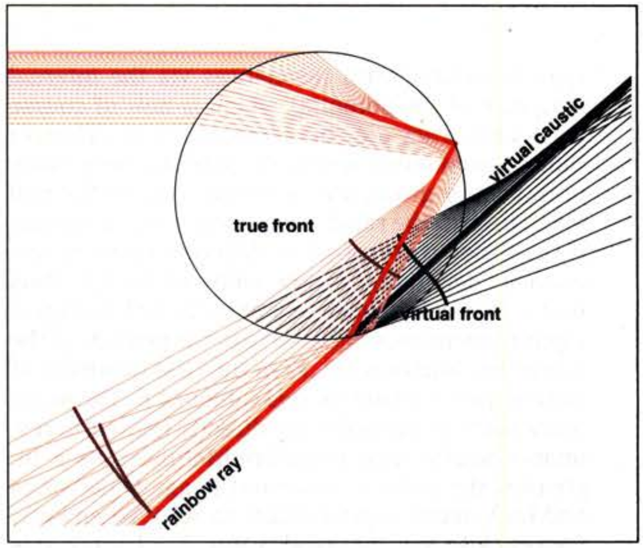


Figure 7. Wavefronts in a raindrop. The caustic is best seen in the virtual rays (projected back from the final exterior rays), as is the basis of Airy's analysis. After the virtual (or Airy) wavefront emerges, the part which is convex forward continues to expand, while the concave forward part collapses to a focus and then expands. This is the reason for the cusped wavefront at the bottom left of the figure.

with an impact parameter $b_l = (l + \frac{1}{2})/k$; i.e., only rays hitting the sphere ($b_l \lesssim a$) are significantly scattered, and the number of terms that must be retained in the series to get an accurate result is of order β. As implied earlier, for visible light scattered by water droplets in the atmosphere, $\beta \sim$ several thousand. This is why, to quote Arnold Sommerfeld, "The series converge so slowly that they become practically useless." This problem can be remedied by using the Poisson summation formula (2) above to rewrite $f(k, \theta)$ as

$$(5) \quad \begin{aligned} f(\beta, \theta) = \frac{i}{\beta}\sum_{m=-\infty}^{\infty}(-1)^m \\ \times \int_0^{\infty}[1 - S(\lambda, \beta)]P_{\lambda-\frac{1}{2}}(\cos\theta)e^{2im\pi\lambda}\lambda\, d\lambda. \end{aligned}$$

For fixed β, $S(\lambda, \beta)$ is a meromorphic function of the complex variable $\lambda = l + 1/2$, and in particular in what follows it is the *poles* of this function that are of interest. In terms of cylindrical Bessel and Hankel functions, the poles are defined by the condition

$$\ln' H_\lambda^{(1)}(\beta) = n\ln' J_\lambda(\alpha)$$

and are called *Regge poles* in the scattering theory literature [7], [8]. Typically, they are associated with surface waves for the *impenetrable* sphere problem, but for the *transparent* sphere *two* types of Regge poles arise—one type (*Regge-Debye poles*) leading to rapidly convergent residue series, representing the surface wave (or diffracted or creeping ray) contributions to the scattering amplitude; and the other type associated with resonances via the internal structure of the potential, which is now of course accessible. They are characterized by an effective radial wavenumber within the potential well. Many in this latter group are clustered close to the real axis, spoiling the rapid convergence of the residue series. They correspond to different types of resonances depending on the value of $\mathrm{Re}(\lambda_j)$. Thus mathematically these resonances are complex eigenfrequencies associated with the poles λ_j of the scattering function $S(\lambda, k)$ in the first quadrant of the complex λ-plane for real values of β. The imaginary parts of the poles are directly related to resonance widths (and therefore lifetimes). As β increases, the poles λ_j trace out Regge trajectories and $\mathrm{Im}\,\lambda_j$ tends exponentially to zero. When $\mathrm{Re}\,\lambda_j$ passes close to a "physical" value, $\lambda = l + 1/2$, it is associated with a resonance in the lth partial wave; the larger the value of β, the sharper the resonance becomes for a given node number j. The other type of significant points to be considered in the complex λ-plane are saddle points (which can be real or complex). In the complex angular momentum method, contour integral paths are deformed to concentrate the dominant contributions to the poles and saddle points. A real saddle point is also a point of stationary phase, and stationarity implies that Fermat's principle is satisfied. Since the phase in many cases at such points can be approximated by the WKB phase, the latter can be identified with the rays of geometrical optics (sometimes called classical paths). The asymptotic contributions from these points are the dominant ones within geometrically illuminated regions [10].

In [8] it is shown that

$$
\begin{aligned}
S(\lambda, \beta) &= \frac{H_\lambda^{(2)}(\beta)}{H_\lambda^{(1)}(\beta)} R_{22}(\lambda, \beta) \\
&+ T_{21}(\lambda, \beta) T_{12}(\lambda, \beta) \frac{H_\lambda^{(1)}(\alpha)}{H_\lambda^{(2)}(\alpha)} \sum_{p=1}^{\infty} [\rho(\lambda, \beta)]^{p-1},
\end{aligned} \tag{6}
$$

where

$$
\rho(\lambda, \beta) = R_{11}(\lambda, \beta) \frac{H_\lambda^{(1)}(\alpha)}{H_\lambda^{(2)}(\alpha)}.
$$

This is the *Debye expansion*, arrived at by expanding the expression $[1 - \rho(\lambda, \beta)]^{-1}$ as an infinite geometric series. R_{22}, R_{11}, T_{21}, and T_{12} are respectively the external/internal reflection and internal/external transmission coefficients for the problem. This procedure transforms the interaction of "wave + sphere" into a series of surface interactions. In so doing it unfolds the stationary points of the integrand so that a given integral in the Poisson summation contains at most one stationary point. This permits a ready identification of the many terms in accordance with ray theory. The first term represents direct reflection from the surface. The pth term in the summation represents transmission into the sphere (via the term T_{21}) subsequently bouncing back and forth between $r = a$ and $r = 0$ a total of p times with $p - 1$ internal reflections at the surface (this time via the R_{11} term in ρ). The final factor in the second term, T_{12}, corresponds to transmission to the outside medium. In general, therefore, the pth term of the Debye expansion represents the effect of $p + 1$ surface interactions. Now $f(\beta, \theta)$ can be expressed as

$$
f(\beta, \theta) = f_0(\beta, \theta) + \sum_{p=1}^{\infty} f_p(\beta, \theta), \tag{7}
$$

where

$$
\begin{aligned}
f_0(\beta, \theta) &= \frac{i}{\beta} \sum_{m=-\infty}^{\infty} (-1)^m \int_0^\infty \left(1 - \frac{H_\lambda^{(2)}(\beta)}{H_\lambda^{(1)}(\beta)} R_{22}\right) \\
&\times P_{\lambda - \frac{1}{2}}(\cos\theta) \exp(2im\pi\lambda)\lambda \, d\lambda.
\end{aligned} \tag{8}
$$

The expression for $f_p(\beta, \theta)$ involves a similar type of integral for $p \geq 1$. The application of the modified Watson transform to the third term ($p = 2$) in the Debye expansion of the scattering amplitude shows that it is this term which is associated with the phenomena of the primary rainbow. Residue contributions also arise from the Regge-Debye poles. More generally, for a Debye term of given order p, a rainbow is characterized in the λ-plane by the occurrence of two real saddle points, $\bar{\lambda}$ and $\bar{\lambda}'$, between 0 and β in some domain of scattering angles θ, corresponding to the two scattered rays on the lighted side. As $\theta \to \theta_R^+$ the two saddle points move toward each other along the real axis, merging together at $\theta = \theta_R$. As θ moves into the dark side, the two saddle points become complex, moving away from the real axis in complex conjugate directions. Therefore, from a mathematical point of view, *a rainbow can be defined as a coalescence of two saddle points in the complex angular momentum plane.*

The rainbow light/shadow transition region is thus associated physically with the confluence of a pair of geometrical rays and their transformation into complex rays; mathematically this corresponds to a pair of real saddle points merging into a complex saddle point. The next problem is to find the asymptotic expansion of an integral having two saddle points that move toward or away from each other. The generalization of the standard saddle-point technique to include such problems was made by Chester et al. [3]. Using their method, Nussenzveig was able to find a uniform asymptotic expansion of the scattering amplitude which was valid throughout the rainbow region and which matched smoothly onto results for neighboring regions [10], [8]. Unsurprisingly perhaps, the lowest-order approximation in this expansion turns out to be the *Airy approximation*, which, as already noted, was the best prior approximate treatment. However, Airy's theory has a limited range of applicability as a result of its underlying assumptions, e.g., $\beta \gtrsim 5000$, $|\theta - \theta_R| \lesssim 0.5^\circ$. By contrast, the uniform expansion (and more generally the complex angular momentum theory) is valid over much larger ranges.

Finally, we examine the rainbow as a diffraction catastrophe following the account by Berry and Upstill [2]. Optics is concerned to a great degree with families of rays filling regions of space; the *singularities* of such ray families are *caustics*. For optical purposes this level of description is important for classifying caustics using the concept of *structural stability*: this enables one to classify those caustics whose topology survives perturbation. Structural stability means that if a singularity S_1 is produced by a generating function ϕ_1, and ϕ_1 is perturbed to ϕ_2, the correspondingly changed S_2 is related to S_1 by a *diffeomorphism* of the control set C (that is, by a smooth reversible set of control parameters, a smooth deformation). In the present context this means physically that distortions of the raindrop shape to incoming wavefronts from their "ideal" spherical or planar forms do not prevent the formation of rainbows, though there may be some changes in the features. Another way of expressing this concept is to describe the system as well posed in the limited sense that small changes in the input generate correspondingly small changes in the output. For the elementary catastrophes, structural stability is a generic property of caustics. Each structurally stable caustic has a characteristic diffraction pattern, the wave function of which has an integral representation in terms of the standard polynomial describing that catastrophe. From a mathematical point of view, these diffraction catastrophes are especially interesting, because they constitute a new hierarchy of functions distinct from the special functions of analysis [2].

As noted above, at the level of geometrical optics the scattering deviation angle D has an extremum corresponding to the rainbow angle (or Descartes ray) when considered as a function of the angle of incidence i. This extremum is a minimum for the primary rainbow. Clearly the point $(i, D(i))$ corresponding to this minimum is a singular point (approximately $(59^\circ, 138^\circ)$) insofar as it separates a two-ray region ($D > D_{\min} = \theta_R$) from a zero-ray region ($D < \theta_R$) at this level of description. This is a singularity or *caustic point*. The rays form a directional caustic at this point; this is a *fold catastrophe*, the simplest example of a catastrophe. It is the only stable singularity with *codimension* one (the dimensionality of the control space (one) minus the dimensionality of the singularity itself (zero)). In physical space the caustic surface is asymptotic to a cone with semiangle 42°.

Diffraction is discussed in terms of the scalar Helmholtz equation (3) at the point $\mathcal{R}$ for the complex scalar wavefunction $\psi(\mathcal{R})$. The concern in catastrophe optics is to study the asymptotic behavior of wave fields near caustics in the short-wave limit $k \to \infty$ (semiclassical theory). In a standard manner, $\psi(\mathcal{R})$ is expressed as

$$\psi(\mathcal{R}) = A(\mathcal{R})e^{i\kappa\chi(\mathcal{R})},$$

where the modulus A and the phase $\kappa\chi$ are both real quantities. The integral representation for ψ is

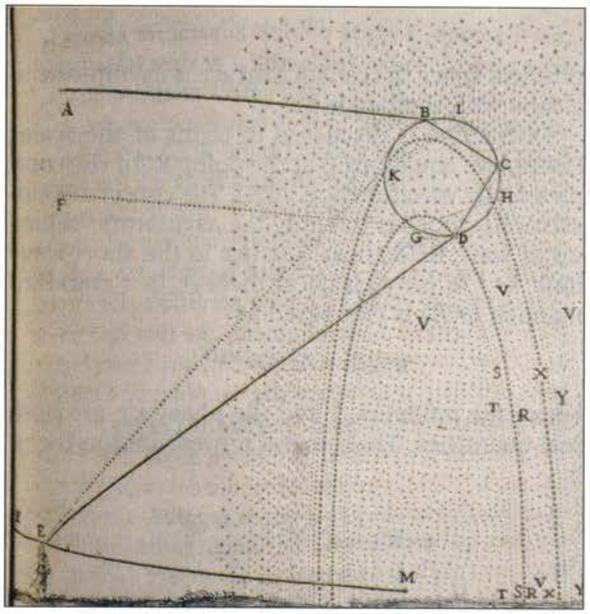
$$\psi(\mathcal{R}) = e^{-iN\pi/4}\left(\frac{\kappa}{2\pi}\right)^{N/2} \times \int \cdots \int b(s;\mathcal{R}) \exp[ik\phi(s;\mathcal{R})]\, d^N s, \tag{9}$$

where N is the number of state (or behavior) variables s and b is a weight function. According to the principle of stationary phase, the main contributions to the above integral for given $\mathcal{R}$ come from the stationary points, i.e., those points s_i for which the gradient map $\partial\phi/\partial s_i$ vanishes; caustics are *singularities* of this map, where two or more stationary points coalesce. Because $k \to \infty$, the integrand is a rapidly oscillating function of s, so other than near the points s_i, destructive interference occurs and the corresponding contributions are negligible. The stationary points are well separated provided $\mathcal{R}$ is not near a caustic; the simplest form of stationary phase can then be applied and yields a series of terms of the form

$$\psi(\mathcal{R}) \approx \sum_\mu A_\mu \exp[ig_\mu(k,\mathcal{R})],$$

where the details of the g_μ need not concern us here. Near a caustic, however, two or more of the stationary points are close (in some appropriate sense), and their contributions cannot be separated without a reformulation of the stationary phase principle to accommodate this or by using diffraction catastrophes. The problem is that the ray contributions can no longer be considered separately; when the stationary points approach closer than a distance $\mathcal{O}(k^{-1/2})$, the contributions are not separated by a region in which destructive interference occurs. When such points coalesce, $\phi(s;\mathcal{R})$ is stationary to higher than first order and quadratic terms as well as linear terms in $s - s_\mu$ vanish. This implies the existence of a set of displacements ds_i, away from the extrema s_μ, for which the gradient map $\partial\phi/\partial s_i$ still vanishes, i.e., for which

$$\sum_i \frac{\partial^2\phi}{\partial s_i \partial s_j} ds_i = 0.$$



René Descartes correctly explained the reasons for the primary and secondary rainbows within the confines of geometrical optics. This image is from a copy of the first edition of "Les météores" at the Thomas Fisher Rare Book Library of the University of Toronto.

The condition for this homogeneous system of equations to have a solution (i.e., for the set of control parameters C to lie on a caustic) is that the Hessian

$$H(\phi) \equiv \det(\frac{\partial^2 \phi}{\partial s_i \partial s_j}) = 0$$

at points $s_\mu(C)$ where $\partial\phi/\partial s_i = 0$. The caustic defined by $H = 0$ determines the bifurcation set for which at least two stationary points coalesce (in the present circumstance this is just the rainbow angle). In view of this discussion there are two other ways of expressing this: (i) rays coalesce on caustics, and (ii) caustics correspond to singularities of gradient maps.

To remedy this problem, the function ϕ is replaced by a simpler "normal form" Φ with the same stationary-point structure, and the resulting diffraction integral is evaluated exactly. This is where the property of structural stability is so important, because if the caustic is structurally stable, it must be equivalent to one of the catastrophes (in the diffeomorphic sense described above). The result is a generic diffraction integral which will occur in many different contexts. The basic diffraction catastrophe integrals (one for each catastrophe) may be reduced to the form

$$(10) \quad \Psi(C) = \frac{1}{(2\pi)^{N/2}} \int \cdots \int \exp[i\Phi(s;C)]\, d^N s,$$

where s represents the state variables and C the control parameters (for the case of the rainbow there is only one of each, so $N = 1$). These integrals stably represent the wave patterns near caustics. For the fold,

$$(11) \quad \Phi(s;C) = \frac{1}{3}s^3 + Cs.$$

The diffraction catastrophes $\Psi(C)$ provide transitional approximations, valid close to the caustic and for short waves but increasingly inaccurate far from the caustic. By substituting the cubic term (11) into the integral (10), we obtain

$$(12) \quad \Psi(C) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \exp[i(s^3/3 + Cs)]\, ds,$$

which is closely related to the Airy integral $\mathrm{Ai}(C)$ (equation (1), with $s = 3^{1/3}t$).

Let us now end where we began: at the rainbow bridge, but this time accompanied by a quotation from H. M. Nussenzveig [9] which aptly summarizes much of the subject matter addressed in this article.

> The rainbow is a bridge between two cultures: poets and scientists alike have long been challenged to describe it. The scientific description is often supposed to be a simple problem in geometrical optics.... This is not so; a satisfactory quantitative theory of the rainbow has been developed only in the past few years. Moreover, that theory involves much more than geometrical optics; it draws on all we know of the nature of light....
>
> Some of the most powerful tools of mathematical physics were devised explicitly to deal with the problem of the rainbow and with closely related problems. Indeed, the rainbow has served as a touchstone for testing theories of optics. With the more successful of those theories it is now possible to describe the rainbow mathematically, that is, to predict the distribution of light in the sky. The same methods can also be applied to related phenomena, such as the bright ring of color called the glory, and even to other kinds of rainbows, such as atomic and nuclear ones.

Acknowledgements

I am grateful to Harold Boas, Bill Casselman, and Allyn Jackson for their valuable assistance in the preparation of this article, and to the authors of the book, Raymond Lee and Alistair Fraser, for their permission to use Figures 8.7 and 8.9 from

their book. I thank Raimondo Anni for his helpful comments at the proof stage of this article.

Note: For information about recent developments in atomic, molecular, and nuclear scattering, visit `http://cl.fisica.unile.it/~anni/Rainbow/Rainbow.htm`.

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About the Cover

Supernumerary Bows along with Airy's Explanation

This month's cover accompanies John Adam's review of *The Rainbow Bridge*. Both images are taken from the book (figures 8-3 and 8-11). The top photograph was taken in 1979 near Kootenay Lake, British Columbia, by Alistair Fraser, one of the book's authors. It is one of hundreds of rainbow photographs he has taken in his life, and shows well a set of supernumerary bows. At the bottom is a plot of rainbow color configurations versus rain drop size, with the size of the drops in the particular rainbow at the top indicated by the slice. Smaller drop radii are at the left, and the slice corresponds to a radius of about a quarter of a millimetre.

The significance, perhaps even the reality, of these 'extra' bows was not appreciated for a long time, quite likely since they were not something Newton's theory could account for. Even today, few people seem to be aware of them. They are faint, but not difficult to observe if one looks carefully.

Alistair Fraser tells us that the historical role played by such bows in motivating the development of the wave theory of light is greater than usually suggested in physics books. He also points out that in nature rain drops are rarely homogeneous in size or shape, and that this has the effect that supernumerary bows are seen only in the top of the bow, where interference arising from the variety of drops does not cancel. He says further, "As supernumerary bows are an interference pattern strongly dependent upon drop size, and as rain showers have a wide range of drop sizes, one would not expect these bows to be seen in showers. They are, nonetheless, seen. Curiously, not all drops contribute equally—through a mixture of the physical optics of small drops and the nonspherical shape of large drops, a narrow bandpass filter is produced which eliminates the supernumerary bows produced by all but a small range of sizes."

The color map is that produced by the theory of George Biddell Airy, dating from roughly 1825. The book includes also a similar map (figure 10-29) deduced from the more exact Mie theory, but emphasizes that the fine detail this predicts, although confirmed under laboratory conditions, is imperceptible in nature, where perturbations blur it.

—Bill Casselman
(`covers@ams.org`)

Black Holes, Geometric Flows, and the Penrose Inequality in General Relativity

Hubert L. Bray

In 1973 R. Penrose [13] made a physical argument that the total mass of a spacetime containing black holes with event horizons of total area A should be at least $\sqrt{A/16\pi}$. An important special case of this physical statement translates into a very beautiful mathematical inequality in Riemannian geometry known as the *Riemannian Penrose inequality*. The Riemannian Penrose inequality was first proved by G. Huisken and T. Ilmanen in 1997 for a single black hole [8] and then by the author in 1999 for any number of black holes [1]. The two approaches use two different geometric flow techniques. The most general version of the Penrose inequality is still open.

A natural interpretation of the Penrose inequality is that the mass contributed by a collection of black holes is (at least) $\sqrt{A/16\pi}$. More generally, the question, How much matter is in a given region of a spacetime? is still very much an open problem [6]. In this paper we will discuss some of the qualitative aspects of mass in general relativity, look at some informative examples, and describe the two very geometric proofs of the Riemannian Penrose inequality.

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Total Mass in General Relativity

Two notions of mass which are well understood in general relativity are local energy density at a point and the total mass of an asymptotically flat spacetime. However, defining the mass of a region larger than a point but smaller than the entire universe is not at all well understood.

Suppose (M^3, g) is a Riemannian 3-manifold isometrically embedded in a (3+1) dimensional Lorentzian spacetime N^4. Suppose that M^3 has zero second fundamental form in the spacetime. This is a simplifying assumption which allows us to think of (M^3, g) as a "$t = 0$" slice of the spacetime. (The second fundamental form is a measure of how much M^3 curves inside N^4; M^3 is also sometimes called "totally geodesic" since geodesics of N^4 which are tangent to M^3 at a point stay inside M^3 forever.) The Penrose inequality (which allows for M^3 to have general second fundamental form) is known as the Riemannian Penrose inequality when the second fundamental form is set to zero.

We also want to consider only (M^3, g) that are asymptotically flat at infinity, which means that for some compact set K, the "end" $M^3 \setminus K$ is diffeomorphic to $\mathbf{R}^3 \setminus B_1(0)$, where the metric g is asymptotically approaching (with certain decay conditions) the standard flat metric δ_{ij} on $\mathbf{R}^3$ at infinity. The simplest example of an asymptotically flat manifold is $(\mathbf{R}^3, \delta_{ij})$ itself. Other good examples are the conformal metrics $(\mathbf{R}^3, u(x)^4\delta_{ij})$, where $u(x)$ approaches a constant sufficiently rapidly at infinity. (Also, sometimes it is convenient to allow (M^3, g) to have multiple asymptotically flat ends, in which case each connected component of $M^3 \setminus K$ must have the property described above.) A qualitative picture of an asymptotically flat 3-manifold is shown in Figure 1.

The point of these assumptions on the asymptotic behavior of (M^3, g) at infinity is that they imply the existence of the limit

$$m = \frac{1}{16\pi} \lim_{\sigma \to \infty} \int_{S_\sigma} \sum_{i,j} (g_{ij,i}\nu_j - g_{ii,j}\nu_j)\, d\mu$$

where S_σ is the coordinate sphere of radius σ, ν is the unit normal to S_σ, and $d\mu$ is the area element of S_σ in the coordinate chart. The quantity m is called the *total mass* (or ADM mass) of (M^3, g) and does not depend on the choice of an asymptotically flat coordinate chart.

The above equation is where many people would stop reading an article like this. But before you do, we will promise not to use this definition of the total mass in this paper. In fact, it turns out that total mass can be quite well understood with an example. Going back to the example $(\mathbf{R}^3, u(x)^4 \delta_{ij})$, if we suppose that $u(x) > 0$ has the asymptotics at infinity

$$u(x) = a + b/|x| + \mathcal{O}(1/|x|^2) \tag{1}$$

(and derivatives of the $\mathcal{O}(1/|x|^2)$ term are $\mathcal{O}(1/|x|^3)$), then the total mass of (M^3, g) is

$$m = 2ab. \tag{2}$$

Furthermore, suppose that (M^3, g) is any metric whose "end" is isometric to $(\mathbf{R}^3 \setminus K, u(x)^4 \delta_{ij})$, where $u(x)$ is harmonic in the coordinate chart of the end $(\mathbf{R}^3 \setminus K, \delta_{ij})$ and goes to a constant at infinity. Then expanding $u(x)$ in terms of spherical harmonics demonstrates that $u(x)$ satisfies condition (1). We will call such Riemannian manifolds (M^3, g) *harmonically flat at infinity*, and we note that the total mass of these manifolds is also given by equation (2).

A very nice lemma by Schoen and Yau states that, given any $\epsilon > 0$, it is always possible to perturb an asymptotically flat manifold to become harmonically flat at infinity in such a way that the total mass changes less than ϵ and the metric changes less than ϵ pointwise, all while maintaining nonnegative scalar curvature (discussed in a moment). Hence, it happens that to prove the theorems in this paper, we need to consider only harmonically flat manifolds! Thus, we can use equation (2) as our definition of total mass. As an example, note that $(\mathbf{R}^3, \delta_{ij})$ has zero total mass. Also, note that, qualitatively, the total mass of an asymptotically flat or harmonically flat manifold is the $1/r$ rate at which the metric becomes flat at infinity.

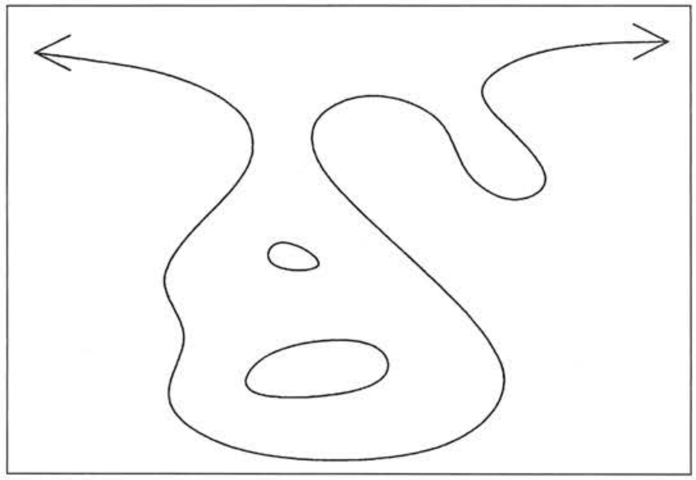

Figure 1.

The Phenomenon of Gravitational Attraction

What do the above definitions of total mass have to do with anything physical? That is, if the total mass is the $1/r$ rate at which the metric becomes flat at infinity, what does this have to do with our real-world intuitive idea of mass?

The answer to this question is very nice. Given a Schwarzschild spacetime metric

$$\left(\mathbf{R}^4, \left(1 + \frac{m}{2|x|}\right)^4 (dx_1^2 + dx_2^2 + dx_3^2) - \left(\frac{1 - m/2|x|}{1 + m/2|x|}\right)^2 dt^2\right), |x| > m/2,$$

for example, the $t = 0$ slice (which has zero second fundamental form) is the spacelike Schwarzschild metric $(\mathbf{R}^3 \setminus B_{m/2}(0), (1 + \frac{m}{2|x|})^4 \delta_{ij})$ (discussed more later). According to equation (2), the parameter m is in fact the total mass of this 3-manifold.

On the other hand, suppose we were to release a small test particle, initially at rest, a large distance r from the center of the Schwarzschild spacetime. If this particle is not acted upon by external forces, then it should follow a geodesic in the spacetime. It turns out that with respect to the asymptotically flat coordinate chart, these geodesics "accelerate" towards the middle of the Schwarzschild metric at a rate proportional to m/r^2 (in the limit as r goes to infinity). Thus, our Newtonian notion of mass also suggests that the total mass of the spacetime is m.

Local Energy Density

Another well-understood quantification of mass is local energy density. In fact, in our setting the local energy density at each point is

$$\mu = \frac{1}{16\pi} R,$$

where R is the scalar curvature of the 3-manifold (which has zero second fundamental form in the spacetime) at each point. Note that $(\mathbf{R}^3, \delta_{ij})$ has zero energy density at each point as well as zero total mass. This is appropriate since $(\mathbf{R}^3, \delta_{ij})$ is in fact a "$t = 0$" slice of Minkowski spacetime, which represents a vacuum. Classically, physicists consider $\mu \geq 0$ to be a physical assumption. Hence, from this point on, we will assume not only that (M^3, g) is asymptotically flat but also that it has nonnegative scalar curvature,

$$R \geq 0.$$

This notion of energy density also helps us understand total mass better. After all, we can take any asymptotically flat manifold and then change the metric to be perfectly flat outside a large compact set, thereby giving the new metric zero total mass. However, if we introduce the physical condition that both metrics have nonnegative scalar curvature, then it is a beautiful theorem that such a modification is not possible unless the original metric was already $(\mathbf{R}^3, \delta_{ij})$! (This theorem is actually a corollary to the positive mass theorem discussed in a moment.) Thus, the curvature obstruction of having nonnegative scalar curvature at each point is a very interesting condition.

Also, notice the indirect connection between the total mass and the local energy density. At this point, there does not seem to be much of a connection at all. Total mass is the $1/r$ rate at which the metric becomes flat at infinity, and local energy density is the scalar curvature at each point. Furthermore, if a metric is changed in a compact set, local energy density is changed, but the total mass is unaffected.

Indeed, the total mass is *not* the integral of the local energy density over the manifold. In fact, this integral fails to take into account either potential energy (which would be expected to contribute a negative energy) or gravitational energy (discussed in a moment). Hence, it is not initially clear what we should expect the relationship between total mass and local energy density to be, so let us begin with an example.

Example Using Superharmonic Functions in $\mathbf{R}^3$

Once again, let us return to the example of $(\mathbf{R}^3, u(x)^4\delta_{ij})$. The formula for the scalar curvature is

$$R = -8u(x)^{-5}\Delta u(x).$$

Hence, since the physical assumption of nonnegative energy density implies nonnegative scalar curvature, we see that the positive function $u(x)$ must be superharmonic (that is, $\Delta u \leq 0$). For simplicity, assume also that $u(x)$ is harmonic outside a bounded set, so that we can expand $u(x)$ at infinity using spherical harmonics. Hence, $u(x)$ has the asymptotics of equation (1). By the maximum principle, it follows that the minimum value for $u(x)$ must be a, referring to equation (1). Hence, $b \geq 0$, which implies that $m \geq 0$! Thus we see that the assumption of nonnegative energy density at each point of $(\mathbf{R}^3, u(x)^4\delta_{ij})$ implies that the total mass is also nonnegative, which is what one would hope.

The Positive Mass Theorem

Why would one hope this? What would be the difference if the total mass were negative? This would mean that a gravitational system of positive energy density could collectively act as a net negative total mass. This phenomenon has not been observed experimentally, and so it is not a property that we would expect to find in general relativity.

More generally, suppose that we have any asymptotically flat manifold with nonnegative scalar curvature. Is it true that the total mass is also nonnegative? The answer is yes, and this fact is known as the positive mass theorem, proved first by Schoen and Yau [14] in 1979 using minimal surface techniques and then by Witten [17] in 1981 using spinors. In the case of zero second fundamental form, the positive mass theorem is known as the Riemannian positive mass theorem and is stated below.

Theorem 1. [16] *Let (M^3, g) be any asymptotically flat, complete Riemannian manifold with nonnegative scalar curvature. Then the total mass $m \geq 0$, with equality if and only if (M^3, g) is isometric to $(\mathbf{R}^3, \delta)$.*

Gravitational Energy

The preceding example fails to illustrate all of the subtleties of the positive mass theorem. For example, it is easy to construct asymptotically flat manifolds (M^3, g) (not conformal to $\mathbf{R}^3$) that have zero scalar curvature everywhere and yet have *nonzero* total mass. By the positive mass theorem, the mass of these manifolds is positive. Physically, this corresponds to a spacetime that has zero energy density everywhere and yet still has positive total mass. From where did this mass come? How can a vacuum have positive total mass?

Physicists refer to this extra energy as gravitational energy. There is no known local definition of the energy density of a gravitational field, and presumably such a definition does not exist. The curious phenomenon then is that for some reason gravitational energy always makes a nonnegative contribution to the total mass of the system.

Black Holes

Another very interesting and natural phenomenon in general relativity is the existence of black holes. Instead of thinking of black holes as singularities in a spacetime, we will think of black holes in terms of their horizons. For example, suppose we are exploring the universe in a spacecraft capable of traveling any speed less than the speed of light. If we are investigating a black hole, we want to make sure that we do not get too close and get trapped by the "gravitational forces" of the black hole. We can imagine a "sphere of no return" beyond which escape from the black hole is impossible. It is called the event horizon of a black hole.

However, one limitation of the notion of an event horizon is the difficulty of determining its location. One way is to let daredevil spacecraft see how close they can get to the black hole and still escape from it eventually. The problem with this approach (besides the cost in spacecraft) is that it is hard to know when to stop waiting for a daredevil spacecraft to return. Even if it has been fifty years, it could be that this particular daredevil was not trapped by the black hole but got so close that it will take one thousand or more years to return. Thus, to define the location of an event horizon even mathematically, we need to know the entire evolution of the spacetime. Hence, event horizons cannot be computed based only on the local geometry of the spacetime.

This problem is solved (at least for the mathematician) by the notion of apparent horizons of black holes. Given a surface in a spacetime, suppose that it emits an outward shell of light. If the surface area of this shell of light is decreasing everywhere on the surface, then this is called a trapped surface. The outermost boundary of these trapped surfaces is called the apparent horizon of the black hole. Apparent horizons can be computed based on their local geometry, and an apparent horizon always implies the existence of an event horizon outside of it [7].

Now let us return to the case we are considering in this paper where (M^3, g) is a "$t = 0$" slice of a spacetime with zero second fundamental form. Then it is a very nice geometric fact that apparent horizons of black holes intersected with M^3 correspond to the connected components of the *outermost minimal surface* Σ_0 of (M^3, g).

All of the surfaces we are considering in this paper will be required to be smooth boundaries of open bounded regions, so outermost is well defined with respect to a chosen end of the manifold [1]. A minimal surface in (M^3, g) is a surface which is a critical point of the area function with respect to any smooth variation of the surface. The first variational calculation implies that minimal surfaces have zero mean curvature. The surface Σ_0 of (M^3, g) is defined as the boundary of the union of the open regions bounded by all of the minimal surfaces in (M^3, g). It turns out that Σ_0 also has to be a minimal surface, so we call Σ_0 the outermost minimal surface. A qualitative sketch of an outermost minimal surface of a 3-manifold is shown in Figure 2.

We also define a surface to be *(strictly) outer minimizing* if every surface which encloses it has (strictly) greater area. Note that outermost minimal surfaces are strictly outer minimizing. Also, we define a *horizon* in our context to be any minimal surface which is the boundary of a bounded open region.

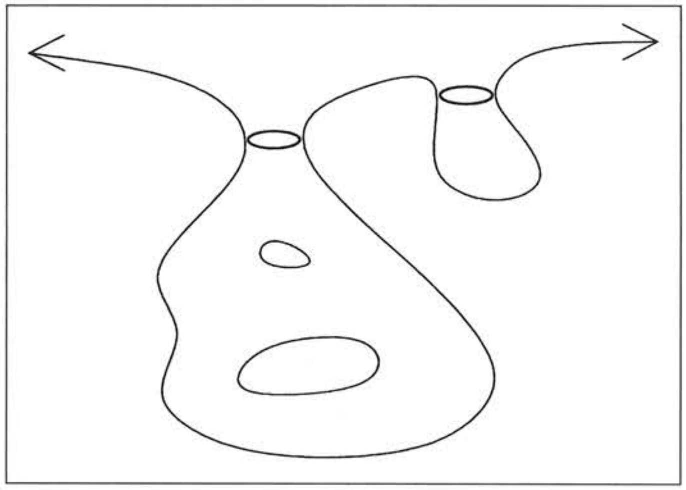

Figure 2.

It also follows from a stability argument (which interestingly uses the Gauss-Bonnet theorem) that each component of an outermost minimal surface (in a 3-manifold with nonnegative scalar curvature) must have the topology of a sphere. Furthermore, there is a physical argument, based on [13], which suggests that the mass contributed by the black holes (thought of as the connected components of Σ_0) should be defined to be $\sqrt{A_0/16\pi}$, where A_0 is the area of Σ_0. Hence, the physical argument that the total mass should be greater than or equal to the mass contributed by the black holes yields the following geometric statement.

The Riemannian Penrose Inequality. *Let (M^3, g) be a complete, smooth 3-manifold with nonnegative scalar curvature, harmonically flat at infinity, with total mass m, and with an outermost minimal surface Σ_0 of area A_0. Then*

$$m \geq \sqrt{\frac{A_0}{16\pi}}, \tag{3}$$

and equality holds if and only if (M^3, g) is isometric to the Schwarzschild metric $(\mathbf{R}^3 \setminus \{0\}, (1 + \frac{m}{2|x|})^4\delta_{ij})$ outside the respective outermost minimal surfaces.

The above statement has been proved by the author [1], and Huisken and Ilmanen [8] proved it when A_0 is defined instead to be the area of the largest connected component of Σ_0. In this article we will discuss both approaches. They are very different, although they both involve flowing surfaces and/or metrics.

We also clarify that the above statement is with respect to a chosen end of (M^3, g), since both the total mass and the definition of outermost refer to a particular end. Nothing very important is gained by considering manifolds with more than one end, since extra ends can always be compactified by connect summing them (around a neighborhood of infinity) with large spheres while still preserving nonnegative scalar curvature. Hence, we will typically consider manifolds with just one end. In the case that the manifold has multiple ends, we will require every surface (which could have multiple connected components) in this paper to enclose all of the ends of the manifold except the chosen end.

The Schwarzschild Metric

The Schwarzschild metric $(\mathbf{R}^3 \setminus \{0\}, (1+\frac{m}{2|x|})^4\delta_{ij})$ referred to in the above statement of the Riemannian Penrose Inequality is a particularly important example to consider. It corresponds to a zero second fundamental form, spacelike slice of the usual (3+1)-dimensional Schwarzschild metric (which represents a spherically symmetric static black hole in a vacuum). The 3-dimensional Schwarzschild metrics have total mass $m > 0$ and are characterized by being the only spherically symmetric, geodesically complete, zero scalar curvature 3-metrics other than $(\mathbf{R}^3, \delta_{ij})$. They can also be embedded in 4-dimensional Euclidean space (x, y, z, w) as the set of points satisfying $|(x, y, z)| = \frac{w^2}{8m} + 2m$, which is a parabola rotated around an S^2. This last picture allows us to see that the Schwarzschild metric, which has two ends, has a Z_2 symmetry fixing the sphere with $w = 0$ and $|(x, y, z)| = 2m$, which is clearly minimal. Furthermore, the area of this sphere is $4\pi(2m)^2$, giving equality in the Riemannian Penrose Inequality.

A Brief History of the Problem

The Riemannian Penrose Inequality has a rich history spanning nearly three decades and has motivated much interesting mathematics and physics. In 1973 R. Penrose in effect conjectured an even more general version of inequality (3) using a very clever physical argument [13], which we will not have room to repeat here. His observation was that a counterexample to inequality (3) would yield Cauchy data for solving the Einstein equations, the solution to which would likely violate the Cosmic Censor Conjecture (which says that singularities generically do not form in a spacetime unless they are inside a black hole).

In 1977 Jang and Wald [11], extending ideas of Geroch, gave a heuristic proof of inequality (3) by defining a flow of 2-surfaces in (M^3, g) in which the surfaces flow in the outward normal direction at a rate equal to the inverse of their mean curvatures at each point. The Hawking mass of a surface (which is supposed to estimate the total amount of energy inside the surface) is defined to be

$$m_{Hawking}(\Sigma) = \sqrt{\frac{|\Sigma|}{16\pi}}\left(1 - \frac{1}{16\pi}\int_\Sigma H^2\right)$$

(where $|\Sigma|$ is the area of Σ and H is the mean curvature of Σ in (M^3, g)), and amazingly it is nondecreasing under this "inverse mean curvature flow". Indeed, under inverse mean curvature flow it follows from the Gauss equation and the second variation formula that

$$\frac{d}{dt} m_{Hawking}(\Sigma) = \sqrt{\frac{|\Sigma|}{16\pi}} \times \left[\frac{1}{2} + \frac{1}{16\pi}\int_\Sigma 2\frac{|\nabla_\Sigma H|^2}{H^2} + R - 2K + \frac{1}{2}(\lambda_1 - \lambda_2)^2\right]$$

when the flow is smooth, where R is the scalar curvature of (M^3, g), K is the Gauss curvature of the surface Σ, and λ_1 and λ_2 are the eigenvalues of the second fundamental form of Σ, or principal curvatures. Hence, since $R \geq 0$, and

$$\int_\Sigma K \leq 4\pi \tag{4}$$

(true for any connected surface by the Gauss-Bonnet Theorem), it follows that

$$\frac{d}{dt} m_{Hawking}(\Sigma) \geq 0. \tag{5}$$

Furthermore,

$$m_{Hawking}(\Sigma_0) = \sqrt{\frac{|\Sigma_0|}{16\pi}},$$

since Σ_0 is a minimal surface and has zero mean curvature. In addition, the Hawking mass of sufficiently round spheres at infinity in the asymptotically flat end of (M^3, g) approaches the total mass m. Hence, if inverse mean curvature flow beginning with Σ_0 eventually flows to sufficiently round spheres at infinity, inequality (3) follows from inequality (5).

As noted by Jang and Wald, this argument works only when inverse mean curvature flow exists and is smooth, which is generally not expected to be the case. In fact, it is not hard to construct manifolds which do not admit a smooth inverse mean curvature flow. The problem is that if the mean curvature of the evolving surface becomes zero or is negative, it is not clear how to define the flow.

For twenty years this heuristic argument lay dormant, until the work of Huisken and Ilmanen [8] in 1997. With a very clever new approach, Huisken and Ilmanen discovered how to reformulate inverse mean curvature flow using an energy minimization principle in such a way that the new generalized inverse mean curvature flow always exists. The added twist is that the surface sometimes jumps outward. However, when the flow is smooth, it equals the original inverse mean curvature flow, and the Hawking mass is still monotone. Hence, as will be described in the next section, their new flow produced the first complete proof of inequality (3) for a single black hole.

Coincidentally, the author found another proof of inequality (3), submitted in 1999, which works for any number of black holes. The approach involves flowing the original metric to a Schwarzschild metric (outside the horizon) in such a way that the area of the outermost minimal surface does not change and the total mass is nonincreasing. Then, since the Schwarzschild metric gives equality in inequality (3), the inequality follows for the original metric. Fortunately, the flow of metrics which is defined is relatively simple and in fact stays inside the conformal class of the original metric. The outermost minimal surface flows outwards in this conformal flow of metrics and encloses any compact set (and hence all of the topology of the original metric) in a finite amount of time. Furthermore, this conformal flow of metrics preserves nonnegative scalar curvature. We will describe this approach later in the paper.

Other contributions on the Penrose Conjecture have been made by Herzlich using the Dirac operator, which Witten used to prove the positive mass theorem; by Gibbons in the special case of collapsing shells; by Tod; by Bartnik for quasi-spherical metrics; and by the author using isoperimetric surfaces. There is also some interesting work of Ludvigsen and Vickers using spinors and of Bergqvist, both concerning the Penrose inequality for null slices of a spacetime.

Inverse Mean Curvature Flow

Geometrically, Huisken and Ilmanen's idea can be described as follows. Let $\Sigma(t)$ be the surface resulting from inverse mean curvature flow for time t beginning with the minimal surface Σ_0. Define $\bar{\Sigma}(t)$ to be the outermost minimal area enclosure of $\Sigma(t)$. Typically, $\Sigma(t) = \bar{\Sigma}(t)$ in the flow, but in the case that the two surfaces are not equal, immediately replace $\Sigma(t)$ with $\bar{\Sigma}(t)$ and then continue flowing by inverse mean curvature.

An immediate consequence of this modified flow is that the mean curvature of $\bar{\Sigma}(t)$ is always nonnegative by the first variation formula, since otherwise $\bar{\Sigma}(t)$ would be enclosed by a surface with less area. This is because if we flow a surface Σ in the outward direction with speed η, the first variation of the area is $\int_\Sigma H\eta$, where H is the mean curvature of Σ.

Furthermore, by stability, it follows that in the regions where $\bar{\Sigma}(t)$ has zero mean curvature, it is always possible to flow the surface out slightly to have positive mean curvature, allowing inverse mean curvature flow to be defined, at least heuristically, at this point. Furthermore, the Hawking mass is still monotone under this new modified flow. Notice that when $\Sigma(t)$ jumps outwards to $\bar{\Sigma}(t)$,

$$\int_{\bar{\Sigma}(t)} H^2 \leq \int_{\Sigma(t)} H^2,$$

since $\bar{\Sigma}(t)$ has zero mean curvature where the two surfaces do not touch. Furthermore,

$$|\bar{\Sigma}(t)| = |\Sigma(t)|$$

because (this is a neat argument) $|\bar{\Sigma}(t)| \leq |\Sigma(t)|$ (since $\bar{\Sigma}(t$ is a minimal area enclosure of $\Sigma(t)$) and we cannot have $|\bar{\Sigma}(t)| < |\Sigma(t)|$ (since $\Sigma(t)$ would have jumped outwards at some earlier time). This is only a heuristic argument, but we can then see by the preceding two equations that the Hawking mass is nondecreasing during a jump.

This new flow can be rigorously defined, always exists, and the Hawking mass is monotone. In [8] Huisken and Ilmanen define $\Sigma(t)$ to be the level sets of a scalar-valued function $u(x)$ defined on (M^3, g) such that $u(x) = 0$ on the original surface Σ_0 and

$$\text{div}\left(\frac{\nabla u}{|\nabla u|}\right) = |\nabla u| \tag{6}$$

in an appropriate weak sense. Since the left-hand side of this equation is the mean curvature of the level sets of $u(x)$ and the right-hand side is the reciprocal of the flow rate, the equation characterizes inverse mean curvature flow for the level sets of $u(x)$ when $|\nabla u(x)| \neq 0$.

Huisken and Ilmanen use an energy minimization principle to define weak solutions to equation (6). Equation (6) is said to be weakly satisfied in Ω by the locally Lipschitz function u if for every locally Lipschitz function v with $\{v \neq u\} \subset\subset \Omega$,

$$J_u(u) \leq J_u(v)$$

where

$$J_u(v) := \int_\Omega |\nabla v| + v|\nabla u|.$$

The Euler-Lagrange equation of the above energy functional yields equation (6).

In order to prove that a solution u exists to the preceding two equations, Huisken and Ilmanen regularize the degenerate elliptic equation (6) to the elliptic equation

$$\text{div}\left(\frac{\nabla u}{\sqrt{|\nabla u|^2 + \epsilon^2}}\right) = \sqrt{|\nabla u|^2 + \epsilon^2}.$$

Solutions to this equation are shown to exist using the existence of a subsolution; then taking the limit as ϵ goes to zero yields a weak solution to equation (6). We are skipping many details here, but these are the main ideas.

As it turns out, weak solutions $u(x)$ to equation (6) often have flat regions where $u(x)$ equals a constant. The level sets $\Sigma(t)$ of $u(x)$ are discontinuous in t in this case, which corresponds to the "jumping out" phenomenon referred to earlier.

We also note that since the Hawking mass of the level sets of $u(x)$ is monotone, this inverse mean curvature flow technique not only proves the

Riemannian Penrose Inequality but also gives a new proof of the Positive Mass Theorem in dimension three. This is seen by letting the initial surface be a very small, round sphere (which will have approximately zero Hawking mass) and then flowing by inverse mean curvature, thereby proving $m \geq 0$.

The Huisken and Ilmanen inverse mean curvature flow also seems ideally suited for proving Penrose inequalities for asymptotically hyperbolic 3-manifolds having $R \geq -6$. This situation occurs if (M^3, g) is chosen to be a constant mean curvature slice of the spacetime or if the spacetime is defined to solve the Einstein equation with nonzero cosmological constant. In these cases there exists a modified Hawking mass that is monotone under inverse mean curvature flow—it is the usual Hawking mass plus $4(|\Sigma|/16\pi)^{3/2}$. However, because the monotonicity of the Hawking mass relies on the Gauss-Bonnet theorem, these arguments do not work in higher dimensions, at least so far. Also, because of the need for equation (4), inverse mean curvature flow proves the Riemannian Penrose Inequality only for a single black hole. In the next section we present a technique which proves the Riemannian Penrose Inequality for any number of black holes and which can likely be generalized to higher dimensions.

The Conformal Flow of Metrics

Given any initial Riemannian manifold (M^3, g_0) which has nonnegative scalar curvature and which is harmonically flat at infinity, we will define a continuous, one-parameter family of metrics (M^3, g_t) for $0 \leq t < \infty$. This family of metrics will converge to a 3-dimensional Schwarzschild metric and will have other special properties which will allow us to prove the Riemannian Penrose Inequality for the original metric (M^3, g_0).

In particular, let Σ_0 be the outermost minimal surface of (M^3, g_0), with area A_0. We will also define a family of surfaces $\Sigma(t)$, with $\Sigma(0) = \Sigma_0$, such that $\Sigma(t)$ is minimal in (M^3, g_t). This is natural, since as the metric g_t changes, we expect that the location of the horizon $\Sigma(t)$ will also change. The interesting quantities to keep track of in this flow are $A(t)$, the total area of the horizon $\Sigma(t)$ in (M^3, g_t); and $m(t)$, the total mass of (M^3, g_t) in the chosen end.

In addition to all of the metrics g_t having nonnegative scalar curvature, we will also have the very nice properties that

$$A'(t) = 0,$$
$$m'(t) \leq 0$$

for all $t \geq 0$. Since (M^3, g_t) converges (in an appropriate sense) to a Schwarzschild metric, which as described in the introduction gives equality in the Riemannian Penrose Inequality, we will have

$$m(0) \geq m(\infty) = \sqrt{\frac{A(\infty)}{16\pi}} = \sqrt{\frac{A(0)}{16\pi}}, \tag{7}$$

which proves the Riemannian Penrose Inequality for the original metric (M^3, g_0). The hard part, then, is to find a flow of metrics which preserves nonnegative scalar curvature and the area of the horizon, decreases total mass, and converges to a Schwarzschild metric as t goes to infinity.

The Definition of the Flow

In fact, the metrics g_t will all be conformal to g_0. This conformal flow of metrics can be thought of as the solution to a first-order ordinary differential equation in t defined by equations (8), (9), (10), and (11). Let

$$g_t = u_t(x)^4 g_0 \tag{8}$$

and $u_0(x) \equiv 1$. Given the metric g_t, define

$$\begin{aligned}\Sigma(t) = {} & \text{the outermost minimal} \\ & \text{area enclosure of } \Sigma_0 \text{ in } (M^3, g_t),\end{aligned} \tag{9}$$

where Σ_0 is the original outer minimizing horizon in (M^3, g_0). In the cases in which we are interested, $\Sigma(t)$ will not touch Σ_0, from which it follows that $\Sigma(t)$ is actually a strictly outer minimizing horizon of (M^3, g_t). Given the horizon $\Sigma(t)$, define $v_t(x)$ such that

$$\begin{cases} \Delta_{g_0} v_t(x) & \equiv 0 \text{ outside } \Sigma(t) \\ v_t(x) & = 0 \text{ on } \Sigma(t) \\ \lim_{x\to\infty} v_t(x) & = -e^{-t} \end{cases} \tag{10}$$

and $v_t(x) \equiv 0$ inside $\Sigma(t)$. Finally, given $v_t(x)$, define

$$u_t(x) = 1 + \int_0^t v_s(x)ds, \tag{11}$$

so that $u_t(x)$ is continuous in t and has $u_0(x) \equiv 1$.

Now equation (11) implies that the first-order rate of change of $u_t(x)$ is given by $v_t(x)$. Hence, the first-order rate of change of g_t is a function of itself, of g_0, and of $v_t(x)$, which is a function of g_0, t, and $\Sigma(t)$, which is in turn a function of g_t and Σ_0. Thus, the first-order rate of change of g_t is a function of t, g_t, g_0, and Σ_0.

Theorem 2. *Taken together, equations (8), (9), (10), and (11) define a first-order ordinary differential equation in t for $u_t(x)$ having a solution which is Lipschitz in the t variable, class C^1 in the x variable everywhere, and smooth in the x variable outside $\Sigma(t)$. Furthermore, $\Sigma(t)$ is a smooth, strictly outer minimizing horizon in (M^3, g_t) for all $t \geq 0$, and $\Sigma(t_2)$ encloses but does not touch $\Sigma(t_1)$ for all $t_2 > t_1 \geq 0$.*

Since $v_t(x)$ is a superharmonic function in (M^3, g_0) (harmonic everywhere except on $\Sigma(t)$, where it is weakly superharmonic), it follows that

$u_t(x)$ is superharmonic as well. Thus, from equation (11) we see that $\lim_{x\to\infty} u_t(x) = e^{-t}$ and consequently that $u_t(x) > 0$ for all t by the maximum principle. Then, since

$$R(g_t) = u_t(x)^{-5}(-8\Delta_{g_0} + R(g_0))u_t(x),$$

it follows that (M^3, g_t) is an asymptotically flat manifold with nonnegative scalar curvature.

Even so, it still may not seem that g_t is naturally defined, since the rate of change of g_t appears to depend on both t and the original metric g_0 in equation (10). We would prefer a flow where the rate of change of g_t can be defined purely as a function of g_t (and Σ_0 perhaps), and interestingly enough this actually does turn out to be the case! In [1] we prove this very important fact and define a new equivalence class of metrics called the harmonic conformal class. Once we decide to find a flow of metrics which stays inside the harmonic conformal class of the original metric (outside the horizon) and keeps the area of the horizon $\Sigma(t)$ constant, we are basically forced to choose the particular conformal flow of metrics defined above.

Theorem 3. *The function $A(t)$ is constant in t, and $m(t)$ is nonincreasing in t, for all $t \geq 0$.*

That $A'(t) = 0$ follows because to first order the metric is not changing on $\Sigma(t)$ (since $v_t(x) = 0$ there) and to first order the area of $\Sigma(t)$ does not change as it moves outward (since $\Sigma(t)$ is a critical point for area in (M^3, g_t)). Hence, the interesting part of Theorem 3 is proving that $m'(t) \leq 0$. Curiously, this follows from a nice trick using the Riemannian positive mass theorem, which we describe later.

Another important aspect of this conformal flow of the metric is that outside the horizon $\Sigma(t)$, the manifold (M^3, g_t) becomes more and more spherically symmetric and "approaches" a Schwarzschild manifold $(\mathbf{R}^3 \setminus \{0\}, s)$ in the limit as t goes to ∞. More precisely:

Theorem 4. *For sufficiently large t, there exists a diffeomorphism ϕ_t between (M^3, g_t) outside the horizon $\Sigma(t)$ and a fixed Schwarzschild manifold $(\mathbf{R}^3 \setminus \{0\}, s)$ outside its horizon. Furthermore, for all $\epsilon > 0$, there exists a T such that for all $t > T$, the metrics g_t and $\phi_t^*(s)$ (when determining the lengths of unit vectors of (M^3, g_t)) are within ϵ of each other and the total masses of the two manifolds are within ϵ of each other. Hence,*

$$\lim_{t\to\infty} \frac{m(t)}{\sqrt{A(t)}} = \sqrt{\frac{1}{16\pi}}.$$

Theorem 4 is not really surprising, although a careful proof is rather long. However, if one is willing to believe that the flow of metrics converges to a spherically symmetric metric outside the horizon, then Theorem 4 follows from two observations. The first is that the scalar curvature of (M^3, g_t) eventually becomes identically zero outside the horizon $\Sigma(t)$ (assuming (M^3, g_0) is harmonically flat). This follows from the facts that $\Sigma(t)$ encloses any compact set in a finite amount of time, that harmonically flat manifolds have zero scalar curvature outside a compact set, that $u_t(x)$ is harmonic outside $\Sigma(t)$, and equation (12). The second observation is that the Schwarzschild metrics are the only complete, spherically symmetric 3-manifolds with zero scalar curvature (except for the flat metric on R^3).

The Riemannian Penrose inequality (3) then follows for harmonically flat manifolds [1] from equation (7) using Theorems 2, 3, and 4. Since asymptotically flat manifolds can be approximated arbitrarily well by harmonically flat manifolds while changing the relevant quantities arbitrarily little, the asymptotically flat case also follows. Finally, the case of equality of the Penrose inequality follows from a more careful analysis of these same arguments.

Qualitative Discussion

The two diagrams below are meant to help illustrate some of the properties of the conformal flow of the metric. Figure 3 is the original metric, which has a strictly outer minimizing horizon Σ_0. As t increases, $\Sigma(t)$ moves outwards but never inwards. In Figure 4 we can observe one of the consequences of the fact that $A(t) = A_0$ is constant in t. Since the

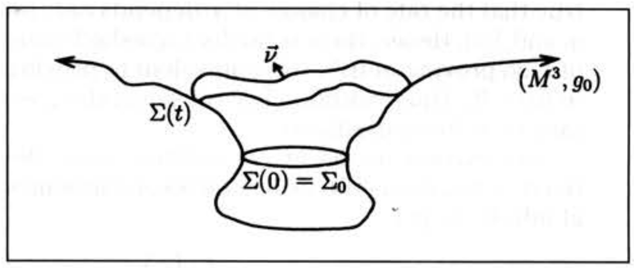

Figure 3.

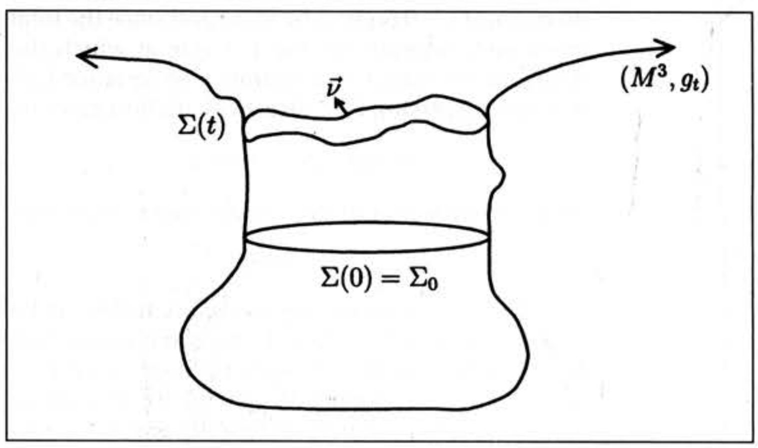

Figure 4.

metric is not changing inside $\Sigma(t)$, all of the horizons $\Sigma(s)$, $0 \leq s \leq t$, have area A_0 in (M^3, g_t). Hence, inside $\Sigma(t)$, the manifold (M^3, g_t) becomes cylinder-like in the sense that it is laminated (meaning foliated but with some gaps allowed) by all of the previous horizons, which all have the same area A_0 with respect to the metric g_t.

Now suppose that the original horizon Σ_0 of (M^3, g) had two components, for example. Then each of the components of the horizon will move outwards as t increases, and at some point before they touch they will suddenly jump outwards to form a horizon with a single component enclosing the previous horizon with two components. Even horizons with only one component will sometimes jump outwards, but no more than a countable number of times. It is interesting that this phenomenon of surfaces jumping is also found in the Huisken-Ilmanen approach to the Penrose conjecture using the generalized $1/H$ flow.

Proof that $m'(t) \leq 0$. The most surprising aspect of the conformal flow of metrics is that $m'(t) \leq 0$. As mentioned above, this important fact follows from a nice trick using the Riemannian positive mass theorem.

The first step is to realize that while the rate of change of g_t appears to depend on both t and g_0, this is in fact an illusion. As described in detail in [1], the rate of change of g_t can be described purely in terms of g_t (and Σ_0). It is also true that the rate of change of g_t depends only on g_t and $\Sigma(t)$. Hence, there is no distinguished value of t, so proving $m'(t) \leq 0$ is equivalent to proving $m'(0) \leq 0$. Thus, without loss of generality, we take $t = 0$ for convenience.

Now expand the harmonic function $v_0(x)$, defined in equation (10), using spherical harmonics at infinity to get

$$v_0(x) = -1 + \frac{c}{|x|} + \mathcal{O}\left(\frac{1}{|x|^2}\right) \tag{13}$$

for some constant c. Since the rate of change of the metric g_t at $t = 0$ is given by $v_0(x)$ and since the total mass $m(t)$ depends on the $1/r$ rate at which the metric g_t becomes flat at infinity (see equation (2)), it is not surprising that direct calculation gives us

$$m'(0) = 2(c - m(0)).$$

Hence, to show that $m'(0) \leq 0$, we need to show that

$$c \leq m(0). \tag{14}$$

In fact, counterexamples to equation (14) can be found if we remove either of the requirements that $\Sigma(0)$ (which is used in the definition of $v_0(x)$) be a minimal surface or that (M^3, g_0) have nonnegative scalar curvature. Hence, we quickly see that equation (14) is a fairly deep conjecture which says something quite interesting about manifolds with nonnegative scalar curvature. Now the Riemannian positive mass theorem is also a deep conjecture which says something quite interesting about manifolds with nonnegative scalar curvature. Hence, it is natural to try to use the Riemannian positive mass theorem to prove equation (14).

Thus, we want to create a manifold whose total mass depends on c from equation (13). The idea is to use a reflection trick similar to one used by Bunting and Masood-ul-Alam for another purpose in [5]. First, remove the region of M^3 inside $\Sigma(0)$ and then reflect the remainder of (M^3, g_0) through $\Sigma(0)$. Define the resulting Riemannian manifold to be $(\bar{M}^3, \bar{g}_0)$, which has two asymptotically flat ends, since (M^3, g_0) has exactly one asymptotically flat end not contained by $\Sigma(0)$. Note that $(\bar{M}^3, \bar{g}_0)$ has nonnegative scalar curvature everywhere except on $\Sigma(0)$, where the metric has corners. Moreover, the fact that $\Sigma(0)$ has zero mean curvature (since it is a minimal surface) implies that $(\bar{M}^3, \bar{g}_0)$ has *distributional* nonnegative scalar curvature everywhere, even on $\Sigma(0)$. This notion is made rigorous in [1]. Thus we have used the fact that $\Sigma(0)$ is minimal in a crucial way.

Recall from equation (10) that $v_0(x)$ was defined to be the harmonic function equal to zero on $\Sigma(0)$ which goes to -1 at infinity. We want to reflect $v_0(x)$ to be defined on all of $(\bar{M}^3, \bar{g}_0)$. The trick here is to define $v_0(x)$ on $(\bar{M}^3, \bar{g}_0)$ to be the harmonic function which goes to -1 at infinity in the original end and goes to 1 at infinity in the reflected end. By symmetry, $v_0(x)$ equals 0 on $\Sigma(0)$ and so agrees with its original definition on (M^3, g_0).

The next step is to compactify one end of $(\bar{M}^3, \bar{g}_0)$. By the maximum principle, we know that $v_0(x) > -1$ and $c > 0$, so the new Riemannian manifold $(\bar{M}^3, (v_0(x) + 1)^4 \bar{g}_0)$ does the job quite nicely and compactifies the original end to a point. In fact, the compactified point at infinity and the metric there can be filled in smoothly (using the fact that (M^3, g_0) is harmonically flat). It then follows from equation (12) that this new compactified manifold has nonnegative scalar curvature since $v_0(x) + 1$ is harmonic.

The last step is simply to apply the Riemannian positive mass theorem to $(\bar{M}^3, (v_0(x) + 1)^4 \bar{g}_0)$. It is not surprising that the total mass $\bar{m}(0)$ of this manifold involves c, but it is quite lucky that direct calculation yields

$$\bar{m}(0) = -4(c - m(0)),$$

which must be positive by the Riemannian positive mass theorem. Thus, we have that

$$m'(0) = 2(c - m(0)) = -\frac{1}{2}\bar{m}(0) \leq 0.$$

Open Questions and Applications

Now that the Riemannian Penrose conjecture has been proved, what are the next interesting directions? What applications can be found? Is this subject only of physical interest, or are there possibly broader applications to other problems in mathematics?

Clearly the most natural open problem is to find a way to prove the general Penrose inequality, in which M^3 is allowed to have any second fundamental form in the spacetime. There is good reason to think that this may follow from the Riemannian Penrose inequality, although this is a bit delicate. On the other hand, the general positive mass theorem followed from the Riemannian positive mass theorem as was originally shown by Schoen and Yau using an idea due to Jang. For physicists this problem is definitely a top priority since most spacetimes do not even admit zero second fundamental form spacelike slices.

Another interesting problem is to ask these same questions in higher dimensions. The author is currently working on a paper to prove the Riemannian Penrose inequality in dimensions less than 8. Dimensions 8 and higher are harder because of the surprising fact that minimal hypersurfaces (and hence apparent horizons of black holes) can have codimension 7 singularities (points where the hypersurface is not smooth). This curious technicality is also the reason that the positive mass conjecture is still open in dimensions 8 and higher for manifolds which are not spin manifolds.

Naturally it is harder to tell what the applications of these techniques might be to other problems, but already there have been some. One application is to the famous Yamabe problem: Given a compact 3-manifold M^3, define $E(g) = \int_{M^3} R_g \, dV_g$, where R_g is the scalar curvature at each point, dV_g is the volume form, and g is scaled so that the total volume of (M^3, g) is equal to 1. An idea due to Yamabe was to try to construct canonical metrics on M^3 by finding critical points of this energy functional on the space of metrics. Define $C(g)$ to be the infimum of $E(\bar{g})$ over all metrics $\bar{g}$ conformal to g. Then the (topological) Yamabe invariant of M^3, denoted here as $Y(M^3)$, is defined to be the supremum of $C(g)$ over all metrics g. It is known that $Y(S^3) = 6 \cdot (2\pi^2)^{2/3} \equiv Y_1$ is the largest possible value for the Yamabe invariant of a 3-manifold. It is also known that $Y(T^3) = 0$ and $Y(S^2 \times S^1) = Y_1 = Y(S^2 \tilde{\times} S^1)$, where $S^2 \tilde{\times} S^1$ is the nonorientable S^2-bundle over S^1.

The author, working with Andre Neves on a problem suggested by Richard Schoen, recently was able to compute the Yamabe invariant of RP^3 using inverse mean curvature flow techniques [3] and found that $Y(RP^3) = Y_1 / 2^{2/3} \equiv Y_2$. A corollary is that $Y(RP^2 \times S^1) = Y_2$ as well. These techniques also yield the surprisingly strong result that the only prime 3-manifolds with Yamabe invariant larger than RP^3 are S^3, $S^2 \times S^1$, and $S^2 \tilde{\times} S^1$. The Poincaré conjecture for 3-manifolds with Yamabe invariant greater than RP^3 is therefore a corollary. Furthermore, the problem of classifying 3-manifolds is known to reduce to the problem of classifying prime 3-manifolds. The Yamabe approach then would be to make a list of prime 3-manifolds ordered by the invariant Y. The first five prime 3-manifolds on this list are therefore S^3, $S^2 \times S^1$, $S^2 \tilde{\times} S^1$, RP^3, and $RP^2 \times S^1$.

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WHAT IS...

an Alteration?

Frans Oort

Motivation. Algebraic varieties, which are zero sets of polynomial equations, appear in geometry, in number theory, and in analysis. For example, Fermat's Last Theorem studies rational solutions of a polynomial equation. The Weierstrass $\wp$-function and its derivative satisfy a cubic polynomial equation. The geometry of these varieties gives important information on the related problems in number theory or analysis.

In a variety the smooth locus is dense, but there can be singularities, such as a node, a cusp on an algebraic curve, a "self-intersection" on a surface, a quotient singularity, and much more complicated forms. Often singularities make it difficult to carry out proofs, to analyze properties of the problem described by the variety, to compute integrals, and so on.

Therefore it is natural to ask: *Is it possible to "desingularize" a given algebraic variety, to replace it in a reasonable way by a nonsingular variety?*

This question was studied and solved successfully for curves and for algebraic surfaces. Oscar Zariski was one of the main contributors, and he stimulated many researchers in this problem. We should pay a tribute to him!

Examples. a) A typical example: let C be the plane curve given by the equation $X^3 = Y^2$. At $(x = 0, y = 0)$ this curve has a singularity, a *cusp*. We map affine space of dimension one by $u \mapsto (u^2, u^3)$ onto C; this is a resolution of singularities of the singular curve C.

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b) Consider the plane curve given by the equation $X^4 + Y^4 = 1$, the *Fermat quartic*. Fermat's Last Theorem tells us (as Fermat proved himself in this special case) that there are no rational solutions $(x, y) \in \mathbb{Q} \times \mathbb{Q}$ to this equation with $xy \neq 0$.

c) Consider the plane curve, the *Bernoulli lemniscate*, given by the equation $(X^2 + Y^2)^2 = X^2 - Y^2$. In this case there are infinitely many rational solutions. One might have difficulties finding them without analyzing the geometry of the related projective curve.

d) Consider a nonsingular variety V, e.g. affine space $\mathbb{C}^n$, and consider a finite group G acting on it. In general the quotient space has singularities, the so-called *quotient singularities*. For example, let $V = \mathbb{C}^2$, and let G be the cyclic group of order two, generated by reflection in the origin. In this case $G \backslash V$ is a surface, and the only singularity is the image of the point $(0, 0)$.

Modifications: Resolution of Singularities. We make more precise what we mean by "changing a variety into a nonsingular one".

Definition. *A morphism $f : W \to V$ of algebraic varieties is called a* modification *if it is birational and proper.*

"Birational" means that f is an isomorphism outside lower-dimensional subvarieties, i.e., an isomorphism almost everywhere. "Proper" means that f is a closed map. The reader may have encountered analogous terminology or related concepts such as a blowing-up, a σ-process, or a Cremona transformation.

The map in example (a) is a modification. The quotient map $V \to G\backslash V$ is not a modification if the action of G on V is nontrivial.

Definition. *A morphism $f : W \to V$ is called a* resolution of singularities *of V if f is a modification and W is a nonsingular variety.*

Hironaka's Theorem. In 1964 Hironaka published his famous theorem on the resolution of singularities [3].

Theorem. *Let k be an algebraically closed field of* characteristic zero, *and let V be an algebraic variety over k. There exists a modification $f : W \to V$, where W is nonsingular.*

This useful theorem was a great breakthrough and admitted many applications. Hironaka's difficult construction has been carefully analyzed, simplified somewhat, and made canonical (see [2] for a survey). Moreover, in the theorem by Hironaka, we can choose f in such a way that it is an isomorphism exactly on the nonsingular part of V; this extra information has technical advantages.

Hironaka's proof, even in later versions, is difficult. Here is a challenge: try to resolve a quotient singularity, as in example (d).

Open Problem. Up to now we have not been able to prove the analogous theorem in positive characteristic (except for low-dimensional cases). There seems to be a need for a completely different approach [1]!

Alterations, A. J. de Jong, 1996.

Definition. *A morphism $f : W \to V$ of algebraic varieties is called an* alteration *if it is surjective, generically finite, and proper.*

Such a morphism is a closed map which is "almost everywhere" finite-to-one.

Theorem. *Let K be a field, and let V be an algebraic variety over K. There exists an* alteration *$f : W \to V$, where W is a nonsingular variety.*

From this theorem we can easily reprove Hironaka's theorem in a weak form (Bogomolov and Pantev, Abramovich and de Jong); for references and a discussion see the first chapter in [2].

Remark. On the one hand, every modification is an alteration. On the other hand, an *alteration* $f : W \to V$ can be factored, using the Stein factorization, as $W \to S \to V$, where $g : W \to S$ is a *modification* and $h : S \to V$ is a *finite morphism*. Any alteration (with V normal) where the corresponding h is not the identity is not a modification. The quotient map $\mathbb{C}^2 \to G\backslash\mathbb{C}^2$ in (d) is an alteration but not a modification.

A morphism of projective varieties is a modification if and only if it is birational (if and only if it is an isomorphism almost everywhere); it is an alteration if it is finite almost everywhere.

Sketch of the Proof of de Jong. In contrast with Hironaka's theorem, where the proof is difficult, the proof by de Jong is very clear. Basically (up to some technical difficulties) one replaces a (singular) variety V by a "fibration" $V \to B$, where all fibers are curves. By induction on the dimension, we assume the theorem to be proven for B: we pull back the fibration $V \to B$ via an alteration $B' \to B$, with B' nonsingular, to a fibration $V' \to B'$ over a nonsingular base. Resolution of singularities of curves is well known, and this can be made effective in the family $V' \to B'$.

Comparison: Modifications ↔ Alterations. In the proof by Hironaka, from the beginning we focus on singularities present. Explicit (algebraic) methods make singularities at one point "less singular" and, as Hironaka proves, do not make a "global invariant" worse. A complicated induction process gives the desired (deep, very useful) result.

In the method by de Jong, in the beginning of the proof singularities are completely ignored, and perhaps even more singularities are created. Explicit resolution of singularities is then carried out in the last, not very difficult, step. This geometric approach lends itself to many geometric situations. Instead of the algebraic, algorithmic approach by Hironaka, de Jong proposes a geometric method, which also works in relative situations (singularities in a family) and in positive characteristic. This allows several applications not possible in Hironaka's theory.

References

[1] A. J. DE JONG, Smoothness, semi-stability and alterations, *Publ. Math. IHÉS* **83** (1996), 51–93. In this paper Johan de Jong introduces "alterations", and a proof is given that any variety is dominated via an alteration by a nonsingular variety.

[2] H. HAUSER, J. LIPMAN, F. OORT, and A. QUIRÓS, eds., *Resolution of Singularities. A Research Textbook in Tribute to Oscar Zariski*, Progr. Math., vol. 181, Birkhäuser-Verlag, Basel, 2000. Based on courses at a conference in Obergurgl, Austria, September 7–14, 1997. In this book we find many references, explanations, and full expositions on the techniques introduced by Hironaka and by de Jong.

[3] H. HIRONAKA, Resolution of singularities of an algebraic variety over a field of characteristic zero, *Ann. Math.* **79** (1964), 109–326. In this paper Hironaka proves his famous theorem.

Comments and suggestions may be sent to `whatis-notices@ams.org`.

TeX and LaTeX 2e

Michael Downes

Most mathematicians today use some variant of TeX to write their mathematical papers and books. Created around 1980 by computer scientist Donald E. Knuth, TeX dramatically changed the process of preparing and distributing mathematical literature. In the ensuing two decades various streams of TeX-related development have sprung up, diverged, converged, and sometimes evaporated in the face of newer software, with the associated terminology proliferating in equal measure—as anyone familiar with software evolution would expect. The aim of this article is to explain some of the terminology and clarify certain distinctions of interest for mathematicians.

Currently, for authors who intend to publish an article or book with the AMS, writing it with LaTeX is particularly recommended because the LaTeX document format is

1. oriented towards capturing the inherent logical structure of the document, which is critically important for long-term archiving;
2. capable of serving as a source from which many other formats can be automatically generated (e.g., HTML, PDF);
3. well established and stable (also good for archiving purposes);
4. readily exchangeable with colleagues;
5. both standardized and flexible in a way that seems well suited to mathematical material;
6. easy to feed directly into the AMS production system.

There is a significant distinction between the current version of LaTeX, known as LaTeX 2e, and the preceding version, known as LaTeX 2.09, superseded by LaTeX 2e in 1994. The AMS definitely recommends LaTeX 2e to its authors and advises anyone still using LaTeX 2.09 to phase it out of use at the earliest reasonable opportunity, because LaTeX 2e is much easier to work with, both for authors and for publishers.

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How Do I Use LaTeX to Write a Document?

Strictly speaking, you don't. You use some other program to write a LaTeX document, and then you invoke LaTeX to *typeset* or *compile* the document. Just about any mainstream text-editor program such as Alpha, Emacs, BBEdit, WinEdt, or vi can be used to write LaTeX documents. Yes, even NotePad in a pinch.

The result of the typesetting is a DVI or PDF file, which you can then print or view on screen at your leisure, using other programs such as `xdvi`, Acrobat Reader, `ghostview`, or `dvips`. In effect, by a slight change of perspective, the *typeset* operation could be understood to mean *save as DVI* or *save as PDF*.

Some programs (e.g., Scientific Word or Textures) integrate the multistep process into something closer to a typical word processor, or WYSIWYG ("What You See Is What You Get") interface, but the fact that LaTeX software is mostly non-WYSIWYG is normally regarded as a virtue rather than a drawback. Among other things, a non-WYSIWYG approach helps sensitize authors to the kind of discrimination between visual appearances and essential information that they need to make if they do not want what they write to be inadvertently encumbered by limitations of the medium (or software, or printer, or type of computer monitor) in which it is originally produced.

How Do I Get LaTeX If I Do Not Have It?

One of the best ways to get LaTeX up and running on a new computer is with the TeX Live CD [12] offered as a benefit of membership in the TeX Users Group. (The CD is not sold separately; the only way to get one is by becoming a member.)

Some other suggested sources for getting LaTeX may be found on the AMS *TeX Resources* webpage [11]. The main decision might be whether to go with one of the free TeX systems or pay money for a commercial one. A commercial TeX system will not be cheap (usually \$300–\$500), but apart from coming with a telephone number to call technical support, it will also tend to be easier to install and more tightly integrated into a given operating system. The Y&Y TeX system, for example, includes a capability for saving LaTeX equations to the Windows clipboard in Windows MetaFile format so that they can be pasted easily into other Windows applications.

From TeX to LaTeX

Rather than attempting to be all things in a single program, TeX is designed with modularity in mind. Thus TeX itself provides only fundamental typesetting capabilities and does not incorporate editing, printing, or previewing capabilities. Instead, the result of running TeX is a graphics file in a format called DVI (for device-independent) that is designed to make it as easy as possible for other programs to print or preview DVI files on an arbitrary printing device or computer screen. This may seem unremarkable nowadays, but it was far from commonplace back in 1980 when Knuth was developing TeX. At that time, the publisher's version of an article or book was usually held in a proprietary format that could be viewed or printed only with special-purpose commercial typesetting equipment.

The typesetting operations of TeX are applied on a very low level. They address the tasks of

- stringing characters together in words and paragraphs,
- positioning symbols properly in mathematical formulas,
- automatically finding good page breaks, and
- dealing with footnotes and other floating objects (such as figures and tables).

For authors, however, it is preferable to work on a higher level. For example, instead of writing

```
\begingroup
\rightskip=0pt plus.2\hsize
\leftskip=\rightskip
\parindent=0pt \parfillskip=0pt
\noindent
...
\par \endgroup
```

every time some text needs to be centered, the usual practice would be to define abbreviations (also known as TeX *macros*) such that one could get the same results by writing

```
\center ... \endcenter
```

By design, then, TeX is almost always used in conjunction with an auxiliary piece of software called a TeX *format* whose purpose is to bridge the gap between the low-level typesetting functions of TeX and a higher-level interface more suitable for authors. A TeX format is made by assembling all of the TeX macros that define the higher-level interface and precompiling them as a unit in order to reduce start-up time.

We are now in position to state a key point of the terminology: **LaTeX is a TeX format**. Some other well-known TeX formats are Plain TeX, AMS-TeX, `eplain`, `texinfo`, and `ConTeXt`. When we speak of running LaTeX, what we are really doing is running TeX+LaTeX; running `texinfo` means running TeX+`texinfo`, and so on.

The Plain TeX Format

Plain TeX is the generic example format that Knuth wrote to be distributed with TeX. It is not really designed for serious publishing use; for example, it provides only one font size: 10-point. Adding support for other sizes is not exactly difficult, but one has to do it oneself, and it can be rather tedious and error prone, especially when math fonts are involved. Plain TeX was, however, incorporated as a base element into just about all of the other TeX formats that came after it (vestiges in LaTeX include `\endgraf`, `\null`, `\empty`, `\slash`, `\*`, and `\pmatrix`, though none of these are documented in the LaTeX book [1]).

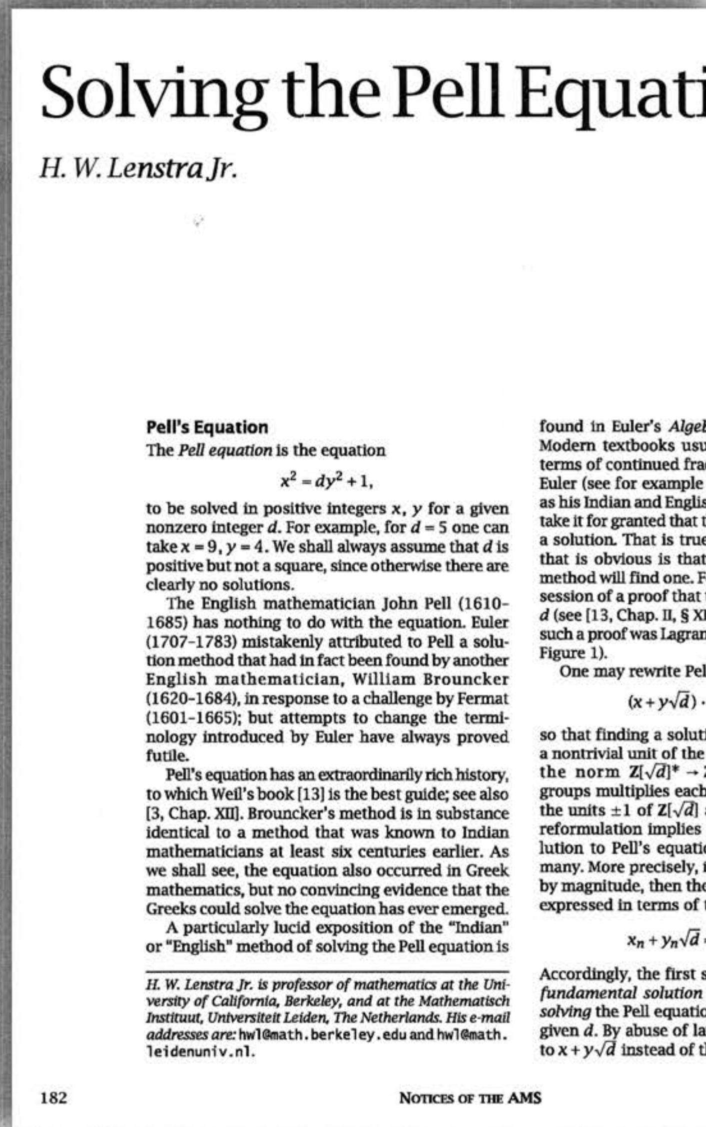
The AMS-TeX Format

Early on, when TeX first came to the attention of the AMS, the promise of putting high-quality mathematical typesetting into the hands of authors was extremely persuasive. The prospect of being able to directly use electronic files provided by the authors instead of retyping everything from manuscripts seemed absolutely compelling. It became apparent, however, after a little experimentation that something more than Plain TeX would be needed for AMS material. The AMS therefore underwrote the development of a TeX format that would be better able to handle the kind of material typically found in AMS publications. Although this format, "AMS-TeX", was used as early as 1981—for a short announcement in the *Notices* that a draft version of the AMS-TeX book could be purchased from the AMS (*The Joy of TeX* by Michael Spivak)—there were caveats in every AMS-TeX-related announcement over the next couple of years that it was still a work in progress. Some additional overhaul necessitated by the appearance of TeX82 was the occasion of further delay (cf. the acknowledgements in the 1986 printing of *The Joy of TeX*). So all in all it seems best to consider that AMS-TeX as we know it became available in 1984.

The LaTeX Format

LaTeX is a TeX format written by computer scientist Leslie Lamport in 1983–5. It was modeled in many respects on a non-TeX precursor called Scribe. Like Scribe, LaTeX takes as one of its central principles that authors are better off concentrating on logical design rather than visual design when writing their documents. This is a step beyond the mere aggregation of lower-level typesetting details into

```
\documentclass{notices}
\usepackage{amsmath}
\usepackage{amsthm}
\usepackage{url}

\newtheorem*{thm}{Theorem}

\newcommand{\term}[1]{\emph{#1}}

\begin{document}

\title{Solving the Pell Equation}
\author{H. W. Lenstra Jr.}

\note{H. W. Lenstra Jr.\@ is professor of
  mathematics at the University of
  California, Berkeley, and at the
  Mathematisch Instituut, Universiteit
  Leiden, The Netherlands. His e-mail
  addresses are:
  \url{hwl@math.berkeley.edu} and
  \url{hwl@math.leidenuniv.nl}.}

\maketitle

\section{Pell's Equation}

The \term{Pell equation} is the equation
\begin{displaymath}
x^{2} = dy^{2} + 1,
\end{displaymath}
to be solved in positive integers $x$, $y$
for a given nonzero integer $d$. For
example, for $d = 5$ one can take $x = 9$,
$y = 4$. We shall always assume that $d$ is
positive but not a square, since otherwise
there are clearly no solutions.

  ...
```



Solving the Pell Equati

H. W. Lenstra Jr.

Pell's Equation

The *Pell equation* is the equation

$$x^2 = dy^2 + 1,$$

to be solved in positive integers x, y for a given nonzero integer d. For example, for $d = 5$ one can take $x = 9$, $y = 4$. We shall always assume that d is positive but not a square, since otherwise there are clearly no solutions.

The English mathematician John Pell (1610–1685) has nothing to do with the equation. Euler (1707–1783) mistakenly attributed to Pell a solution method that had in fact been found by another English mathematician, William Brouncker (1620–1684), in response to a challenge by Fermat (1601–1665); but attempts to change the terminology introduced by Euler have always proved futile.

Pell's equation has an extraordinarily rich history, to which Weil's book [13] is the best guide; see also [3, Chap. XII]. Brouncker's method is in substance identical to a method that was known to Indian mathematicians at least six centuries earlier. As we shall see, the equation also occurred in Greek mathematics, but no convincing evidence that the Greeks could solve the equation has ever emerged.

A particularly lucid exposition of the "Indian" or "English" method of solving the Pell equation is

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found in Euler's *Algeb*
Modern textbooks usu
terms of continued frac
Euler (see for example [
as his Indian and Englis
take it for granted that t
a solution. That is true,
that is obvious is that
method will find one. Fe
session of a proof that t
d (see [13, Chap. II, § XII
such a proof was Lagran
Figure 1).

One may rewrite Pell

$(x + y\sqrt{d}) \cdot$

so that finding a soluti
a nontrivial unit of the
the norm $\mathbf{Z}[\sqrt{d}]^* \to \mathbf{Z}$
groups multiplies each
the units ± 1 of $\mathbf{Z}[\sqrt{d}]$ a
reformulation implies t
lution to Pell's equatio
many. More precisely, if
by magnitude, then the
expressed in terms of t

$x_n + y_n\sqrt{d} =$

Accordingly, the first s
fundamental solution
solving the Pell equatio
given d. By abuse of la
to $x + y\sqrt{d}$ instead of th

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Figure 1. A typical LaTeX file (cf. "Solving the Pell Equation", by H. W. Lenstra Jr., *Notices of the AMS* 49 (2002), 182–92).

a convenient higher-level set: defining macros `\vspace`, `\centering`, `\Large` makes it possible to write a section title as

```
\vspace{1.5cm}
\begin{centering}\Large
2. Section Title
\end{centering}
```

But LaTeX goes further: authors simply write

```
\section{Section Title}
```

and not only the visual appearance but the numbering is taken care of automatically. In other words, authors are encouraged to write in a way that describes the material conceptually, rather than visually—a practice sometimes referred to as *logical markup* or *conceptual markup*.[1] This will be recognizable to many as equivalent to the *stylesheet* feature of modern word processors; Lamport was well ahead of the curve in 1983 in recognizing the importance of this approach and building a TeX format around it that made it available to authors.

Another noteworthy early feature of LaTeX is that it was designed to interoperate nicely with auxiliary programs `makeindex` and BibTeX, which help automate the tasks of making indexes and bibliographies. The original versions of these programs are starting to show their age, but they continue in active use today—and a usable lifetime of over

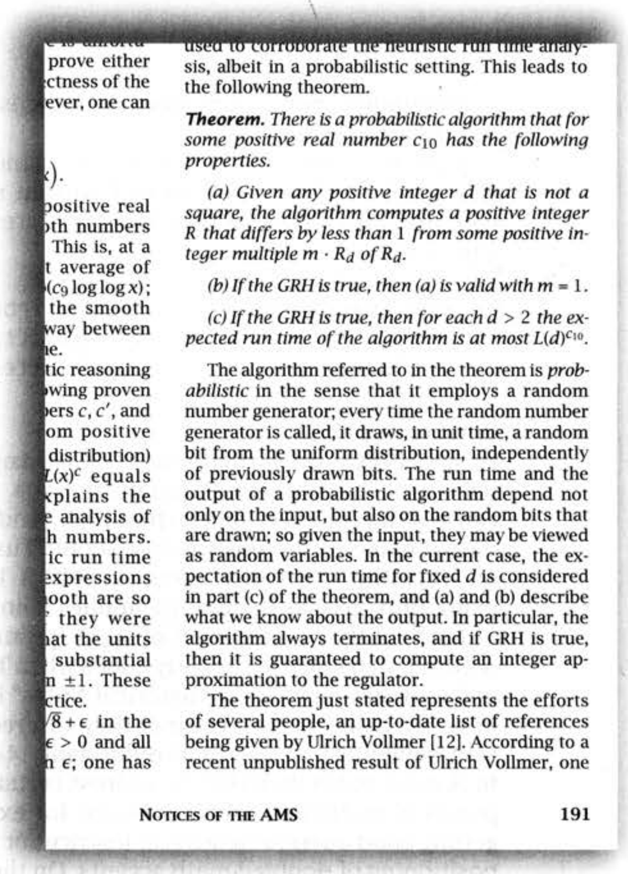
[1]*Cf.* Standard Generalized Markup Language, `http://xml.coverpages.org/sgml.html`; *SGML became an ISO standard in 1986 and was the ancestor of HTML (HyperText Markup Language) and XML (Extensible Markup Language).*

```
\begin{thm}
There is a probabilistic algorithm that for some
positive real number $c_{10}$ has the following
properties.
\begin{enumerate}
\item \label{first} Given any positive integer $d$
that is not a square, the algorithm computes a
positive integer $R$ that differs by less than $1$
from some positive integer multiple $m\cdot R_d$ of
$R_d$.

\item If the GRH is true, then \ref{first} is valid
with $m = 1$.

\item If the GRH is true, then for each $d > 2$ the
expected run time of the algorithm is at most
$L(d)^{c_{10}}$.
\end{enumerate}
\end{thm}

The algorithm referred to in the theorem is
\term{probabilistic} in the sense that it employs a
random number generator; every time the random
number generator is called it draws, in unit time, a
random bit from the uniform distribution,
independently of previously drawn bits.
```


used to corroborate the heuristic run time analysis, albeit in a probabilistic setting. This leads to the following theorem.

Theorem. *There is a probabilistic algorithm that for some positive real number c_{10} has the following properties.*

(a) Given any positive integer d that is not a square, the algorithm computes a positive integer R that differs by less than 1 from some positive integer multiple $m \cdot R_d$ of R_d.

(b) If the GRH is true, then (a) is valid with $m = 1$.

(c) If the GRH is true, then for each $d > 2$ the expected run time of the algorithm is at most $L(d)^{c_{10}}$.

The algorithm referred to in the theorem is *probabilistic* in the sense that it employs a random number generator; every time the random number generator is called, it draws, in unit time, a random bit from the uniform distribution, independently of previously drawn bits. The run time and the output of a probabilistic algorithm depend not only on the input, but also on the random bits that are drawn; so given the input, they may be viewed as random variables. In the current case, the expectation of the run time for fixed d is considered in part (c) of the theorem, and (a) and (b) describe what we know about the output. In particular, the algorithm always terminates, and if GRH is true, then it is guaranteed to compute an integer approximation to the regulator.

The theorem just stated represents the efforts of several people, an up-to-date list of references being given by Ulrich Vollmer [12]. According to a recent unpublished result of Ulrich Vollmer, one

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Figure 2. An example theorem as it would usually be done in LaTeX (from "Solving the Pell Equation", by H. W. Lenstra Jr., *Notices of the AMS* 49 (2002), 182–92).

fifteen years is no small accomplishment in the software industry.

"Old" LaTeX 2.09 versus "New" LaTeX 2e

LaTeX 2e is the name used when distinguishing the current version of LaTeX from its predecessor, LaTeX 2.09. At the time when the work for LaTeX 2e was being carried out (1994), there were also ambitious plans laid for a substantially new and improved version of LaTeX, to be known as LaTeX 3. Thus LaTeX 2e was intended chiefly to consolidate the existing state of LaTeX and unify some branches of development that had begun branching off in their own directions (including NFSS and AMS-LaTeX; see below). Even so, LaTeX 2e does include some significant improvements over LaTeX 2.09:

1. LaTeX 2e shields the author from various kinds of troublesome complications concerning fonts, especially mathematics fonts.
2. LaTeX 2e provides a powerful unified interface for putting various kinds of figures and diagrams into a document, a notorious source of difficulties for authors.
3. LaTeX 2e has a coherent "package" system that makes it fairly easy to write special-purpose packages that add new capabilities. Consequently, a great many extension packages for LaTeX 2e are available, and more are being added all the time.
4. LaTeX 2e gives authors access to certain modern packages that do not work at all with old LaTeX. One example is the `hyperref` package, which facilitates producing PDF files from LaTeX documents with active links for bibliography citations, equations, figures, theorems, and sections.

As for LaTeX 3, it has not yet been released, perhaps chiefly (in my opinion) because the ambitious scope of the project has not been matched by sufficient funding. One would have hoped to see it reach a level that could support at least one full-time programmer. Although a fair amount of progress has been made anyway, it is the product of dedicated volunteers doing LaTeX development in their spare time.

Is It Old LaTeX or LaTeX 2e?

Older LaTeX documents begin with `\documentstyle`, whereas LaTeX 2e documents begin with `\documentclass`. There are two other major differences: In old LaTeX, packages are invoked via the option list of the `\documentstyle` command, whereas in LaTeX 2e they are invoked through a separate command, `\usepackage`; and in old LaTeX, font changes have the form {`\bf...`}, whereas in LaTeX 2e they have the form `\textbf{...}` or `\mathbf{...}`. (The old forms of the font commands still work in LaTeX 2e, for the sake of compatibility, but in new documents it is advisable to avoid them.)

Here are some other commands (to name a few) that would indicate a document written specifically for LaTeX 2e, since they were not present in LaTeX 2.09:

```
\providecommand        \begin{lrbox}
\emph                  \frontmatter
\includegraphics       \backmatter
```

What Is AMS-LaTeX?

Is AMS-LaTeX a TeX format too? Well, yes and no. It used to be, but only for pragmatic reasons, not because it differed very much from LaTeX. And nowadays it makes little sense to ask "Should I use LaTeX or AMS-LaTeX?" because using AMS-LaTeX implies using LaTeX, just as using LaTeX implies using TeX.

Much of the development of AMS-TeX and LaTeX occurred in parallel in the early 1980s when TeX was in its infancy (see "Some Historical Notes" below). In many respects the features they offered were complementary rather than redundant. AMS-TeX took more pains than LaTeX to address certain finer points of mathematical typography: for example, getting good interline spacing in matrices or proper positioning of doubled math accents. On the other hand, the lack of automatic numbering and cross-referencing in AMS-TeX was a notable drawback. Nor did it have facilities comparable to LaTeX's for handling indexes, working with a separate database file for bibliographic data, splitting books up into chapters, or producing simple pictures. Growing recognition of this complementarity led to a rising demand in the late 1980s among mathematician-authors for a way to get the best features of both formats.

Obviously, combining AMS-TeX and LaTeX could have been done by adding LaTeX features to AMS-TeX or adding AMS-TeX features to LaTeX. Having settled after some debate on the latter option, the AMS sponsored the necessary development in 1989–90 that led to the `amsmath` and `amssymb` packages described in the *Short Math Guide for LaTeX* [3], which were distributed together with some AMS document styles, `amsbook` and `amsart`. This distribution was called collectively AMS-LaTeX.

There was one key problem in LaTeX 2.09 that had to be solved in the development of AMS-LaTeX. The handling of math fonts just was not good enough. Misfeatures such as printing bold subscripts at full size instead of subscript size were typical. And in LaTeX 2.09 most of the font setup was built into the format, making it difficult to correct the problems without changing the format itself.

Fortunately, a solution for this already existed, thanks to a couple of German programmers (Frank Mittelbach and Rainer Schöpf), in the form of a thoroughly overhauled and improved font handling scheme for LaTeX known as NFSS, for *New Font Selection Scheme*. In order to simplify installation, a copy of NFSS was included in the AMS-LaTeX distribution along with instructions on how to build a new LaTeX format with it. Depending on how it was installed, this format was called LaTeX+NFSS or AMS-LaTeX.

When LaTeX 2e came out, it incorporated the New Font Selection Scheme as standard into the LaTeX format. This meant that since 1994 it has no longer been necessary to build a separate format called AMS-LaTeX: one simply uses AMS packages with LaTeX in the same way as one uses packages from any other source. For reasons of history and convenience, the ones that originated in the old AMS-LaTeX distribution are sometimes still referred to collectively as AMS-LaTeX. Any decent TeX system that one gets nowadays will include copies of all the AMS-LaTeX files as a matter of course, along with many other extra LaTeX packages.

Further Progress in Conceptual Markup

In the years since LaTeX first appeared there has been a steady increase in awareness among publishers and authors of the importance of conceptual markup for capturing the essence of written material, especially when the material has great intrinsic complexity as, for example, in the scientific literature. Although LaTeX was a major step forward, in some areas the principles of conceptual markup were only sketchily applied, e.g., math formulas and bibliographies.

The claim that LaTeX does not sufficiently apply the principle of conceptual markup for bibliographies is in a sense unfair, because the usual method is to use BibTeX, which breaks down the components of a typical reference in a natural and well-designed way. The only problem is that, in practice, the conceptual markup present in the BibTeX database file is lost when entries are imported into a LaTeX file. As a consequence, the bibliography part of the LaTeX document ends up being less well structured than one would wish if it is to be used as the primary archival form of the document (and it probably should be if it is the form used by the author in the writing process).

This loss of internal structure was the primary impetus behind the development of a LaTeX package called `amsrefs`, released in January 2002 [15]. Using the `amsrefs` package makes it easy to retain the internal structure when importing bibliography entries into a LaTeX file.

Concerning math formulas, noteworthy recent developments outside of LaTeX include the MathML [13] and OpenMath [14] initiatives. An adequate discussion of these is beyond the scope of this article, but any readers who are somewhat acquainted with them already will recognize that converting LaTeX math formulas to *Presentation MathML* is far more feasible than converting them to *Content MathML* and that this is precisely because many elements in a LaTeX math formula are described in terms of visual appearance rather than meaning. If something is written in LaTeX as a superscript, human readers have little difficulty sorting out the actual meaning, but conversion software cannot readily tell whether the superscript means "exponent" or something else, and the distinction is essential when converting to Content MathML or OpenMath.

Some Historical Notes about TeX

On January 4, 1978, when Donald Knuth gave his Gibbs Lecture in Atlanta on "Mathematical Typography" (*Bull. Amer. Math. Soc. (N.S.)* **1** (1979), 337–72), the development of TeX was well under way, and a usable version of TeX was released into the wild—to people outside Stanford, that is—in September 1978. Over the next year or two of real-world use by himself and others, however, Knuth began to view that first version with increasing dissatisfaction and by 1980 felt compelled to rewrite it almost from scratch. Among other things, he wanted to change the programming language from SAIL to PASCAL, since the limited availability of SAIL on other computer systems hindered many people from using TeX. In the rewriting process he added many features needed for professional-quality typesetting and made some significant syntactic changes in the TeX macro language, particularly with respect to conditionals and fonts.

Although Knuth denominated the new version TeX82 to distinguish it from its precursor (TeX78), the change log shows that a number of significant primitives were still being added in late 1982 and early 1983—some of them in response to feedback from Leslie Lamport, who was hard at work on LaTeX at that time:

12/02/82: `\everymath`, `\everydisplay` added
12/02/82: `\futurelet` added
12/07/82: `\endinput` added
12/25/82: `\jobname primitive`
12/27/82: `\pagetotal`, `\pagegoal` added
01/06/83: `\pageshrink` etc. added
01/06/83: `\floatingpenalty` etc. added

Several almost-final versions, 0.99, 0.999, ..., of TeX were released in 1983 to permit others to try them out and report bugs, but it was not until December 3, 1983, that version 1.0 was released. This date probably has a better claim than any other to be considered the true birthday of TeX as we know it; it is no coincidence that usage of TeX really took off after that, with new formats blooming into life everywhere like desert flowers after a rainstorm.

The version numbers of TeX increased to 2.x and eventually 3.x as time went by. The release of version 3.0 in March 1990 established the set of primitives (built-in TeX commands) and behavior that constitute what I would call "standard TeX" and that is described in current editions of *The TeXbook* [16]. Although there has been some further development since then by people other than Knuth, it has been done under different names (e-TeX, Omega, pdfTeX, and so forth) and is not covered by *The TeXbook*.

In retrospect it seems fitting to consider TeX78 as an alpha version of the software, giving us this chronology:

- TeX78 = alpha version
- TeX82 preliminary releases (1982–3) = beta version
- TeX 1.0 = first version of TeX as we know it: December 3, 1983
- TeX 2.0 = November 27, 1985[2]
- TeX 3.0 = the last major version of TeX: March 25, 1990
- TeX 3.14159... = **the** final version of TeX

Knuth has chosen to increment the minor version number after 3.0 by using the digits of π, adding a digit whenever a new bug fix is done (a rare event nowadays), with the idea that after his death TeX itself will be permanently frozen and the version number will change from an approximation of π to π itself. The approximation currently stands at 3.14159.

e-TeX, pdfTeX, and Omega

Three descendants of TeX seem worth singling out for special mention. Among other things, many readers may find that they already have working copies of all three included in their current TeX system.

e-TeX. Practically speaking, this version of TeX is quite close to the original, since many of its enhancements address technical limitations and are noticeable mainly to programmers. But two of the more visible additions are (1) support for right-to-left typesetting, as needed for languages like Arabic, and (2) a `\middle` command to go along with `\left` and `\right`.

Omega. The chief distinction of Omega is its ambitious goal of doing professional-quality typesetting in all the world's languages: Arabic, Chinese, Greek, Japanese, Sanskrit, Tibetan, etc. The set of languages that one can practically handle with Omega falls short of being all-inclusive, of course, but the remarkable thing is how many languages are supported already.

[2] *Conjectural; the historical record for this release seems to be unclear. The 11/27/85 date is the date of the last change recorded in* `tex82.bug` *after the release of version 1.5 and prior to other changes designated as belonging to version 2.1. An announcement by David Fuchs in the March 1986 issue of* TUGboat *stated that "TeX1.5, when used with the new CM fonts, is officially called TeX2.0." Should this be interpreted, perhaps, to mean that the release date of 2.0 is the same as for 1.5?*

pdfTEX. As its name suggests, pdfTEX is much like TEX but directly produces its output in PDF form (Portable Document Format) rather than DVI. Many people are using it nowadays because it enables authors to readily achieve a number of useful PDF effects while continuing to write LaTEX files in their accustomed way.

Since e-TEX, pdfTEX, and Omega are variants of TEX, they too work with formats in the same way as TEX. This increases the potential format names in combinatorial fashion: in theory for e-TEX we could have Plain e-TEX, e-AMS-TEX, e-LaTEX, e-ConTEXt, and similarly for the others. In practice we have `etex` (= Plain e-TEX) and `elatex`, `pdftex` and `pdflatex`, `omega` and `lambda` (= `omegalatex`), and `gamma` (= `omegacontext`). Because the enhancements in e-TEX and pdfTEX do not interfere with each other, they can be, and have been, combined, giving us also `pdfetex` and `pdfelatex`.

Some other alternatives on the horizon—e.g., ConTEXt, Publicon™, or XML/Docbook+MathML—are already sufficiently usable to make them interesting avenues of experimentation for more intrepid authors, but it seems premature to recommend them for everyone. Some links for these and other software are given on the webpage *Authoring Software for Mathematicians* (`http://www.ams.org/tools/authoring-software.html`).

Further Information

For someone starting out with LaTEX, if mathematics is an important part of the material to be written, here is the minimal set of documentation that I would recommend:

[1] *LaTEX: A Document Preparation System,* 2nd edition, Leslie Lamport, Addison-Wesley, 1994. This is the authoritative primary reference for LaTEX. *Note: It is important to follow the 2nd edition (1994) rather than the 1st edition (1985), because the 1st edition is for LaTEX2.09, while the 2nd edition describes LaTEX 2e.*

[2] *LaTEX Guides.* These are partly intended to describe the differences between LaTEX 2.09 and LaTEX 2e, but they also serve as a good overview for some areas that had only sketchy coverage in the first edition of the LaTEX book: industrial-strength font setup, incorporating graphics, writing a new package.

- LaTEX 2e *for authors,* `http://www.latex-project.org/guides/usrguide/usrguide.html`
- LaTEX 2e *graphics guide,* `http://www.ctan.org/tex-archive/macros/latex/required/graphics/grfguide.ps`
- LaTEX 2e *font selection,* `http://www.latex-project.org/guides/fntguide/fntguide.html`
- LaTEX 2e *for class and package writers,* `http://www.latex-project.org/guides/clsguide/clsguide.html`

These guides are free, and if you have a decent LaTEX system, you should find that they are already present on your computer in DVI, PostScript, or PDF form: look for, e.g., `.../texmf/doc/latex/base/usrguide.pdf`, `.dvi`, or `.ps`.

[3] *Short Math Guide for LaTEX,* `http://www.ams.org/tex/short-math-guide.html` (about 20 pages). Another free resource. It offers a concise overview of the features in LaTEX and the `amsmath` package that authors are likely to need when writing math formulas. It includes a list of the math symbols that are normally available in any standard installation of LaTEX. For questions about how to get other fonts and math symbols beyond those described therein, see the *Comprehensive LaTEX Symbol List* (below), which lives up to its name.

Other Useful Resources

[4] *Comprehensive LaTEX Symbol List,* S. Pakin. This is a rather large document to download, because it uses so many different math fonts! You will almost certainly want to get the PDF or PostScript version. `http://www.ctan.org/tex-archive/info/symbols/comprehensive/`

[5] *Math into LaTEX,* G. Grätzer, Birkhäuser, 2000. A book-length treatment of AMS-LaTEX. It contains, among other things, some useful information about practical aspects of using LaTEX that are not often addressed in other LaTEX documentation.

[6] *Using Imported Graphics in LaTEX 2e,* K. Reckdahl. `http://www.ctan.org/tex-archive/info/epslatex.pdf`

[7] *AMS-LaTEX* (webpage with various links), `http://www.ams.org/tex/amslatex.html`; see also `http://www.ams.org/tex/author-info.html`.

[8] *References for TEX and Friends,* P. Karp and M. Wiedmann. Among other things, includes individual documentation for each LATEX command. `http://www.miwie.org/tex-refs/`

[9] *The Not So Short Introduction to LATEX 2e,* T. Oetiker et al. This covers ground similar to the Lamport book in about 100 pages. It was originally written in German but has translations available in other languages. `http://www.ctan.org/tex-archive/info/lshort/english/`

[10] *A Guide to LATEX,* H. Kopka and P. Daly, Addison Wesley, 1999. This is a lengthier treatment of LATEX (about 600 pages), with many good examples and more depth of detail than the Lamport book. New or casual users might find it overkill.

[11] *TEX Resources,* `http://www.ams.org/tex/`; see also *What Is LATEX?,* `http://www.ams.org/tools/what-is-latex.html`.

[12] *TEX Live CD,* `http://www.tug.org/texlive.html`; see also the *TEX Users Group* home page, `http://www.tug.org/welcome.html`

[13] *MathML,* `http://www.w3.org/Math`

[14] *OpenMath,* `http://www.nag.co.uk/projects/openmath/omsoc/society/description.html`

[15] *The amsrefs package,* `http://www.ams.org/tex/amsrefs.html`

[16] *The TEXbook,* D. E. Knuth, Addison Wesley, 1984. Describes TEX and the Plain TEX format.

There is a series of *Companion* books that are also worth looking at: *The LATEX Companion, The LATEX Graphics Companion, The LATEX Web Companion.*

Beware of Obsolete Documentation!

In the case of *The LATEX Companion,* it should be noted that Chapter 8, on mathematics, in the first edition (1994) became obsolete in some crucial details soon after publication, thanks to some unfortunate timing problems. Pending the appearance of the second edition, one could make do by using the first edition in conjunction with something more up-to-date for math-related questions, such as the *Short Math Guide* mentioned above.

But this is only one instance of a more general pitfall that LATEX users should be careful to watch out for. There is a lot of helpful information freely available out there on the World Wide Web, but if one downloads something called, for example, "Essential Mathematical LATEX" that bears a date of September 1989, it seems obvious that in the year 2002 whatever good and useful advice it may contain remains good and useful *only for those who are still using the version of LATEX that was extant in 1989* and that advice that was originally good may now be downright bad for the unsuspecting reader if it concerns features which have changed in the meantime.

A variation of this pitfall is to go astray indirectly by following the example of a colleague. Your colleague's example might have been exemplary indeed when she first started writing that book of hers seven years ago using LATEX 2.09, but if you are just now beginning to write a book of your own, it behooves you to reflect for your own sake on the passing of time to see whether any labor-saving devices have been invented in the meantime that you can take advantage of. For example, using the LATEX 2e font commands instead of their 2.09 predecessors would save you the bother of fussing with "italic corrections".

Book Review

Does God Play Dice: The New Mathematics of Chaos and *What Shape Is a Snowflake? Magical Numbers in Nature*

Reviewed by Philip Holmes

Does God Play Dice: The New Mathematics of Chaos
Ian Stewart
Second Edition
Blackwell Publishers Inc., Malden, MA, 2002
$21.95, xii+ 401 pages, softcover
ISBN 0-631-23251-6

What Shape Is a Snowflake? Magical Numbers in Nature
Ian Stewart
W. H. Freeman and Co., New York, 2002
$29.95, 224 pages, hardcover
ISBN 0-7167-4794-4

Ian Stewart is certainly the most prolific, and probably the most successful, among the current popularizers of mathematics. ("Further Reading" in the second of the books reviewed here lists no fewer than seven of his other books on topics ranging from bifurcation and catastrophe to philosophy, including the first reviewed here.) He is also a serious research mathematician, working in dynamical systems with an emphasis on systems with symmetries; indeed, he was recently elected a Fellow of the Royal Society, and in 1995 he won the Society's Faraday Medal for his contributions to the public understanding of science. He is thus unusually and ideally placed to reveal to the vast world that has never heard of the AMS or its *Notices* what readers of this journal spend their working hours doing. How well does he succeed in the pair of books under review? I have to say, "Pretty well." I qualify this at length below, but of course I, along with most of you, do not belong to his primary target audience, so my opinions may be irrelevant. Nonetheless, the ways in which mathematics does or does not get beyond the pages of technical and learned journals should be of some interest to all of us.

First, some remarks on style. In his popular writings Stewart favors a punchy (perhaps sometimes punch-drunk) mode. Reading the second edition of his 1989 (mathematical) bestseller *Does God Play Dice*, which appeared in the U.K. in 1997 but was published in the U.S. only this year, I noted closing paragraphs as short as: "And was horrified by it" (Poincaré, on discovering chaos), "So, 'nonlinear' it is", and simply "We don't" (on human ignorance of quantum states). Sentences may begin with conjunctions or may be missing a subject or verb; an early pair of paragraphs reads:

"Simple. Elegant. Elusive.

Order from chaos."

Epigraphs drawn from literature suggest the author's wide reading but often have little to do with the chapter's contents beyond echoing a key word. From time to time I chuckled or winced at puns such as "the goat in the machine" (*Dice*, p. 370), and I wonder if we need the "bug-eyed monster…Worzel of Velantia" to flap its "scaly reptilian wings" in a neighboring galaxy to illustrate infinitesimal

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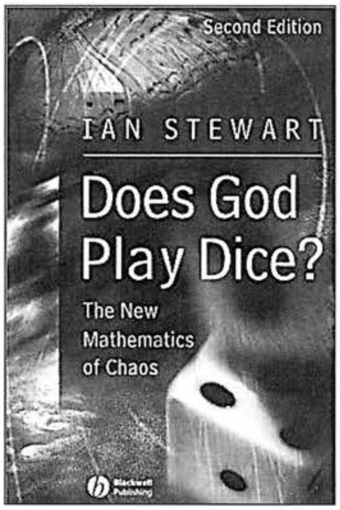
perturbations (p. 52), or "Mummy Bear" to complain that "someone's been iterating [her] Poincaré map" (p. 106). On the other hand, some of the one-liners really do hit the mark: "On any exponential curve, yesterday is invisible and tomorrow is explosive" (p. 131).

So, I don't always warm to the style.
But I had to get this out of the way.
For these *are* pretty good books.
At least, the first is.

Does God Know the Initial Conditions?

The second edition of *Does God Play Dice* adds three new chapters (14–16), on prediction and control of chaos, and quantum mechanics and chaos. There are a few updates elsewhere, but the rest of the book remains, according to the preface, "virtually untouched." (Alas, the poor quality of some figures is also untouched, a constraint evidently imposed by the publishers.) For those who missed the first edition of this account of the mathematics and applications of dynamical systems theory, I shall outline the contents as I comment on them.



Chapter 1 opens with the Newtonian universe and Laplace's remark from his *Philosophical Essays on Probabilities* that for an intellect knowing the equations of motion and initial conditions of "Nature...nothing would be uncertain; and the future...be present before its eyes" (I paraphrase). Stewart then exhorts the reader to iterate the quadratic function $x \mapsto kx^2 - 1$ on a calculator (I am among the laptopless few who still carry them) and thereby convince himself that, for certain values of k, the future is not quite so clear. This quickly gets one involved.

Two historical chapters exploring deterministic and probabilistic equations and laws follow, leading to "The Last Universalist". Here there is a fairly good account of Henri Poincaré's work on the planar, restricted, circular, three-body problem (*not*, as Stewart states, Hill's problem, which further simplifies the system by moving one of the primaries to infinity) and of Poincaré's entry [8] to the prize competition sponsored by King Oscar II of Sweden and Norway. This work essentially founded the modern theory of dynamical systems and led in turn to the rich and disorganized riot of nonlinear dynamics and chaos theory that is Stewart's subject. The historical study by June Barrow-Green [2], which he mentions but does not cite, gives considerably greater detail for those interested.

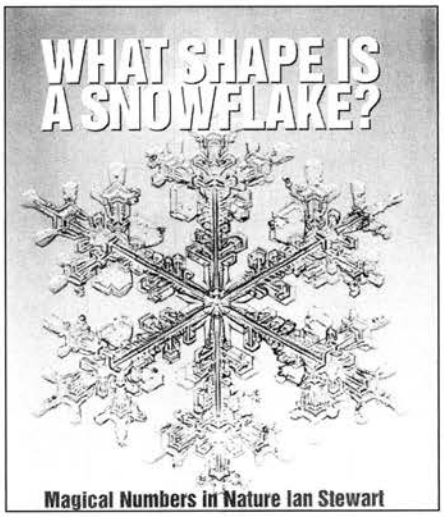
In Chapters 5 and 6 the book begins to engage its subject more substantially, with a rather good discussion of the dynamics of a simple pendulum from a phase-space and energy-conservation perspective, moving on to general phase spaces, invariant sets, and strange attractors, using a mod 10 version of the solenoid mapping to illustrate chaos and sensitive dependence on initial conditions. This avoids introducing mod 2 arithmetic, as in the usual discussions of symbolic dynamics and coding for quadratic-like maps. The mathematical foundations thus sketched, Stewart discusses weather forecasting and Edward Lorenz's now-famous 1963 paper [4], although he does not cite Lorenz's own delightful book [5] (developed from lectures given at the University of Washington in the early 1990s), which, while it does not have the range of the one under review, in some respects does a better job and in any case retells the story of Lorenz's discoveries from his own viewpoint.

Chapter 8 returns to sketching more of the basic ingredients of chaotic dynamics: stretching and folding in phase space, Stephen Smale's horseshoe map and historical developments that motivated it, the work of physicists such as Hénon and Chirikov, and the logistic map (reprise). Chapter 9 considers turbulent fluids and notes the Ruelle-Takens paper [9], another landmark, and the key experiments of Swinney and Gollub revealing that these abstract ideas really are relevant in practice. Feigenbaum's discovery of universal scaling in cascades of period-doubling bifurcations and his proposal that renormalization methods account for it appear in Chapter 10. At this point "Feigenvalues" are inevitable, as will be "Mandelbrots" in the discussion of complex-analytic dynamics and fractals in Chapter 11, appropriately titled "The Texture of Reality". Here as throughout the book science (mostly physics) and mathematics are nicely interwoven, although the lack of precision makes the discussions of fractal structures in phase space (attractors) and in the physical space of mixing fluids somewhat confusing.

Stewart returns to astronomy (the chaotic rotation of Hyperion, a Saturnian satellite) and Hamiltonian mechanics in Chapter 12 and moves on to biology in Chapter 13, with sketches of dynamical population and disease models and of the entrainment of oscillators with reference to cardiac dynamics. Apart from the final chapter (portentously titled "Farewell, Deep Thought"), this is where the first edition ended.

The first of the three additional chapters concerns prediction in chaotic systems. After again making the important distinction between the real world and (mathematical) *models* of (parts of) it, Stewart returns to sensitive dependence and Liapunov exponents and shows that short-term prediction is possible. He mounts a spirited defense of academic life and pure research and ends with a lengthy description of an industrial project on which he and his colleagues at the University of Warwick consulted for a U.K. manufacturer of coil springs, prompting the building of a prototype "coilability" testing machine that uses phase-space reconstruction methods to improve predictability.

In the second he describes the control of chaos work due to Ott, Grebogi, Yorke, et al. This has already received a fair bit of notice in the scientific press, although, contrary to some impressions, nonlinear control theory was a flourishing subject before their work appeared (albeit largely confined to electrical engineering departments). Again, applications—to steering space missions and to cardiac pace-makers—are included.



Stewart admits that his third new chapter, on quantum mechanics, is "much more speculative," and indeed it is. Here he enlarges on five pages from the final chapter of the first edition, sketching familiar puzzles associated with interpreting the physical meaning of QM (Bell's inequality and the Einstein-Podolsky-Rosen paradox) and arguing that sensitive dependence of underlying *deterministic* processes, as exemplified in throwing a die, might lie behind quantum indeterminacy. The discussion remains pretty vague, and Stewart does not convince me that dynamical systems theory will elucidate quantum mechanics much more than Roger Penrose manages to illuminate the role of quantum mechanics in consciousness [7].

The closing chapter has been expanded to include sections on scientific theories and why the reductionist viewpoint beloved of fundamental-laws-style physicists is not necessarily appropriate to understanding complex systems. In an annoying but provocative figure, between the long-sought "theory of everything" and "nature", Stewart interposes Chris Langton's cellular automaton "ant country" with its emergent behavior and uses this to plead for a series of "levels of description." Unfortunately he does not cite what is still one of the finest comments on the failings of reductionism: Philip Anderson's wonderful 1972 article in *Science* [1].

The editing is occasionally careless. For example, on page 350 the conjectured existence of "technically 'nice' invariant measures" is mentioned in passing, as if the reader were expected to take this in stride, but four pages later we are cautioned "for theoretical understanding [to] appeal to things known as 'invariant measures', which are very similar to probabilities." I noted numerous minor and a few more serious misleading or incorrect statements, including persistent errors from the first edition. On page 186 the spacing of successive period-doubling bifurcations is said to *increase* by a factor of about four, when *decrease* is intended. On page 291 an italicized *not* inverts the intended sense (that one is trying to shoot down the suggestion that chaos *does* fit the data). In Chapter 5, discussing a nice example of a mechanical system with a higher-dimensional phase space, the bicycle, Stewart notes that the five main moving parts require five position and five velocity variables to characterize the dynamical state. An engineer calls this five degrees of freedom, not ten. He gets the terminology wrong in the text on page 81 but right in the picture on page 82. A trivial point perhaps, but then he appeals to the bicycle again in discussing Liouville's $2n$-volume conservation theorem for (canonical) Hamiltonian systems. The problem here is that this lovely result does *not* apply to steerable wheeled vehicles such as bicycles, which are *non-holonomically* constrained, are not canonical, and can exhibit asymptotic stability with respect to some variables, corresponding to phase-space contraction, even while energy is conserved [6]. In a popular book it is fine to omit obsessive technical detail, but in this case imprecision misleads.

Such complaints aside, this is a lively and broad introduction to a fascinating field of research in which mathematicians and scientists of all kinds are once more interacting in a manner almost worthy of the eighteenth and nineteenth centuries. Stewart ties his story together well with examples and leitmotivs spanning the chapters. And, as I've noted, he interweaves mathematics and science, theory and experiment, ideas and human actors in a manner appropriate to the subject and provides much of the solid science missing from James Gleick's entertaining account [3]. He may sometimes frustrate, but he almost always informs and provokes.

Does God Play Dice is aimed at nonmathematicians and nonscientists, and, as I've argued, it does a good job of conveying the main ideas and excitement of a relatively new field to a general audience. It can also be read with profit by mathematicians and even by specialists in dynamical systems. *What Shape Is a Snowflake* is much more of a coffee table book, with attractive photographs of things natural and manmade on almost every page. It is basically a rumination on patterns and symmetries in nature and as such covers some of the same ground as Marty Golubitsky's books with Stewart and Mike Field [11].

Snowflake contains sixteen short chapters organized into three parts: Principles and Patterns, The Mathematical World, and Simplicity and Complexity. The investigation starts and ends with snowflakes but visits a vast range of patterns and environments in between, including "Order in Chaos", a twenty-page précis of *Does God Play Dice*. Each chapter is in turn divided into 1–3 page segments, with text and extensively captioned color and line illustrations intermingled in a busy fashion. The result is that the story proceeds on two levels: in the main text and in the pictures and captions (like a *Scientific American* article). One could therefore skim by just looking at the pictures and reading their captions and pick up the main ideas without ever dipping into the text. The text, in fact, adds less than one might hope, for the treatment is rather superficial.

Mathematical ideas and applications are again interwoven, but the short sections mean that each little nugget is rapidly followed by another. One-, two-, and three-dimensional patterns; crystal lattices; spots and stripes on animal coats; waves in sea, sand, and cloud; scales in animal size and music; seashell patterns; spirals of sunflower seeds, chemical reactions, and hurricanes; space-time footfall patterns of animal gaits (a topic that Stewart, Golubitsky, and Jim Collins have studied in detail); fractals, image compression, and seashells (again); chaos and cosmology follow in dizzying succession. A rich and wonderful series of snapshots is presented in an engaging manner, and we are told over and over that the patterns "are a consequence of simple mathematical rules" (caption, p. 125). Names are dropped (Turing's reaction-diffusion systems, p. 164), but things move so fast that specific "rules" are rarely vouchsafed. The discussions of symmetry breaking on pages 152–5, of fractals on pages 158–63, of intrinsic geometry and the universe in Chapter 15, and the closing explanation of snowflake forms of Chapter 16 are notable exceptions, but the blur of images tends to obscure the main message: that fundamental mathematical principles (the symmetries of Euclidean space, for example) determine a catalog of what we *expect* to see, while physical laws and the mathematical models encoding them determine what we actually *do* see. Stewart stresses that mathematics helps us idealize and hence better understand the world, but this could have been a deeper and stronger book had he applied his considerable talents to explaining some elements of his own professional interests—normal form theory and bifurcation with symmetry—thereby revealing more of the "underlying mathematics."

Not only does the mathematics remain largely implicit, but many of the images that appear in the illustrations are incompletely identified, although some are acknowledged. For example, Constable's painting *The White Horse* (now in the Frick Collection, New York), which is reproduced unnamed on page 101 in connection with a discussion on mathematics and beauty, is mysteriously credited to "Geoffrey Clements". Specificity is thereby lost, and it begins to seem as if the book was partly composed by graphic artists in the publishing house.[1] In the discussion of Penrose tilings and quasicrystals in Chapter 7, for instance, the former are nicely illustrated, but inclusion of electron micrographs (or their Fourier transforms) of quasicrystals would have demonstrated the link more strongly. In summary, the book *looks* very attractive, but with properly integrated illustrations and a more modest range of phenomena treated at greater length, the story could have been made tighter and clearer.

So, while it would make a nice gift for a nonscientist friend or relative who will enjoy the pictures and wonder at the range of phenomena touched on, this book is at best an appetizer. Others, including *Does God Play Dice* and [11], will be needed to appreciate the work of mathematicians and scientists in understanding those phenomena.

In closing, I must confess that I'm not an entirely unbiased reviewer, since Florin Diacu and I have also taken aim at that elusive quarry, the intelligent layperson. Moreover, Ian Stewart reviewed our book [10], praising the story but faulting our "attempt to explain the mathematics at an advanced technical level." (I tend to agree that we probably *did* tilt too far in that direction.) In these books Stewart avoids the details and moves from subtopic to subtopic in an attractive way. One can safely put down either of them without losing the thread. We took a more pedestrian approach. Boooring? Maybe.

Ian isn't.

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[1] *Ian Stewart confirms that this is the case: the images and layout were handled by Ivy Press, a "packager" that set the book for the publishers. Copyright laws and licensing agreements evidently determined how pictures were acknowledged. Realities of trade publishing!*

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[6] J. I. Neimark and N. A. Fufaev, *Dynamics of Nonholonomic Systems*, Transl. Math. Monogr., vol. 33, Amer. Math. Soc., Providence, RI, 1972.

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[9] D. Ruelle and F. Takens, On the nature of turbulence, *Comm. Math. Phys.* **20** (1971), 167–72; **23** (1971), 343–4.

[10] I. Stewart, Looking back in chaos, a review of *Celestial Encounters: The Origins of Chaos and Stability*, by F. Diacu and P. Holmes, *New Scientist* (1997), 42–3.

[11] I. Stewart and M. Golubitsky, *Fearful Symmetry: Is God a Geometer?* Basil Blackwell, Oxford, U.K., 1992; M. Field and M. Golubitsky, *Symmetry in Chaos: A Search for Pattern in Mathematics, Art and Nature*, Oxford Univ. Press, Oxford, U.K., 1992.

Mathematics People

Prizes of the CRM, Montreal

Several prizes have been awarded to mathematicians by the Centre de Recherches Mathématiques (CRM), Montreal, Canada. They are listed below.

PAVEL WINTERNITZ of the University of Montreal was awarded the 2002 CAP-CRM Prize in Theoretical and Mathematical Physics jointly by the CRM and the Canadian Association of Physicists (CAP) for his work on symmetry methods in physics. The CAP-CRM Prize, instituted in 1995, is intended to recognize exceptional achievements in research in the fields of theoretical and mathematical physics. The prize is given for research done primarily in Canada or in affiliation with a Canadian university or industry. It carries a cash award of $2,000 and a commemorative medal. Awardees are invited to lecture at the annual congress of the CAP.

JOHN B. FRIEDLANDER of the University of Toronto was awarded the 2002 CRM/Fields Institute Prize by The Fields Institute for Research in Mathematical Sciences (Toronto) and the CRM. The prize recognizes exceptional achievement in the mathematical sciences. Recipients are chosen on the basis of outstanding contributions to the advancement of research, with research having been done primarily in Canada or in affiliation with a Canadian university. A prize of $5,000 is awarded, and the recipients present lectures at the CRM and at The Fields Institute.

JINYI CHEN of the University of British Columbia has been awarded the 2001 André Aisenstadt Mathematics Prize. The prize, instituted in 1991, consists of an award of $3,000 and is intended to recognize talented young Canadian researchers in pure and applied mathematics who have held the Ph.D. for no more than seven years.

—From a CRM announcement

Lieb Receives Honor from Austria

On July 29, 2002, ELLIOTT H. LIEB of Princeton University received the prestigious order Österreichisches Ehrenzeichen für Wissenschaft und Kunst (Austrian Honor for Science and Art) in a ceremony held at the Austrian Federal Ministry for Education, Science, and Culture. The order was awarded to Lieb by the president of the Republic of Austria, Thomas Klestil.

In honor of Lieb on the occasion of his seventieth birthday, a symposium on mathematical physics, Stability Matters, was held at the International Erwin Schrödinger Institute for Mathematical Physics from July 28 to August 2, 2002, in Vienna, Austria.

—Austrian Federal Ministry for Education, Science, and Culture

Ando Awarded Hans Schneider Prize

TSUYOSHI ANDO of Hokusei Gakuen University, Japan, has been awarded the 2002 Hans Schneider Prize of the International Linear Algebra Society (ILAS). Ando is an editor of the *Journal of Inequalities in Pure and Applied Mathematics*. His major research interests are operator theory and matrix theory. The prize was awarded at the ILAS meeting in June 2002.

—From an ILAS announcement

Wu Receives Radcliffe Institute for Advanced Study Fellowship

SIJUE WU of the University of Maryland, College Park, has been awarded a Radcliffe Institute fellowship for the academic year 2002–2003. Wu is a past winner of the Satter Prize of the AMS. Her research interests include harmonic analysis and partial differential equations, in particular nonlinear equations from fluid mechanics. Her recent work concerns the full nonlinear water wave problem and the motion of general two-fluid flows. The Radcliffe Institute for Advanced Study at Harvard University awards more than fifty funded postdoctoral fellowships each year to scholars, professionals, writers, and artists from throughout the world.

—From a Radcliffe announcement

National Defense Science and Engineering Graduate Fellowships Awarded

Eighteen young mathematicians have been awarded National Defense Science and Engineering Graduate (NDSEG) Fellowships by the Department of Defense (DoD). As a means of increasing the number of U.S. citizens trained in disciplines of military importance in science and engineering, DoD awards fellowships to individuals who have demonstrated ability and special aptitude for advanced training in science and engineering. The fellowships are sponsored by the United States Army, Navy, and Air Force.

Following are the names of the fellows in mathematics, followed by the students' institutions and the offices that awarded the fellowships.

Jomy Alappattu, Northwestern University, Office of Naval Research (ONR); James Brink, Indiana University, Air Force Office of Scientific Research (AFOSR); Kevin Chu, Stanford University, AFOSR; Michael Geline, University of Illinois, AFOSR; Teena Gerhardt, Stanford University, Army Research Office (ARO); Geir Helleloid, University of Wisconsin, Madison, ARO; Erez Lieberman, Princeton University, ARO; Philip Matchett, Harvard University, AFOSR; Christopher Mihelich, Harvard University, AFOSR; Jerome O'Neal, Georgia Institute of Technology, ARO; Alexander Pekker, Stanford University, ONR; Daniel Ramras, Cornell University, ONR; Camillia Smith, Michigan State University, ARO; Saverio Spagnolie, University of Colorado, AFOSR; Seth Tribble, Rice University, ARO; Lauren Williams, Massachusetts Institute of Technology, AFOSR; Paul Wright, University of California, Berkeley, ONR; and Boris Zbarsky, Massachusetts Institute of Technology, ONR.

—From an NDSEG announcement

Trjitzinsky Memorial Awards Presented

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

For the 2002 awards the AMS chose eight geographically distributed schools to receive one-time awards of $4,000 each. The mathematics departments at those schools then chose students to receive the funds to assist them in pursuing careers in mathematics. The schools are selected in a random drawing from the pool of AMS institutional members.

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

Following are the names of the selected schools for 2002, the names of the students receiving Trjitzinsky awards, and brief biographical sketches of the students.

Stephen F. Austin State University: Marcus A. Arreguin. Arreguin is a resident of rural East Texas and majors in mathematics and geography. He has maintained an A average at the university. He is a member of the Honors School and has completed several courses with additional projects or papers for honors credit. Arreguin has also published several original poems and musical arrangements and is a member of community and church choirs. He is looking forward to a career using his interests in mathematics, geography, and computer science.

Bates College: Challis Kinnucan. Kinnucan was born in Albuquerque, New Mexico, and grew up in London, Ontario, Canada. She is "one of the best mathematics students in recent years at Bates," said Peter Wong, chair of the mathematics department. Kinnucan spent a semester studying in Budapest, where she took a graduate-level course in abstract algebra. She participated in a Research Experience for Undergraduates program in 2001 and reported her research findings at the Joint Mathematics Meetings in San Diego in 2002. Kinnucan loves to travel and learn about different cultures. She enjoys charcoal drawing and working with children.

Brigham Young University: Julie Brinton. Brinton was raised in Wenatchee, Washington, as one of seven children. She was the valedictorian of her high school class. She competed in the Washington State mathematics olympiad as a fifth-grader and decided to pursue mathematics after that experience.

The College of William and Mary: Suzanne L. Robertson. Robertson grew up in Mt. Sinai, New York, and was the valedictorian of her high school class. At William and Mary she has been a volunteer tutor at an elementary school, conducted research on nonlinear population dynamics, and attended the National Youth Science Camp. She has also maintained a grade point average of 3.9, which "ranks her as one of the top rising seniors at The College of William and Mary," according to the departmental committee, which "wholeheartedly" nominated Robertson for the Trjitzinsky scholarship.

Furman University: Kevin L. Smith. Smith was born and raised in Lexington, South Carolina, and graduated from high school with the highest average in mathematics and science in his graduating class. As a freshman at Furman he plans a double major in mathematics and computer science. "As a first-year student, he has been one of the highest achieving students in classes usually taken by sophomore mathematics majors," said Douglas F. Rall of the Department of Mathematics. "Kevin is an ideal student to receive this award." Smith plans to go to graduate school in computer science.

University of Hartford: AIMEE J. GROUDAS. Groudas grew up in Chatham, New York. She was a member of the National Honor Society and competed on the varsity track and field team. She has a 4.0 grade point average at Hartford and hopes to pursue a career using her mathematical skills, possibly in business. Joel Kagan of the Departments of Mathematics, Physics, and Computer Science at Hartford said, "She is a wonderful student and received unanimous support from the faculty in recommending her for the Trjitzinsky Scholarship."

University of Southern California (USC): PETER KIRKPATRICK. Kirkpatrick grew up in the state of Washington. He received the highest scores in his high school on the American High School Mathematics Exam in his freshman, sophomore, and senior years and graduated as salutatorian of his class. "I've come to realize that education and the experience that goes with it are gifts," he said. At USC he works in the Joint Educational Project, helping to design a curriculum in which USC physics students will team-teach science at local middle and high schools. He maintains a 3.8 grade point average and was recently inducted into Phi Beta Kappa. He is also interested in music.

University of Texas at Dallas (UTD): KEVIN R. POND. Pond received the Mathematics Award from his high school in Boyd, Texas. He began to tutor mathematics in college, and this work led him to become an undergraduate assistant in the UTD calculus program. His mathematical interests are in number theory and logic. He is also interested in languages, classical music, and computer science.

For further information about the Trjitzinsky Memorial Fund, contact the AMS Development Office, 201 Charles Street, Providence, RI 02904-2294; email: `development@ams.org`; telephone: 401-455-4111.

—*Elaine Kehoe*

AMS Award for Outstanding Student Paper Presentations

Each year the AMS sponsors the AMS Award for Outstanding Pi Mu Epsilon Student Paper Presentation. The awards, first presented in 1989, are made by Pi Mu Epsilon (PME), the U.S. honorary mathematics society, to recognize the best undergraduate student papers presented at a PME student paper session. Each awardee receives a prize of $150. Seven students received awards for presentations at the Student Conference held in Burlington, Vermont, July 31–August 2, 2002. The conference was jointly sponsored by PME and the Mathematical Association of America. The names of the students, together with their institutions and the titles of their talks, are listed below.

ELIZABETH DONOVAN, Worcester Polytechnic Institute, "Maximum chromatic status of a graph"; ED KENNEY, University of Richmond, "Search for constructions of partial difference sets; BORISLAV MEZHERICHER, Queen's College, "Graphs that count: Generalized Catalan number"; F. RONALD OGBORNE, State University of New York at Fredonia, "Reciprocity gap and general linear 'crack' identification"; TERESA SELEE, Youngstown State University, "The assumptions and strategies of repeated games"; ROBERT SHUTTLEWORTH, Youngstown State University, "Numerical solutions of PDEs"; and BRIAN WYMAN, University of Richmond, "Game strategy development".

—*Allyn Jackson*

Royal Society of Canada Elections

The Royal Society of Canada has elected fifty-eight new fellows. Among these are three who work in the mathematical sciences. They are NIKY KAMRAN of McGill University, NEAL MADRAS of York University, and VIDYADHAR GODAMBE of the University of Waterloo. The new fellows will be inducted in a ceremony on November 22, 2002.

—*From a Royal Society of Canada announcement*

Mathematics Opportunities

CARGO Program

The National Science Foundation (NSF) and the Defense Advanced Research Projects Agency (DARPA) sponsor a program called Computational and Algorithmic Representations of Geometric Objects (CARGO).

CARGO supports research and development teams focusing on mathematical and computational innovations relevant to representation and computational manipulation of geometrical objects. The awards are administered by the NSF. Areas of specific interest include: computational topology and geometry, computational and geometric cartography (including spatial statistics), and geometric aspects of graphics and computer-aided design. Particularly encouraged are proposals for efforts involving collaborations of experts in the mathematical and computational sciences with other scientists, engineers, and practitioners representing diverse application areas. Proposals for incremental improvements of ongoing efforts will not be selected for funding. What is sought are proposals that offer new approaches and promising significant breakthroughs.

A program announcement for the 2003 competition is available at `http://www.nsf.gov/pubsys/ods/getpub.cfm?nsf02155`. The deadline is **December 3, 2002**.

—From an NSF announcement

NRC Research Associateship Programs

The Policy and Global Affairs Division of the National Research Council (NRC) is sponsoring the 2003 Postdoctoral and Senior Research Associateship Programs. The programs are meant to provide opportunities for Ph.D., Sc.D., or M.D. scientists and engineers of unusual promise and ability to perform research at one of more than 120 research laboratories throughout the United States and overseas.

Full-time associateships will be awarded for research in the fields of mathematics, chemistry, earth and atmospheric sciences, engineering, applied sciences and computer science, life and medical sciences, space and planetary sciences, and physics. Most of the laboratories are open to both U.S. and non-U.S. nationals and to both recent doctoral recipients and senior investigators.

Awards are made for one or two years, renewable for a maximum of three years. Annual stipends for recent Ph.D. recipients range from \$30,000 to \$50,000, depending on the sponsoring laboratory; the awards for senior recipients will be higher. Support is also provided for allowable relocation expenses and for limited professional travel during the period of the award.

Awards will be made three times during the year, and applications will be accepted on a continuous basis. The deadlines for application materials to be postmarked are **January 15, April 15**, and **August 15, 2003**. The award recipients will be announced in March-April, July, and November.

For further information and application materials, see the NRC website at `http://www4.nationalacademies.org/pga/rap.nsf/`, or contact the National Research Council, Associateship Programs (TJ 2114), 2101 Constitution Avenue, NW, Washington, DC 20418; telephone: 202-334-2760; fax: 202-334-2759; email: `rap@nas.edu`.

—From an NRC announcement

National Defense Science and Engineering Graduate Fellowships

As a means of increasing the number of U.S. citizens trained in disciplines of military importance in science and engineering, the Department of Defense (DoD) plans to award approximately 200 new three-year graduate fellowships in April 2002, based on available funding. The DoD will offer these fellowships to individuals who have demonstrated ability and special aptitude for advanced training in science and engineering. National Defense Science and Engineering Graduate (NDSEG) Fellowships will be awarded for study and research leading to doctoral degrees in mathematical, physical, biological, ocean, and engineering sciences.

The NDSEG Fellowship Program is open only to applicants who are citizens or nationals of the United States. NDSEG Fellowships are intended for students at or near the beginning of their graduate studies in science or engineering. Applicants must have received their bachelor's degrees by fall of 2003. Applications are encouraged from women, persons with disabilities, and minorities, including members of ethnic minority groups such as African American, American Indian and Alaska Native, Asian, Native Hawaiian and other Pacific Islander, Hispanic, or Latino.

The deadline for submitting a complete application is **January 6, 2003.** Application materials are available from, and completed applications should be returned to, the American Society for Engineering Education (ASEE) at NDSEG Fellowship Program, c/o American Society for Engineering Education, 1818 N Street, N.W. #600, Washington, DC 20036; telephone: 202-331-3516; fax: 202-265-8504; email: `ndseg@asee.org`. For further information see the website `http://www.asee.org/ndseg/html/preface.htm`.

—From an NDSEG announcement

NRC-Ford Foundation Fellowships for Minorities

The National Research Council (NRC) administers the Ford Foundation Fellowships for Minorities program. This program offers predoctoral fellowships, dissertation fellowships, and postdoctoral fellowships. Eligible applicants must be U.S. citizens or nationals who are members of one of the following groups: Black/African American, Alaskan Native, Mexican American/Chicano/Chicana, Native American, Native Pacific Islander (Polynesian, Micronesian, Filipino), or Puerto Rican.

The predoctoral fellowship program offers support for three years in research-based programs in social and behavioral sciences, humanities, physical and biological sciences, engineering, and mathematics, or for interdisciplinary programs comprising two or more eligible disciplines leading to the Ph.D. or Sc.D. The annual stipend is $16,000 and an additional cost of education allowance of $7,500. The deadline to apply is **November 20, 2002**.

The dissertation fellowship is intended for the final year of dissertation writing. The stipend is $21,000. The application deadline is **December 4, 2003**.

The postdoctoral fellowship offers one year of postdoctoral support for individuals who have received their Ph.D.'s no earlier than January 1996 and no later than February 14, 2003. The stipend is $34,000, with an additional $7,500 cost of education allowance. The application deadline is **January 8, 2003**.

Applicants are encouraged to apply online at `http://national-academies.org/fellowships/`. The postal address is Ford Foundation Fellowships/TJ 2041, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418. The telephone number is 202-334-2872. The email address is `infofell@nas.edu`.

—From an NRC announcement

EDGE Summer Program

Funded by the National Science Foundation, the National Security Agency, and the Andrew W. Mellon Foundation, the Enhancing Diversity in Graduate Education (EDGE) Program, a postbaccalaureate summer enrichment program, is designed to strengthen the ability of women and minority students to successfully complete graduate programs in the mathematical sciences.

The summer program consists of two core courses in analysis and algebra/linear algebra. There will also be minicourses in vital areas of mathematical research in pure and applied mathematics, short-term visitors from academia and industry, guest lectures, graduate student mentors, and problem sessions. In addition, a follow-up mentoring program and support network will be established with the participants' respective graduate programs.

Applicants to the program should be women who are (i) graduating seniors who have applied to graduate programs in the mathematical sciences, (ii) recent recipients of undergraduate degrees who are now entering graduate programs, or (iii) first-year graduate students. All applicants should have completed standard junior–senior-level undergraduate courses in analysis and abstract algebra and have a desire to earn the doctorate degree. Women from minority groups who fit one of the above three categories are especially encouraged to apply. Final acceptance to the program is contingent upon acceptance to a graduate program in the mathematical sciences.

In 2003 the program will be held at Pomona College in Claremont, California. The dates for the summer program are June 2–June 27, 2003. It will be codirected by Sylvia Bozeman (Spelman College), Rhonda Hughes (Bryn Mawr College), and local coordinator Ami Radunskaya (Pomona College). A stipend of $2,000 plus room and board will be awarded to participants. Names of applicants chosen to participate in the program will be announced by April 15, 2003.

Applications should consist of the following: (1) a completed application form; (2) a statement describing the expected value of this program to the applicant's academic goals; (3) two letters of recommendation from mathematical sciences faculty familiar with the applicant's work; (4) a transcript and current résumé; (5) a list of graduate programs to which the applicant has applied, together with a ranked list of her two or three top choices.

The application deadline is **March 3, 2003.** Applications should be sent to: EDGE Program, Department of Mathematics, Spelman College, Atlanta, GA 30314. For more information visit the program's website at `http://www.edgeforwomen.org/`.

—EDGE Program announcement

AMS-AAAS Mass Media Fellowships

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

Fellows receive a weekly stipend of $450 plus travel expenses to work for ten weeks during the summer as reporters, researchers, and production assistants in media organizations. They observe and participate in the process by which events and ideas become news, improve their ability to communicate about complex technical subjects in a manner understandable to the public, and increase their understanding of editorial decision making and of how information is effectively disseminated. Each fellow attends an orientation and evaluation session in Washington, DC, and begins the internship in mid-June. Fellows submit interim and final reports to AAAS. A wrap-up session is held at the end of the summer.

Mathematical sciences faculty are urged to make their graduate students aware of this program. The deadline to apply for fellowships for the summer of 2003 is **January 15, 2003**. Further information about the fellowship program and application procedures is available online at http://ehrweb.aaas.org/massmedia.htm; or contact Katrina Malloy, Program Coordinator, AAAS Mass Media Science and Engineering Fellows Program, 1200 New York Avenue, NW, Washington, DC 20005; telephone: 202-326-6760; fax: 202-371-9849; or the AMS Washington Office, 1527 Eighteenth Street, NW, Washington, DC 20036; telephone: 202-588-1100; fax: 202-588-1853; email: amsdc@ams.org.

—*Elaine Kehoe*

News from The Fields Institute

The Fields Institute for Research in Mathematical Sciences has announced its program for 2002–2003.

The Thematic Program on Set Theory and Analysis runs from September to December 2002 and centers on the relationship between set theory and analysis.

November 10–16, 2002: Workshop on Geometry of Banach Spaces and Infinite Dimensional Ramsey Theory. Organizers: E. Odell, T. Schlumprecht, S. Todorcevic, and N. Tomczak-Jaegermann. For more detailed information, see the website http://www.fields.utoronto.ca/programs/scientific/02-03/set_theory/workshop2/.

The Thematic Program on Automorphic Forms will be held from January through May 2003. The program will concentrate on the geometric and analytic aspects of the subject.

January 21–April 29, 2003: Course on Automorphic L-Functions. Instructors: H. Kim and R. Murty.

March 4–8, 2003 (tentative): Workshop on Shimura Varieties and Related Topics. Organizers: T. Haines and G. Pappas.

May 5–9, 2003: Workshop on Automorphic L-Functions. Organizers: H. Kim and R. Murty.

June 2–27, 2003: Summer School Program supported by The Clay Mathematics Institute. Organizers: J. Arthur, R. Kottwitz, J. Milne, and F. Muraghan.

For more detailed information, see the website http://www.fields.utoronto.ca/programs/scientific/02-03/automorphic_forms/index.html.

The Fields Institute invites applications for postdoctoral fellowship positions at the institute for the 2003–2004 academic year. These fellowships provide an opportunity to spend at least one year engaged in research and participating in the research activities of the institute. Applications for the Program on Partial Differential Equations should be received by **January 2, 2003**.

Applicants seeking postdoctoral fellowships funded by other agencies (such as NSERC and international fellowships) should request The Fields Institute as their proposed location of tenure and should apply to The Fields Institute for a letter of invitation. For further information please see http://www.fields.utoronto.ca/proposals/postdoc.html.

—*From a Fields Institute announcement*

News from the IMA

The 2002–2003 program at the Institute for Mathematics and its Applications (IMA) is Mathematical Optimization. The winter quarter will focus on advances in the underlying methods dealing with both nonlinear and linear optimization, and the spring quarter will deal with the connections between optimization and information technology. The dates and topics of the workshops follow.

January 6–7, 2003: Short Course on Industrial Strength Optimization.

January 8–16, 2003: Tutorial and workshop on Optimization in Simulation-Based Models.

March 11–19, 2003: Tutorial and workshop on Semidefinite Programming and Robust Optimization.

April 6–11, 2003: Tutorial and workshop on Network Management and Design.

May 5–9, 2003: Tutorial and workshop on Data Analysis and Optimization.

The organizing committee consists of John Birge (Northwestern University), William Cook (Georgia Institute of Technology), Donald Goldfarb (Columbia University), Brenda Dietrich (IBM, Yorktown), William Pulleyblank (IBM, Yorktown), and Prabhakar Raghavan (Verity, Inc., Sunnyvale, CA). Further information and application forms are available at the IMA website, http://www.ima.umn.edu/.

—*From an IMA announcement*

Inside the AMS

AMS Sponsors NExT Fellows

Project NExT (New Experiences in Teaching) is a professional development program started in 1994 by the Mathematical Association of America (MAA). Each year sixty to seventy new Ph.D.'s receive Project NExT Fellowships, which allow them to attend special events at the MAA MathFest and at the Joint Mathematics Meetings. The purpose of the program is to prepare the fellows for life as productive mathematics faculty members in colleges or universities.

This is the second year that the AMS is supporting six "AMS NExT Fellows" who are from Ph.D.-granting institutions and who show promise in mathematics research. The AMS will also hold activities for the AMS NExT Fellows at the Joint Mathematics Meetings.

The names and affiliations of the 2002 AMS NExT Fellows are: DOROTHY BUCK, Brown University; TIM CHARTIER, University of Washington, Seattle; PALLAVI JAYAWANT, University of Arizona; INGA JOHNSON, University of Rochester; MARC LAFOREST, Colorado State University; and GREGORY S. WARRINGTON, University of Massachusetts, Amherst.

For further information about Project NExT, visit the website `http://archives.math.utk.edu/projnext/`. Information about applying for Project NExT Fellowships will appear in the *Notices* in early 2003.

—*Allyn Jackson*

Fan and Caldwell Scholarships Awarded

The AMS awarded five scholarships to students attending programs for mathematically talented high-school students held in the summer of 2002. Four Ky and Yu-Fen Fan Scholarships and one Roderick P. C. Caldwell Scholarship were awarded. The scholarships are intended to cover the tuition for the programs.

The names of the students receiving Fan Scholarships, their high schools, their hometowns, and the programs they attended (in parentheses) are: GRIGORI I. AVRAMIDI, Socorro High School, Socorro, New Mexico (Ross Mathematics Program, Ohio State University); EUGENE WON, Great Neck South High School, Great Neck, New York (PROMYS, Program in Mathematics for Young Scientists, Boston University); WAIN YEE, Armand Hammer United World College, Montezuma, New Mexico (Canada/USA Mathcamp, Colorado College); and ARACELI FERNANDEZ, Harlandale High School, San Antonio, Texas (SWT Honors Summer Math Camp, Southwest Texas State University). Receiving a Roderick P. C. Caldwell Scholarship is: JOSEPH COOPER III, Sherman High School, Sherman, Texas (PROMYS, Program in Mathematics for Young Scientists, Boston University).

In the fall of 1999, Ky Fan and his wife, Yu-Fen Fan, made a gift of approximately $1 million to the AMS. The funds were used to establish the Ky and Yu-Fen Fan Endowment. Income from the endowment supports mathematics in China and mathematically talented high-school students in the U.S.

Ky Fan is an emeritus professor of mathematics at the University of California, Santa Barbara. Born on September 19, 1914, in Hangchow, China, he received his B.S. degree from Peking University (1936) and his D.Sc. degree from the University of Paris (1941). He was a member of the Institute for Advanced Study in Princeton from 1945 to 1947 and held positions at the University of Notre Dame, Wayne State University, and Northwestern University before going to Santa Barbara in 1965. Elected a member of the Academia Sinica in 1964, Fan served as the director of the Institute of Mathematics there from 1978 to 1984. The author of approximately 130 papers, Fan made fundamental contributions to operator and matrix theory, convex analysis and inequalities, linear and nonlinear programming, topology and fixed point theory, and topological groups. His work in fixed point theory, in addition to influencing nonlinear functional analysis, has found wide application in mathematical economics and game theory, potential theory, calculus of variations, and differential equations.

In December 1999 Winifred A. Caldwell endowed the Roderick P. C. Caldwell Scholarship within the AMS Epsilon Fund. The scholarship will be given each year to support at least one student of demonstrated needs to participate in a program for mathematically talented high-school students.

Roderick P. C. Caldwell was professor of mathematics at the University of Rhode Island for over twenty-two years. A graduate of Harvard University, he received his master's and doctoral degrees from the University of Illinois. After his retirement Caldwell continued teaching for several years and contributed his salary to establish an endowment within the URI Foundation for needy and promising URI mathematics students. His students particularly appreciated the fact that he shared with them his personal library, which contained many rare mathematical books. Winifred A. Caldwell endowed the scholarship to keep alive her husband's wish to instill a love of mathematics in his students.

—*Allyn Jackson*

Resolution Honoring Martin Gardner

At its meeting in May 2002 the AMS Executive Committee and Board of Trustees passed the following resolution honoring Martin Gardner:

"During more than half a century Martin Gardner has written books about mathematics, educating and enticing both amateurs and professionals with over 65 books and hundreds of articles. His monthly columns in *Scientific American* drew many professional mathematicians into their careers. His books have been read by thousands of mathematicians around the world. For all that he has done for mathematics and for mathematicians, the American Mathematical Society expresses its deep appreciation and sincere gratitude, and hereby awards Martin Gardner an honorary lifetime membership in the Society."

In 1987 Gardner was awarded the AMS Steele Prize for Mathematical Exposition.

—*Allyn Jackson*

Deaths of AMS Members

HEINZ BAUER, University of Erlangen-Nuremberg, Germany, died on August 15, 2002. He was a member of the Society for 47 years.

HANS F. BUECKNER, of Schenectady, NY, died on July 20, 2002. He was a member of the Society for 33 years.

IOANA CIORANESCU, of the University of Puerto Rico, died on July 28, 2002. Born on March 25, 1942, she was a member of the Society for 5 years.

MARTIN HANNA, of the University of Kansas, Lawrence, died on July 19, 2002. Born on August 8, 1932, he was a member of the Society for 41 years.

C. FREDERICK KOEHLER, professor emeritus, St. Joseph's University, Philadelphia, died on January 9, 2001. Born on November 9, 1919, he was a member of the Society for 53 years.

BENJAMIN LEPSON, adj. professor emeritus, Catholic University of America, died in January 2002. Born on March 4, 1924, he was a member of the Society for 56 years.

CANDIDO SITIA, president, Centro Morin, Italy, died on May 22, 2002. Born on January 25, 1922, he was a member of the Society for 23 years.

Reference and Book List

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

Contacting the *Notices*

The preferred method for contacting the *Notices* is electronic mail. The editor is the person to whom to send articles and letters for consideration. Articles include feature articles, memorial articles, communications, opinion pieces, and book reviews. The editor is also the person to whom to send news of unusual interest about other people's mathematics research.

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

The electronic-mail addresses are notices@math.tamu.edu in the case of the editor and notices@ams.org in the case of the managing editor. The fax numbers are 979-845-6028 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines

November 15, 2002: Applications for Postdoctoral Fellowships and General Memberships at MSRI. See http://www.msri.org/, or contact MSRI, 1000 Centennial Drive, Berkeley, CA 94720-5070.

November 20, 2002: Applications for NRC-Ford Foundation Predoctoral Fellowship Program. See "Mathematics Opportunities" in this issue.

December 1, 2002: Applications for AMS Centennial Fellowships. See http://www.ams.org/employment/centflyer.html, or contact: Professional Services Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294; telephone: 401-455-4107; email: prof-serv@ams.org.

December 1, 2002: Submissions for Sunyer i Balaguer Prize. Contact Centre de Recerca Matemàtica, Fundació Ferran Sunyer i Balaguer, Apartat 50, E-08193 Bellaterra, Spain; http://www.crm.es/info/ffsb.htm; email: crm@crm.es.

Where to Find It

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

December 1, 2002: Applications for NSF/NIH East Asia and Pacific Program. See http://www.nsf.gov/pubs/2002/nsf02007/nsf02007.htm.

December 3, 2002: NSF CARGO Program. See "Mathematics Opportunities" in this issue.

December 4, 2002: Applications for NRC-Ford Foundation Dissertation Fellowship Program. See "Mathematics Opportunities" in this issue.

December 16, 2002: Applications for AMS Epsilon Fund. See http://www.ams.org/careers-edu/epsilon.html, or contact Professional Services Department, AMS, 201 Charles Street, Providence, RI 02904; telephone: 800-321-4267, ext. 4105; email: prof-serv@ams.org.

December 31, 2002: Nominations for Alan T. Waterman Award. Contact Susan E. Fannoney, telephone: 703-292-8096 or email: sfannone@nsf.gov.

January 2, 2003: Applications for postdoctoral positions at The Fields Institute. See "Mathematics Opportunities" in this issue.

January 6, 2003: Applications for National Defense Science and Engineering Graduate Fellowships. See "Mathematics Opportunities" in this issue.

January 8, 2003: Applications for NRC-Ford Foundation Postdoctoral Fellowship Program. See "Mathematics Opportunities" in this issue.

January 10, 2003: Applications for AAUW Selected Professions Fellowships. See http://www.aauw.org/3000/fdnfelgra/selectprof.html, or contact the AAUW Educational Foundation, 1111 Sixteenth St., N.W., Washington, DC 20036; telephone: 800-326-2289 (AAUW); fax: 202-872-1425; email: info@aauw.org.

January 15, 2003: Applications for AMS-AAAS Mass Media Fellowships. See "Mathematics Opportunities" in this issue.

January 15, 2003: Applications for National Research Council Research Associateship Program. See "Mathematics Opportunities" in this issue.

January 24, 2003: Applications for AWM Workshop for Women Graduate Students and Postdocs. See http://www.awm-math.org/.

January 31, 2003: Applications for postdoctoral fellowships for Institut Mittag-Leffler. See http://www.ml.kva.se/.

February 1, May 1, 2003: Applications for NSF/AWM Travel Grants for Women. See http://www.awm-math.org/ travelgrants.html; telephone: 301-405-7892; email: awm@math.umd.edu.

March 1, 2003: Nominations for Third World Academy of Science Prizes. See http://www.ictp.trieste.it/~twas/twas_prizes.html.

March 3, 2003: Applications for EDGE Summer Program. See "Mathematics Opportunities" in this issue.

April 15, 2003: Applications for National Research Council Research Associateship Program. See "Mathematics Opportunities" in this issue.

April 18, 2003: Full proposals for NSF IGERT program. See http://www.nsf.gov/pubsys/ods/getpub.cfm?nsf02145/.

May 15, 2003: Applications for fall semester of Math in Moscow and for AMS scholarships. See http://www.mccme.ru/mathinmoscow/, or contact Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax: +7095-291-65-01; email: mim@mccme.ru. For information about and application forms for the AMS scholarships, see http://www.ams.org/careers-edu/mimoscow.html, or contact Math in Moscow Program, Professional Services Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904; email: prof-serv@ams.org.

June 30, 2003: Nominations for the Fermat Prize for Mathematics Research. See http://www.ups-tlse.fr/ACTUALITES/Sciences/Prix_Fermat_2003/Areglement.html.

August 15, 2003: Applications for National Research Council Research Associateship Program. See "Mathematics Opportunities" in this issue.

NSF Division of Mathematical Sciences

Listed below are names, email addresses, and telephone numbers for the program directors for the coming academic year in the Division of Mathematical Sciences of the National Science Foundation.

Algebra, Number Theory, and Combinatorics
Andrew D. Pollington
703-292-4877
adpollin@nsf.gov

William M. Snyder
703-292-4876
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Sylvia M. Wiegand
703-292-4868
swiegand@nsf.gov

Analysis
David Drasin
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Book List

The Book List highlights books that have mathematical themes and hold appeal for a wide audience, including mathematicians, students, and a significant portion of the general public. When a book has been reviewed in the Notices, *a reference is given to the review. Generally the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers' attention to older books. Suggestions for books to include on the list may be sent to* notices-booklist@ams.org.

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

The Algorithmic Beauty of Seaweeds, Sponges and Corals, by Jap Kaandorp and Janet Kübler. Springer-Verlag, January 2001. ISBN 3-540-67700-3.

The Annotated Flatland: A Romance of Many Dimensions, Edwin A. Abbott; introduction and notes by Ian Stewart. Perseus Publishing, November 2001. ISBN 0-7382-0541-9. (Reviewed November 2002.)

The Bit and the Pendulum: How the New Physics of Information Is Revolutionizing Science, by Tom Siegfried. John Wiley & Sons, February 2000. ISBN 0-47132-174-5. (Reviewed August 2002.)

The Book of Nothing: Vacuums, Voids, and the Latest Ideas about the Origins of the Universe, by John D. Barrow. Pantheon Books, April 2001. ISBN 0-375-42099-1. (Reviewed June/July 2002.)

Codes and Ciphers: Julius Caesar, the Enigma, and the Internet, by Robert Churchhouse. Cambridge University Press, January 2002. ISBN 0-521-81054-X.

The Colossal Book of Mathematics: Classic Puzzles, Paradoxes, and Problems, by Martin Gardner. W. W. Norton & Company, August 2001. ISBN 0-393-02023-1. (Reviewed October 2002.)

Conned Again, Watson! Cautionary Tales of Logic, Math, and Probability, by Colin Bruce. Perseus Publishing, January 2001. ISBN 0-7382-0345-9. (Reviewed November 2002.)

Conversations with a Mathematician: Math, Art, Science, and the Limits of Reason, by Gregory J. Chaitin. Springer, November 2001. ISBN 1-85233-549-1.

Curve Ball: Baseball, Statistics, and the Rules of Chance in the Game, by Jim Albert and Jay Bennett. Copernicus-Springer Verlag, July 2001. ISBN 0-387-98816-5.

Damned Lies and Statistics: Untangling Numbers from the Media, Politicians, and Activists, by Joel Best. University of California Press, May 2001. ISBN 0-520-21978-3.

Does God Play Dice? The New Mathematics of Chaos, by Ian Stewart. Revised second edition, Blackwell, January 2002. ISBN 0-631-23251-6. (Reviewed in this issue.)

Entanglement: The Greatest Mystery in Physics, by Amir D. Aczel. Four Walls Eight Windows, October 2002. ISBN 1-56858-232-3.

The Essential John Nash, Harold Kuhn and Sylvia Nasar, editors. Princeton University Press, December 2001. ISBN 0-691-09527-2.

Euclid's Window: The Story of Geometry from Parallel Lines to Hyperspace, by Leonard Mlodinow. Free Press, April 2001. ISBN 0-684-86523-8. (Reviewed May 2002.)

Flatterland: Like Flatland, Only More So, by Ian Stewart. Perseus Publishing, May 2001. ISBN 0-7382-0442-0. (Reviewed April 2002.)

Fooled by Randomness: The Hidden Role of Chance in the Markets and Life, by Nassim Nicholas Taleb. Texere, October 2001. ISBN 1-587-99071-7.

The Fractal Murders, by Mark Cohen. Muddy Gap Press, May 2002. 0-9718986-0-X.

Fragments of Infinity: A Kaleidoscope of Math and Art, by Ivars Peterson. John Wiley & Sons, October 2001.

ISBN 0-471-16558-1. (Reviewed October 2002.)

A Gardner's Workout: Training the Mind and Entertaining the Spirit, by Martin Gardner. A K Peters, June 2001. ISBN 1-56881-120-9.

Geometry: Our Cultural History, by Audun Holme. Springer, April 2002. ISBN 3-540-41949-7.

Go To: The Story of the Math Majors, Bridge Players, Engineers, Chess Wizards, Scientists and Iconoclasts Who Were the Hero Programmers of the Software Revolution, by Steve Lohr. Basic Books, October 2001. ISBN 0-465-04225-2.

* *God in the Equation: How Einstein Became the Prophet of the New Religious Era*, by Corey S. Powell. Free Press, August 2002. ISBN 0-684-86348-0.

Gödel's Proof, by Ernest Nagel and James R. Newman. Revised edition, New York University Press, February 2002. ISBN 0-8147-5816-9.

The Hilbert Challenge, by Jeremy J. Gray. Oxford University Press, December 2000. ISBN 0-198-50651-1. (Reviewed September 2002.)

* *Hinged Dissections: Swinging and Twisting*, by Greg N. Frederickson. Cambridge University Press, September 2002. ISBN 0-521-81192-9.

The Honors Class, by Benjamin Yandell. A K Peters, December 2001. ISBN 1-568-81141-1. (Reviewed September 2002.)

How the Other Half Thinks: Adventures in Mathematical Reasoning, by Sherman Stein. McGraw-Hill, July 2001. ISBN 0-071-37339-X. (Reviewed September 2002.)

How the Universe Got Its Spots, by Janna Levin. Princeton University Press, April 2002. ISBN 0-691-09657-0.

It Must Be Beautiful: Great Equations of Modern Science, Graham Farmelo, editor. Granta Books, February 2002. ISBN 1-862-07479-8.

The Lady Tasting Tea: How Statistics Revolutionized Science in the Twentieth Century, by David Salsburg. W. H. Freeman & Co., April 2001. ISBN 0-716-74106-7.

Lebesgue's Theory of Integration: Its Origins and Development, by Thomas Hawkins. AMS, September 2001. ISBN 0-8218-2963-7.

* *Linked: The New Science of Networks*, by Albert-Laslo Barabasi. Perseus Publishing, May 2002. ISBN 0-738-20667-9.

The Mathematical Explorer, by Stan Wagon. Electronic book, Wolfram Research, Inc., 2001. (Reviewed June/July 2002.)

Mathematical Vistas, by Peter Hilton, Derek Holton, and Jean Pedersen. Springer-Verlag, January 2002. ISBN 0-387-95064-8.

A Mathematician Grappling with His Century: The Autobiography of Laurent Schwartz. Translated from the French by L. Schneps. Birkhäuser, 2001. ISBN 3-7643-6052-6.

The Mathematician Sophus Lie: It Was the Audacity of My Thinking, by Arild Stubhaug. Springer, 2002. ISBN 3-540-42137-8.

Mathematics and the Roots of Postmodern Thought, by Vladimir Tasic. Oxford University Press, 2001. ISBN 0-195-13967-4.

* *Mathematics Elsewhere: An Exploration of Ideas across Cultures*, by Marcia Ascher. Princeton University Press, September 2002. ISBN 0-691-07020-2.

Mathematics Galore: Masterclasses, Workshops, and Team Projects in Mathematics and Its Applications, by C. J. Budd and C. J. Sangwin. Oxford University Press, June 2001. ISBN 0-198-50769-0 (hardcover), 0-198-50770-4 (paperback). (Reviewed September 2002.)

Mathematics in a Postmodern Age: A Christian Perspective, Russell W. Howell and W. James Bradley, editors. Wm. B. Eerdmans Publishing Company, May 2001. ISBN 0-802-84910-5.

* *The Mathematics of Oz: Mental Gymnastics from beyond the Edge*, by Clifford Pickover. Cambridge University Press, October 2002. ISBN 0-521-01678-9.

The Measure of the World, by Denis Guedj. University of Chicago Press, October 2001. ISBN 0-226-31030-2.

More Mathematical Astronomy Morsels, by Jean Meeus. Willmann-Bell Inc., 2002. ISBN 0-943396-743.

A New Kind of Science, by Stephen Wolfram. Wolfram Media, Inc., May 2002. ISBN 1-579-55008-8.

* *Nexus: Small Worlds and the Groundbreaking Science of Networks*, by Mark Buchanan. W. W. Norton & Company, May 2002. ISBN 0-393-04153-0.

Niels Hendrik Abel and His Times: Called Too Soon by Flames Afar, by Arild Stubhaug; translated by R. Daly. Springer, May 2000. ISBN 3-540-66834-9. (Reviewed August 2002.)

Political Numeracy: Mathematical Perspectives on Our Chaotic Constitution, by Michael Meyerson. W. W. Norton & Company, March 2002. ISBN 0-393-04172-7.

Puzzlers' Tribute: A Feast for the Mind, Tom Rodgers, David Wolfe, editors. A K Peters, December 2001. ISBN 1-56881-121-7.

The Quest for the Quantum Computer, by Julian Brown. Touchstone Books, August 2001. ISBN 0-684-87004-5.

Radical Equations: Math Literacy and Civil Rights, by Robert P. Moses and Charles E. Cobb Jr. Beacon Press, February 2001. ISBN 0-807-03126-7. (Reviewed March 2002.)

The Rainbow Bridge: Rainbows in Art, Myth, and Science, by Raymond L. Lee Jr. and Alistair B. Fraser. Pennsylvania State University Press and SPIE Press, 2001. ISBN 0-271-01977-8. (Reviewed in this issue.)

The Riddle of the Compass, by Amir Aczel. Harcourt Brace, August 2001. ISBN 0-151-00506-0.

Science and an African Logic, by Helen Verran. University of Chicago Press, January 2002. ISBN 0-226-85389-6 (cloth), 0-226-85391-8 (paper).

The Science of Conjecture: Evidence and Probability before Pascal, by James Franklin. Johns Hopkins University Press, June 2001. ISBN 0-8018-6569-7.

Signs of Life: How Complexity Pervades Biology, by Richard Solé and Brian Goodwin. Basic Books, January 2001. ISBN 0-465-01927-7.

Spaceland, by Rudy Rucker. Tor Books, June 2002. ISBN 0-765-30366-3.

Statisticians of the Centuries, C. C. Heyde and E. Seneta, editors. Springer, September 2001. ISBN 0-387-953283-7.

The Story of Mathematics, by Richard Mankiewicz. Princeton University Press, February 2001. ISBN 0-691-08808-X. (Reviewed April 2002.)

Such Silver Currents: The Story of William and Lucy Clifford, 1845–1929, by M. Chisholm. Lutterworth Press, March 2002. ISBN 0-7188-3017-2.

Things a Computer Scientist Rarely Talks About, by Donald Knuth. Center for the Study of Language and Information, July 2001. ISBN 1-57586-327-8.

Thinks, by David Lodge. Viking Press, May 2001. ISBN 0-670-89984-4.

Triangle of Thoughts, by Alain Connes, André Lichnerowicz, and Marcel Paul Schützenberger. AMS, July 2001. ISBN 0-8218-2614-X. (Reviewed March 2002.)

Turing and the Universal Machine: The Making of the Modern Computer, by Jon Agar. Totem Books, June 2001. ISBN 1-840-46250-7.

Understanding Mathematics for Aircraft Navigation, by James S. Wolper. McGraw-Hill, May 2001. ISBN 0-07-137572-4.

The Unfinished Revolution: Human-Centered Computers and What They Can Do for Us, by Michael L. Dertouzos. Harperbusiness, January 2001. ISBN 0-066-62067-8.

The Universal History of Computing: From the Abacus to the Quantum Computer, by Georges Ifrah; translated from the French and with notes by E. F. Harding, assisted by Sophie Wood, Ian Monk, Elizabeth Clegg, and Guido Waldman. John Wiley & Sons, November 2000. ISBN 0-471-39671-0. (Reviewed in two parts, January 2002 and February 2002.)

The Universal History of Numbers: From Prehistory to the Invention of the Computer, by Georges Ifrah; translated from the French by David Bellos, E. F. Harding, Sophie Wood, and Ian Monk. John Wiley & Sons, December 1999. ISBN 0-471-37568-3. (Reviewed in two parts, January 2002 and February 2002.)

The Universe in a Nutshell, by Stephen Hawking. Bantam Doubleday Dell, November 2001. ISBN 0-553-80202-X. (Reviewed May 2002.)

What Shape Is a Snowflake?, by Ian Stewart. W. H. Freeman & Co., November 2001. ISBN 0-716-74794-4. (Reviewed in this issue.)

The Zen of Magic Squares, Circles, and Stars: An Exhibition of Surprising Structures across Dimensions, by Clifford A. Pickover. Princeton University Press, January 2001. ISBN 0-691-07041-5.

REFERENCE & BOOK LIST

Add this Cover Sheet to all of your Academic Job Applications

How to use this form

1. Using the facing page or a photocopy, (or visit the AMS web site for a choice of electronic versions at `www.ams.org/coversheet/`), fill in the answers which apply to *all* of your academic applications. Make photocopies.

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

The purpose of the cover form is to aid department staff in tracking and responding to each application for employment. Mathematics departments in Bachelor's-, Master's-, and Doctorate-granting institutions are expecting to receive the form from each applicant, along with the other application materials they require.

The AMS suggests that applicants and employers visit the Job Application Database for Mathematicians (`www.mathjobs.org`), a new electronic resource being offered by the AMS (in partnership with Duke University) for the second year in 2002-03. The system provides a way for applicants to produce printed coversheet forms, apply for jobs, or publicize themselves in the "Job Wanted" list. Employers can post a job listing, and once applications are made, search and sort among their applicants. Note-taking, rating, e-mail, data downloading and customizable EOE funnctions are available to employers. Also, reference writers can submit their letters online. A paperless application process is possible with this system, however; employers can choose to use any portion of the service. There will be annual employer fees beginning this year. This system was developed at the Duke University Department of Mathematics.

Please direct all questions and comments to: `emp-info@ams.org`.

Academic Employment in Mathematics

AMS Standard Cover Sheet

Last Name ______________________________

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Address *through next June* ______________________________ **Home Phone** ______________

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Current Institutional Affiliation ______________________________ **Work Phone** ______________

Highest Degree Held or Expected ______________________________

Granting Institution ______________ **Date (optional)** ______________

Ph.D. Advisor ______________________________

Ph.D. Thesis Title (optional) ______________________________

***Indicate** the mathematical subject area(s) in which you have done research using the Mathematics Subject Classification printed on the back of this form or on the AMS website. Use the two-digit classification which best fits your interests in the Primary Interest line and additional two-digit numbers in the Secondary Interest line.*

Primary Interest ☐☐ ______________________________

Secondary Interests *optional* ☐☐ ☐☐ ______________________________

***Give a brief synopsis** of your current research interests (e.g. finite group actions on four-manifolds). Avoid special mathematical symbols and please do not write outside of the boxed area.*

Most recent, if any, position held *post Ph.D.*

University or Company ______________________________

Position Title ______________________________

Indicate the position for which you are applying and position posting code, if applicable

____

If unsuccessful for this position, would you like to be considered for a temporary position?

☐ Yes ☐ No If yes, please check the appropriate boxes.

☐ Postdoctoral Position ☐ 2+ Year Position ☐ 1 Year Position

***List the names, affiliations, and e-mail addresses** of up to four individuals who will provide letters of recommendation if asked. Mark the box provided for each individual whom you have already asked to send a letter.*

☐ ______________________________

☐ ______________________________

☐ ______________________________

☐ ______________________________

This form is provided courtesy of the American Mathematical Society.

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

2000 Mathematics Subject Classification

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

Statistics on Women Mathematicians Compiled by the AMS

At its August 1985 meeting the Council of the AMS approved a motion to regularly assemble and report in the *Notices* information on the relative numbers of men versus women in at least the following categories: membership in the AMS, invited hour addresses at AMS meetings, speakers at Special Sessions at AMS meetings, percentage of women speakers in AMS Special Sessions by gender of organizers, and members of editorial boards of AMS journals.

It was subsequently decided that this information would be gathered by determining the sex of the individuals in the above categories based on name identification and that additional information on the number of Ph.D.'s granted to women would also be collected using the AMS-IMS-MAA Annual Survey. Since name identification was used, the information for some categories necessitated the use of three classifications:

Male: names that were obviously male

Female: names that were obviously female

Unknown: names that could not be identified as clearly male or female (e.g., only initials given, non-gender-specific names, etc.)

The following is the seventeenth reporting of this information. Updated reports will appear annually in the *Notices.*

Invited Hour Address Speakers at AMS Meetings (1992–2001)

Male:	468	84%
Female:	80	15%
Unknown:	6	1%
Total checked:	554	

Speakers at Special Sessions at AMS Meetings (1997–2001)

Male:	9,865	79%
Female:	1,605	13%
Unknown:	973	8%
Total checked:	12,443	

Percentage of Women Speakers in AMS Special Sessions by Gender of Organizers (2001)

Special Sessions with at Least One Woman Organizer

Total number of speakers:	612	
Male:	447	73%
Female:	135	22%
Unknown:	30	5%

Special Sessions with No Women Organizers

Total number of speakers:	1,795	
Male:	1,450	81%
Female:	201	11%
Unknown:	144	8%

Members of the AMS Residing in the U.S.

Male:	12,252	71%
Female:	2,943	17%
Unknown:	2,147	12%
Total checked:	17,342	

Trustees and Council Members

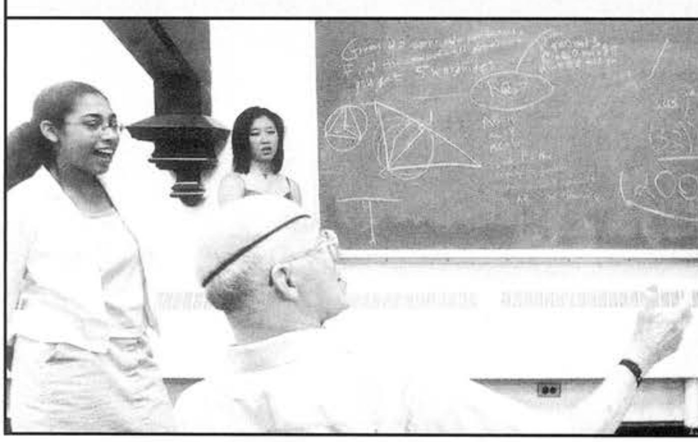
	2001		2000		1999		1998	
Total:	49		50		51		48	
Male:	37	76%	37	74%	39	76%	37	77%
Female:	12	24%	13	26%	12	24%	11	23%

Members of Editorial Boards of AMS Journals

	2001		2000		1999		1998		1997		1996		1995		1994		1993		1992	
Total:	224		219		230		213		213		198		194		176		177		178	
Male:	190	85%	186	85%	198	86%	182	85%	189	89%	177	89%	175	90%	161	91%	159	90%	163	92%
Female:	34	15%	33	15%	32	14%	31	15%	24	11%	21	11%	19	10%	15	9%	18	10%	15	8%

Ph.D.'s Granted to U.S. Citizens

	2001		2000		1999		1998		1997		1996		1995		1994		1993		1992	
Total:	494		537		554		586		516		493		567		469		526		430	
Male:	343	69%	379	71%	367	66%	423	72%	368	71%	377	76%	426	75%	345	74%	381	72%	327	76%
Female:	151	31%	158	29%	187	34%	163	28%	148	29%	116	24%	141	25%	124	26%	145	28%	103	24%



Mathematics Calendar

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

December 2002

2–6 **Joint IMA/CRM Workshop: Distribution Systems: Location and Vehicle Routing**, University of Montreal, Quebec, Canada. (Sept. 2002, p. 996)

2–21 **Workshop (02-18) & Conference (19-21) on Geometric Group Theory**, Guwahati, India. (Sept. 2002, p. 996)

4–6 **DIMACS Workshop on Implementation of Geometric Algorithms**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Sept. 2002, p. 996)

* 4–6 **IMA "Hot Topics" Workshop: Data-Driven Control and Optimization**, University of Minnesota, Minneapolis, Minnesota.
Organizers: S. Massoud Amin (EPRI), G. Cybenko (Dartmouth), R. Kulhavy (Honeywell), T. Samad (Honeywell).
Contact: Institute for Mathematics and its Applications, University of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; email: visit@ima.umn.edu; http://www.ima.umn.edu/optimization/fall/data-driven.html.

5–8 **Geometry and Topology of Quotients**, University of Arizona, Tucson, Arizona. (Sept. 2002, p. 996)

9–12 **ICDM '02: The 2002 IEEE International Conference on Data Mining Sponsored by the IEEE Computer Society**, Maebashi TERRSA, Maebashi City, Japan. (Sept. 2002, p. 996)

9–12 **2002 WSEAS Int. Conf. on Electronics, Control & Signal Processing**, Singapore, Singapore. (Nov. 2002, p. 1286)

9–13 **9th Annual Biopharmaceutical Applied Statistics Symposium**, Savannah, Georgia. (Sept. 2002, p. 996)

9–13 **Elliptic Cohomology and Chromatic Phenomena**, Isaac Newton Institute for Mathematical Sciences, Cambridge, England. (Apr. 2002, p. 504)

9–13 **FICOFEST, A Conference in Low-Dimensional Topology to Celebrate the Sixtieth Birthday of Francisco Javier "Fico" Gonzalez Acuna**, Universidad Autonoma de Yucatan, Merida, Yucatan, Mexico. (May 2002, p. 608)

9–13 **27th Australasian Conference on Combinatorial Mathematics and Combinatorial Computing (27ACCMCC)**, The University of Newcastle, Newcastle, NSW, Australia. (Feb. 2002, p. 271)

9–13 **II Workshop on Dynamics and Randomness**, Departamento de Ingeniería Matemática, Universidad de Chile, Santiago, Chile. (Sept. 2002, p. 997)

14–16 **International Symposium on Pure and Applied Mathematics: ISPAM 2002**, Calcutta, India. (Sept. 2002, p. 997)

27–30 **ASL Winter Meeting (with APA)**, Philadelphia Marriott, Philadelphia, Pennsylvania. (Sept. 2002, p. 997)

January 2003

* 27–July 11 **Nonlinear Hyperbolic Waves in Phase Dynamics and Astrophysics**, Isaac Newton Institute for Mathematical Sciences, Cambridge, UK.
Workshops: Mathematical Theory of Hyperbolic Systems of Conservation Laws (March 24–28, 2003); Multiphase Fluid Flows and Multi-Dimensional Hyperbolic Problems (March 31–April 4, 2003); EuroConference–Hyperbolic Models in Astrophysics and Cosmology (June 23–27, 2003).
Organizers: C. M. Dafermos (Providence, USA), P. G. LeFloch (Palaiseau, France), E. F. Toro (Trento, Italy).

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

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

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

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

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

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

Information: Isaac Newton Institute for Mathematical Sciences, 20 Clarkson Road, Cambridge, CB3 0EH, UK; tel: +44 (0) 1223 335999; fax: +44 (0) 1223 330508; email: info@newton.cam.ac.uk; http://www.newton.cam.ac.uk/programs/NPA/.

January–August **Thematic Program on Automorphic Forms**, The Fields Inst. for Research in Math. Sciences, Toronto, Canada. (Dec. 2001, p. 1368)

3–5 **3rd Mediterranean Conference on Mathematical Education**, Athens, Greece. (Sept. 2002, p. 997)

6–7 **IMA Short Course: Industrial Strength Optimization**, Minneapolis, Minnesota. (Sept. 2002, p. 997)

6–9 **Third International Workshop on Scientific Computing and Applications**, City University of Hong Kong, Hong Kong, China. (Sept. 2002, p. 997)

6–11 **International Conference on Dynamical Systems and Geometry to Celebrate the Sixtieth Anniversary of Alberto Verjovsky**, Cuernavaca, Mexico. (Oct. 2001, p. 1051)

8 **IMA Tutorial: Optimization in Simulation-Based Models**, Minneapolis, Minnesota. (Sept. 2002, p. 998)

9–16 **IMA Workshop 4: Optimization in Simulation-Based Models**, Minneapolis, Minnesota. (Sept. 2002, p. 998)

12–14 (REVISED) **ACM-SIAM Symposium on Discrete Algorithms**, Hyatt Regency, Baltimore, Maryland. (May 2002, p. 608)

13–17 **Multiscale Geometric Analysis: Theory, Tools, and Applications**, Institute for Pure and Applied Mathematics, UCLA, Los Angeles, California. (Oct. 2002, p. 1134)

15–18 **Joint Mathematics Meetings**, Baltimore Convention Center, Baltimore, Maryland. (Sept. 2002, p. 998)

17–18 **2002–2003 ASL Winter Meeting (with Joint Mathematics Meetings)**, Baltimore Convention Center, Baltimore, Maryland. (Sept. 2002, p. 998)

20–24 **Mathematical Challenges in Scientific and Engineering Computation**, Isaac Newton Institute for Mathematical Sciences, Cambridge, England. (Oct. 2002, p. 1134)

February 2003

3–7 **Emerging Applications of the Nonlinear Schrödinger Equations**, Institute for Pure and Applied Mathematics at UCLA, Los Angeles, California. (Sept. 2002, p. 998)

9 **Short Course prior to Conference on Computational Science and Engineering**, Hyatt Regency Islandia Hotel and Marina, San Diego, California. (May 2002, p. 608)

10–13 **SIAM Conference on Computational Science and Engineering (CSE03)**, Hyatt Regency Islandia Hotel & Marina, San Diego, California. (Nov. 2002, p. 1286)

10–14 **Permutation Patterns**, University of Otago, Dunedin, New Zealand. (May 2002, p. 608)

13–15 **4th WSEAS International Conferences on: Neural Networks and Applications (NNA '03); Fuzzy Sets & Fuzzy Systems (FSFS '03); Evolutionary Computation (EC '03)**, Lanzarote Island, Canary Islands, Spain. (Oct. 2002, p. 1134)

18–21 **Cells & Materials: At the Tissue Engineering Interface**, Institute for Pure and Applied Mathematics at UCLA, Los Angeles, California. (Sept. 2002, p. 998)

* 20–22 **Workshop on Statistical Aspects of Microarray Data**, Department of Mathematical Sciences, University of Aarhus, Denmark.
Organizers: J. L. Jensen (Univ. of Aarhus), M. de Gunst (Eurandom), M. Rudemo (Stochastic Centre, Gothenburg), M. Sörensen (Univ. of Copenhagen).
Invited Speakers: I. K. Glad (Oslo), R. A. Irizarry (Baltimore), M. Langaas (Trondheim), V. Liebscher (Munich), C. Mayer (Aberdeen), T. F. Örntoft (Aarhus), M. Rudemo (Gothenburg), A. van Heydebreck (Berlin), E. Wit (Glasgow).
Information: http://www.maphysto.dk/events/MicroArr03/.

21–22 **XVIII Inter-University Seminar on Research in the Mathematical Sciences (SIDIM)**, Pontifical Catholic University, Ponce, Puerto Rico. (Sept. 2002, p. 998)

* 24–28 **A-HYKE: Around Hyperbolic and Kinetic Equations**, TU Vienna, Austria.
Description: This is the first annual meeting of the EU-funded Research Training Network HYKE, Hyperbolic and Kinetic Equations: Asymptotics, Numerics, Applications, in collaboration with several EU-funded "partner networks".
Main Organizers: N. J. Mauser, G. Rein, C. Schmeiser, Wolfgang Pauli Institute, Wien.
Information: http://www.wpi.ac.at/.

March 2003

10–12 **International Conference on Mathematics and Its Applications**, Kuwait University, Kuwait. (Sept. 2002, p. 998)

11 **IMA Tutorial: Semidefinite Programming and Robust Optimization**, Minneapolis, Minnesota. (Sept. 2002, p. 998)

12–19 **IMA Workshop 5: Semidefinite Programming and Robust Optimization**, Minneapolis, Minnesota. (Sept. 2002, p. 998)

14–16 **AMS Southeastern Section Meeting**, Louisiana State University, Baton Rouge, Louisiana. (Sept. 2002, p. 998)

* 15–20 **Recent Developments in Superstring Theory**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: J. Bryan (Univ. BC), S. Giddings (Univ. Calif, Santa Barbara), M. Kapranofv (Univ. Toronto), A. Karch (Univ. Washington), A. Peet (Univ. Toronto), K. Viswanathan (San Francisco Univ.), M. Rozali, G. Semenoff (Univ. BC), M. Van Raamsdonk (Univ. BC).
Information: http://www.pims.math.ca/birs/.

17–20 (REVISED) **SIAM Conference on Mathematical and Computational Issues in the Geosciences**, Radisson Hotel and Suites Austin, Austin, Texas. (Sept. 2002, p. 998)

17–June 13 **Symplectic Geometry and Physics**, Institute for Pure and Applied Mathematics, Los Angeles, California. (Oct. 2002, p. 1134)

20–22 **Spring Topology and Dynamical Systems Conference 2003**, Texas Tech University, Lubbock, Texas. (Oct. 2002, p. 1134)

* 22–27 **Scattering and Inverse Scattering**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: R. Froese (Univ. B.C.), G. Uhlmann (Univ. Washington).
Information: http://www.pims.math.ca/birs/.

24–28 **Symplectic Geometry and Physics: Workshop I: Symplectic Geometry**, Institute for Pure and Applied Mathematics, UCLA, Los Angeles, California. (Oct. 2002, p. 1134)

27–30 **Quadrature Domains and Related Topics**, University of California, Santa Barbara. (Sept. 2002, p. 998)

27–30 **Sixth IMACS International Symposium on Iterative Methods in Scientific Computing**, University of Colorado, Denver, Colorado. (Oct. 2002, p. 1134)

28–30 **Southeast Geometry Conference**, College of Charleston, Charleston, South Carolina. (Nov. 2002, p. 1287)

* 29–April 3 **Commutative Algebra and Geometry**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: M. Green (IPAM), J. Herzog (Univ. Essen), B. Sturmfels (Univ. Calif., Berkeley).
Information: http://www.pims.math.ca/birs/.

April 2003

4-6 **AMS Central Section Meeting**, Indiana University, Bloomington, Indiana. (Sept. 2002, p. 999)

* 5-10 **BIRS Workshop on Noncommutative Geometry**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: A. Connes (IHES), J. Cuntz (Univ. Muenster), G. Elliott (Univ. Toronto), M. Khalkhali (Univ. Western Ont.), B. Tsygan (Penn State Univ.).
Information: `http://www.pims.math.ca/birs/`.

6 **IMA Tutorial: Network Management and Design**, Minneapolis, Minnesota. (Sept. 2002, p. 999)

7-11 **IMA Workshop 6: Network Management and Design**, Minneapolis, Minnesota. (Sept. 2002, p. 999)

10-13 **Louisiana Conference on Mathematical Control Theory**, Louisiana State University, Baton Rouge, Louisiana. (Oct. 2002, p. 1134)

12-13 **AMS Eastern Section Meeting**, Courant Institute, New York, New York. (Sept. 2002, p. 999)

* 12-17 **Quantum Mechanics on the Large Scale**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: P. Stamp (Univ. BC), G. Sawatzky (Univ. BC), A. Leggett (Univ. Illinois-Urbana), T. Havel (MIT), S. Popescu (HH Wills Lab), R. Gill (Utrecht Univ.).
Information: `http://www.pims.math.ca/birs/`.

17-19 **The Sixth Asian Symposium on Computer Mathematics (ASCM 2003)**, Beijing, China. (Sept. 2002, p. 999)

* 19-24 **Computational Fuel Cell Dynamics-II**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: J. Kenna (Ballard Power), T. Van Nguyen (Univ. Kansas), K. Promislow (San Francisco Univ.), B. Wetton (Univ. BC).
Information: `http://www.pims.math.ca/birs/`.

* 26-May 1 **The Many Aspects of Mahler's Measure**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: D. Boyd (Univ. BC), D. Lind (Univ. Washington), F. Rodriquez-Villegas (Univ. Texas-Austin), C. Deninger (Univ. Muenster).
Information: `http://www.pims.math.ca/birs/`.

May 2003

1-3 (REVISED) **SIAM International Conference on Data Mining**, Cathedral Hill Hotel, San Francisco, California. (Sept. 2002, p. 999)

3-4 **AMS Western Section Meeting**, San Francisco State University, California. (Sept. 2002, p. 999)

3-5 **First International Conference on Smarandache Geometries**, Griffith Univ., Gold Coast Campus, Australia. (Dec. 2001, p. 1368)

* 3-8 **Recent Advances in Algebraic and Enumerative Combinatorics**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: S. Billey (MIT), I. Goulden (Univ. Waterloo), C. Greene (Haverford Coll.), D. Jackson (Univ. Waterloo), R. Stanley (MIT).
Information: `http://www.pims.math.ca/birs/`.

5 **IMA Tutorial: Data Analysis and Optimization**, Minneapolis, Minnesota. (Sept. 2002, p. 999)

6-9 **IMA Workshop 7: Data Analysis and Optimization**, Minneapolis, Minnesota. (Sept. 2002, p. 999)

* 10-15 **Statistical Mechanics of Polymer Models**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: C. Soteros (Univ. Saskatchewan), D. Sumners (Florida State Univ.), S. Whittington (Univ. Toronto).
Information: `http://www.pims.math.ca/birs/`.

11-16 **International Conference on General Control Problems and Applications (GCP 2003): Dedicated to the 100th Anniversary of A. N. Kolmogorov**, Tambov State University, Tambov, Russia. (Sept. 2002, p. 999)

11-18 **Conference on Topological Algebras, Their Applications, and Related Topics**, Poznan, Poland. (Sept. 2002, p. 999)

* 12-14 **CMEM 2003: Eleventh International Conference on Computational Methods and Experimental Measurements**, Halkidiki, Greece.
Organizer: Wessex Institute of Technology, UK; University of Naples, Italy; and University of Thessaloniki, Greece.
Information: Visit the conference website for the latest details: `http://www.wessex.ac.uk/conferences/2003/cmem03/`.

18-23 **Applied Inverse Problems: Theoretical and Computational Aspects**, Institute for Pure and Applied Mathematics, UCLA, Los Angeles, California. (Oct. 2002, p. 1134)

* 19-21 **OPTI 2003: Eighth International Conference on Computer Aided Optimum Design of Structures**, Detroit, Illinois.
Organizer: Wessex Institute of Technology, UK; University of Coruna, Spain; and Kettering University, USA.
Information: Visit the conference website for the latest details: `http://www.wessex.ac.uk/conferences/2003/opti03/`.

* 19-21 **BETECH 2003: 15th International Conference on Boundary Element Technology**, Detroit, Illinois.
Organizer: Wessex Institute of Technology, UK; Kettering University, USA; and Philips Display, USA.
Information: Visit the conference website for the latest details: `http://www.wessex.ac.uk/conferences/2003/betech03/`.

19-23 **Symplectic Geometry and Physics: Workshop II: Chaotic Dynamics and Transport**, Institute for Pure and Applied Mathematics, UCLA, Los Angeles, California. (Oct. 2002, p. 1134)

* 20-23 **31st Annual Canadian Operator Algebra Symposium**, UNB, Fredericton, New Brunswick, Canada.
Information: For more information, see the webpage `http://www.math.unb.ca/~coas2003/`.

20-24 **31st Annual Canadian Operator Theory and Operator Algebras Symposium**, UNB, Fredericton, New Brunswick, Canada. (Sept. 2001, p. 910)

* 21-24 **Dynamic Systems and Applications**, Atlanta, Georgia.
Sponsor: International Federation for Nonlinear Analysts.
Topics: Dynamical Systems; Computational Mathematics; Simulation; Stochastic/Deterministic: Differential Equations, Partial Differential Equations, Integral Equations, Integro-Differential Equations, Difference Equations, and related topics.
Abstracts: Authors are requested to submit an abstract of their research presentation not exceeding half a page on or before March 1, 2003. Please email the abstract or type each abstract single-spaced on one side of 8.5×11 size paper with a one-inch margin on all sides.
Deadlines: Pre-registration: (on or before March 31, 2003) US $175, (Students: US $100). Registration: (after April 1, 2003) US $200, (Students: US $125). Banquet: May 22, 2003. Registration includes copy of the proceedings, banquet, and coffee and snacks during the meeting.
Conference Address: Department of Mathematics, Morehouse College, Atlanta, GA 30314, USA. To receive the second announcement, send (email) your name, address, telephone number, and email address before January 30, 2003.
Information: Conference Coordinator, M. Sambandham, ICDSA 04, Department of Mathematics, Morehouse College, Atlanta, GA 30314; Ph. (404) 215-2614; Fax: (404) 589-1661; email: `icdsa4@yahoo.com`; `http://www.dynamicpublishers.com/`.

21-25 **Logic and Mathematics: Connections and Interactions**, University of Illinois at Urbana-Champaign. (Oct. 2002, p. 1134)

* 24-29 **Constraint Programming, Belief Revision and Combinatorial Optimization**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: R. Goebel (Univ. Alberta).
Information: http://www.pims.math.ca/birs/.

25-29 **Dynamical Systems, Denton 2003**, University of North Texas, Denton, Texas. (Nov. 2002, p. 1287)

26-30 **SampTA03 (Sampling Theory and Applications 2003)**, Strobl, Salzburg, Austria. (Sept. 2002, p. 1000)

27-31 (REVISED) **SIAM Conference on Applications of Dynamical Systems**, Snowbird Ski and Summer Resort, Snowbird, Utah. (Sept. 2002, p. 1000)

28-30 **Lattices, Universal Algebra and Applications**, Centro de Algebra da Universidade de Lisboa, Lisboa, Portugal. (Oct. 2002, p. 1134)

* 31-June 5 **Symmetry and Bifurcation in Biology**, Banff International Research Station, Banff, Alberta, Canada.
Organizers: M. Golubitsky (Univ. Houston), W. Langford (Univ. Guelph), I. Stewart (Univ. Warwick).
Information: http://www.pims.math.ca/birs/.

June 2003

1-4 **2003 ASL Annual Meeting**, University of Illinois at Chicago, Chicago, Illinois. (Sept. 2002, p. 1000)

1-6 **International Conference on Group Theory: Combinatorial, Geometric, and Dynamical Aspects of Infinite Groups**, Gaeta, Italy. (Sept. 2002, p. 1000)

2-6 **Symplectic Geometry and Physics: Workshop III: Symplectic Geometry and String Theory**, Institute for Pure and Applied Mathematics, UCLA, Los Angeles, California. (Oct. 2002, p. 1135)

* 10-14 **XIX Rolf Nevanlinna Colloquium**, University of Jyäskylä, Jyväskylä, Finland.
Topics: Emphasis will be on subjects connected to analysis and especially to geometric aspects of analysis.
Information: See http://www.math.jyu.fi/research/rnc/.

16-20 **2003 SIAM Annual Meeting**, Queen Elizabeth Hotel, Montreal, Quebec, Canada. (Sept. 2002, p. 1000)

16-21 **International Conference: Kolmogorov and Contemporary Mathematics**, Moscow, Russia. (Sept. 2002, p. 1000)

17-21 **Fourth Geoffrey J. Butler Memorial Conference**, University of Alberta, Edmonton, Alberta, Canada. (Sept. 2002, p. 1000)

18-21 **First Joint International Meeting between the American Mathematical Society and the Real Sociedad Matematica Espanola**, Seville, Spain. (Sept. 2002, p. 1000)

* 19-26 **Some Intermediate Questions of Model Theory and Universal Algebra: ERLOGOL-2003**, Novosibirsk State Technical University, Novosibirsk, Siberia/Russia.
Description: This is a preliminary announcement only. The meeting is organized at the camping center of Novosibirsk State Technical University in the mountains of Altai. It is devoted to any problems of model theory and universal algebra.
Organizers: Novosibirsk State Technical Univ. (Russia) and Mathematical Institute (Siberian Branch of Russian Academy of Sciences).
Cochairmen of Conference: A. G. Pinus, V. D. Mazurov, K. N. Ponomarev.
Information: http://www2.nstu.ru/deps/algebra/erlogol/.

* 22-25 **IEEE Symposium on Logic in Computer Science 2003: Call for Workshop Proposals**, Ottawa, Ontario, Canada.
Description: The organizers have made arrangements for pre- and post-LICS workshops to be run in conjunction with the main conference. Possible dates are June 21 and June 26-27. Researchers and practitioners are invited to submit proposals for workshops on topics relating logic, broadly construed, to computer science or related fields. Funding is available to help defray the costs of a *limited number* of workshops.
Proposals Should Include: (1) A short scientific summary and justification of the proposed topic. This should include a discussion of the particular benefits of the topic to the LICS community. (2) A discussion of the proposed format and agenda. (3) The proposed duration, which may vary from half a day to two days, and preferred dates. (4) Procedures for selecting participants and papers. (5) Expected number of participants. (6) Potential invited speakers. (7) Plans for proceedings or other publications. Proposals are due November 1, 2002, and should be submitted electronically to: P. Panangaden, Workshops Chair LICS'03; email: prakash@cs.mcgill.ca.
Selection Committee: S. Abramsky (LICS General Chair), P. Kolaitis (LICS'03 Program Committee Chair), P. Panangaden (LICS Workshop Chair), and P. Scott and A. Felty (LICS'03 Conference Cochairs). The results will be announced by November 15, 2002.
Information: http://www.lfcs.informatics.ed.ac.uk/lics/.

23-25 **SIAM Conference on Mathematics for Industry: Challenges and Frontiers**, The Metropolitan Hotel, Toronto, Ontario, Canada. (Nov. 2002, p. 1287)

23-27 **Workshop on Extremal Graph Theory (Miklos Simonovits Is 60)**, Lake Balaton, Hungary. (Oct. 2002, p. 1135)

23-27 **Workshop on Harmonic Analysis and Partial Differential Equations**, Puerto Vallarta, Mexico. (Oct. 2002, p. 1135)

23-28 **Tools for Mathematical Modelling**, Saint-Petersburg State Technical University, Saint-Petersburg, Russia. (Nov. 2002, p. 1287)

* 24-26 **Fluid Structure Interaction 2003**, Cadiz, Spain.
Organizer: Wessex Institute of Technology, UK, and the University of Cadiz, Spain.
Information: For the latest details: http://www.wessex.ac.uk/conferences/2003/fluidstructure03/.

24-27 **Day on Diffraction - 2003 (DD'03)**, St. Petersburg Univ., St. Petersburg, Russia. (Oct. 2002, p. 1135)

25-28 (REVISED) **Mathematics in XXI Century**, Novosibirsk University, Novosibirsk, Russia. (Sept. 2002, p. 1000)

July 2003

* 1-December 31 **Mathematics and Computation in Imaging Science and Information Processing**, Institute for Mathematical Sciences (IMS), National University of Singapore, Singapore.
Program: The objective of the program is to conduct multidisciplinary studies involving mathematical perspectives and the foundation of imaging science and information processing.
Topics: Two main themes are ideal data representations and computational methods in imaging science. In conjunction with the program, two international conferences: (1) Wavelet Theory and Applications: New Directions and Challenges (July 14-,18, 2003 and (2) Numerical Methods in Imaging Science and Information Processing (December 15-19, 2003), as well as several workshops and tutorials, will be held. Detailed information on the program can be found on the IMS official website at http://www.ims.nus.edu.sg/.
Participants: The complete list of participants who will be visiting the IMS is given on our website, or see individual conference listings in this calendar.
Registration: Registration forms for the conferences/workshops/tutorials are available at http://www.ims.nus.edu.sg/Programs/imgsci/index.htm and should be received at least one month

before the commencement of each activity. Registration is free. IMS membership is not required for participation.

Contacts: For general enquiries, send email to ims@nus.edu.sg, while for enquiries on academic matters, send email to S. S. Goh at matgohss@nus.edu.sg.

7-11 **ICIAM 2003, 5th International Congress on Industrial and Applied Mathematics**, Sydney, Australia. (Sept. 2002, p. 1000)

14-15 **Mathematics of Computation and Approximation: A Conference in Honour of the 65th Birthday of Professor Ian Sloan**, University of New South Wales, Sydney, Australia. (Nov. 2002, p. 1287)

14-18 (NEW DATE) **International Conference on Algebras, Modules and Rings**, University of Lisbon, Lisbon, Portugal. (Oct. 2002, p. 1135)

14-18 **Wavelet Theory and Applications: New Directions and Challenges**, Institute for Mathematical Sciences, National University of Singapore, Singapore.

Organizers: S. S. Goh (National Univ. of Singapore), S. L. Lee (National Univ. of Singapore), Amos Ron (Univ. of Wisconsin-Madison,), Z. Shen (National Univ. of Singapore).

Plenary Speakers: A. Cohen (Univ. Pierre et Marie Curie, France), W. Dahmen (Rheinisch Westfälische Technische Hochschule-Aachen, Germany), I. Daubechies (Princeton Univ.), R. DeVore (Univ. of South Carolina), D. Donoho (Stanford Univ.), R.-Q. Jia (Univ. of Alberta, Canada), Y. Kevrekidis (Princeton Univ.), A. Ron (Univ. of Wisconsin-Madison), P. Schröder (California Inst. of Technology), G. Strang (MIT), M. Vetterli (Univ. of California, Berkeley/École Polytechnique Fédérale de Lausanne, Switzerland).

Registration: Registration forms are available at http://www.ims.nus.edu.sg/Programs/imgsci/wavelet.htm and should be received at least one month before the conference. For general enquiries, send email to ims@nus.edu.sg, while for enquiries on academic matters, send email to S. S. Goh at matgohss@nus.edu.sg.

Poster Sessions: Abstracts for poster sessions are welcomed and should be received by June 13, 2003. Please submit abstracts to S. S. Goh at matgohss@nus.edu.sg. Authors will be notified within one month of submission of the abstracts.

15-19 **SIAM Conference on Applied Linear Algebra**, William and Mary College, Williamsburg, Virginia. (Sept. 2002, p. 1001)

21-August 1 **IMA 2003 Summer Program: Probability and Partial Differential Equations in Modern Applied Mathematics Data Analysis and Optimization**, University of Minnesota, Minneapolis, Minnesota.

Organizers: E. C. Waymire (Oregon), J. Duan (IIT).

Contact: Institute for Mathematics and its Applications, University of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; email: visit@ima.umn.edu; or visit: http://www.ima.umn.edu/prob-pde/.

26-31 **Algebra and Discrete Mathematics—Symmetries and Ordered Structures under the Influence of Model Theory and Combinatorics**, Hattingen, Germany.

Description: The main focus of the meeting will be the rich interaction between the theory of infinite permutation groups, specifically realized as automorphism groups of sufficiently homogeneous structures, and model theory. Themes which have been pursued with considerable success in this field include classification theory for homogeneous structures; reconstruction of the structures from their automorphism groups, including use of the "small index property"; and detailed analysis of homogeneous structures by means of their automorphism groups. The conference is open to researchers worldwide, whether from industry or academia. Participation will be limited to 100. The emphasis will be on discussion about new developments. The conference fee covers registration, full board and lodging. Some grants will be available upon request.

Invited Speakers: E. Bouscaren (Univ. Paris VII); G. Cherlin (Rutgers Univ., Piscataway); T. Coulbois (Univ. Paris VII); M. Droste (TU Dresden); M. Dzamonja (Univ. of East Anglia, Norwich, UK); D. Evans (Univ. of East Anglia, Norwich, UK); R. Göbel (Univ. Essen); G. Gomes (Univ. Lisbon); C. Holland (Bowling Green Univ.); D. Kuske (Leicester Univ., UK); C. Michaux (UMH, Mons); A. Morozov (Novosibirsk Univ.); L. Newelski (Wroclaw Univ.); A. Rhemtulla (Alberta Univ., Edmonton); M. Rubin (Ben Gurion Univ., Beer Sheva); V. Tolstykh (Kemerovo Univ.); M. Volkov (Ekaterinburg Univ.); F. Wagner (Lyon Univ.).

Applications: Deadline for applications: 3-4 months prior to the conference. Scientific Programme and online application at http://www.esf.org/euresco/03/pc03101/.

*27-31 **First Announcement of the 11th International Conference on Finite or Infinite Dimensional Complex Analysis and Applications**, Chiangmai University, Chiangmai, Thailand.

Information: P. Niamsup, Dept. of Math., Faculty of Science, Chiangmai Univ., Chiangmai 50200, Thailand; tel: (053)943327, (053)862807; fax: (053)892280.

27-August 9 (NEW DATE) **Banach Algebras and Their Applications: Banach Algebras 2003**, Edmonton, Alberta, Canada. (Sept. 2002, p. 1001)

August 2003

*3-9 **29th Stochastic Processes and Their Applications**, Hotel do Frade, Angra dos Reis, State of Rio de Janeiro, Brazil.

Scientific Committee: E. Bothausen (Univ. of Zurich), C. Burzdy (Seattle), P. Ferrari (Sao Paulo), M. Keane (Amsterdam), C. Landim (Rio de Janeiro, chair), M. Ledoux (Toulouse), S. Olla (Paris), S. R. S. Varadhan (New York), O. Zeitouni (Haifa),

List of Speakers: A. Bovier (Berlin), R. Burton (Oregon State Univ.), C. Burzdy (Univ. Washington), P. Ferrari (USP, Sao Paulo), A. Guionnet (ENS, Lyon), F. Den Hollander (EURANDOM), D. Ioffe (Technion, Haifa), J. Norris (Cambridge), H. T. Yau (NYU, New York), O. Zeitouni (Technion, Haifa).

Information: http://www.impa.br/Conferencias/Spa/.

4-9 **4th International Algebraic Conference**, Lviv, Ukraine. (Nov. 2002, p. 1287)

14-20 **2003 ASL European Summer Meeting (Logic Colloquium '03)**, Helsinki, Finland. (Sept. 2002, p. 1001)

*18-22 **7th International Symposium on Orthogonal Polynomials, Special Functions and Applications**, Copenhagen, Denmark.

Invited Speakers: R. Askey, Univ. of Wisconsin, Madison, USA; P. Deift, New York Univ., USA; A. J. Duran, Univ. of Sevilla, Spain; U. Haagerup, Univ. of Southern Denmark, Denmark; M. Ismail, Univ. of South Florida, USA; E. Koelink, Technical Univ. Delft, The Netherlands; M. Noumi, Kobe Univ., Japan; F. Peherstorfer, Univ. of Linz, Austria; S. Ruijsenaars, Center for Math. and Comp. Sci., The Netherlands; J. F. van Diejen, Univ. of Talca, Chile; Y. Xu, Univ. of Oregon, USA.

Organizers: C. Berg, J. S. Christiansen, H. L. Pedersen; email: opsfa@math.ku.dk.

Information: http://www.math.ku.dk/conf/opsfa2003/.

September 2003

1-6 **The Sixth International Workshop on Differential Geometry and Its Applications and The Third German-Romanian Seminar on Geometry**, Cluj-Napoca, Romania. (Oct. 2002, p. 1135)

8-10 **25th World Conference on Boundary Element Methods: BEM 25: Incorporating Electromagnetic Effects on Human Beings and Equipment Seminar**, Split, Croatia. (Oct. 2002, p. 1135)

8-December 13 **Inverse Problems: Computational Methods and Emerging Applications**, Institute for Pure and Applied Mathematics, UCLA, Los Angeles, California. (Oct. 2002, p. 1135)

10–12 **Sixth International Conference on Computational Methods for the Solution of Electrical and Electromagnetic Engineering Problems: ELECTROCOMP 2003**, Split, Croatia. (Oct. 2002, p. 1135)

15–19 **Colloquium on the Occasion of the 200th Anniversary of Charles-François Sturm and Workshop on Sturm-Liouville Theory**, University of Geneva, Geneva, Switzerland. (Oct. 2002, p. 1135)

24–26 **International Conference on Differential Equations Devoted to the 100th Anniversary of K. P. Persidskii**, Institute of Mathematics of the ME&S of the RK, Almaty, Kazakhstan (CIS). (Sept. 2002, p. 1001)

October 2003

11–12 **AMS Eastern Section Meeting**, SUNY-Binghamton, Binghamton, New York. (Sept. 2002, p. 1001)

15–20 **Von Neumann Centennial Conference: Linear Operators and Foundations of Quantum Mechanics**, Budapest, Hungary. (Sept. 2002, p. 1001)

24–25 **AMS Southeastern Section Meeting**, University of North Carolina, Chapel Hill, North Carolina. (Sept. 2002, p. 1001)

November 2003

3–5 **Second International Conference on Computational Methods in Multiphase Flow**, Santa Fe, New Mexico. (Oct. 2002, p. 1135)

4–6 **Seventh International Conference on Computational Modelling of Free and Moving Boundary Problems**, Santa Fe, New Mexico. (Oct. 2002, p. 1135)

10–13 **SIAM Conference on Geometric Design & Computing**, Elliott Grand Hyatt, Seattle, Washington. (Nov. 2002, p. 1287)

The following new announcements will not be repeated until the criteria in the next to the last paragraph at the bottom of the first page of this section are met.

December 2003

*15–19 **Numerical Methods in Imaging Science and Information Processing**, Institute for Mathematical Sciences, National University of Singapore, Singapore.

Organizers: R. Chan (Chinese Univ. of Hong Kong, China), S. S. Goh (National Univ. of Singapore), Z. Shen (National Univ. of Singapore), C.-W. Shu (Brown Univ.).

Plenary Speakers: J. Benedetto (Univ. of Maryland), N. Bose (Pennsylvania State Univ.), R. Chan (Chinese Univ. of Hong Kong, China), T. Chan (Univ. of California, Los Angeles), C. Chui (Stanford Univ./Univ. of Missouri - St. Louis), M. Hanke-Bourgeois (Johannes-Gutenberg-Univ., Germany), M. Hegland (Australian National Univ., Australia), A. Katsaggelos (Northwestern Univ.), S. Osher (Univ. of California, Los Angeles), R. Plemmons (Wake Forest Univ.), C.-W. Shu (Brown Univ.).

Registration: Registration forms are available at `http://www.ims.nus.edu.sg/Programs/imgsci/numerical.htm` and should be received at least one month before the conference. For general enquiries, send email to `ims@nus.edu.sg`, while for enquiries on academic matters, send email to S. S. Goh at `matgohss@nus.edu.sg`.

Contributed Talks: Abstracts for 15-minute contributed talks are welcomed and should be received by November 14, 2003. Please submit abstracts to S. S. Goh at `matgohss@nus.edu.sg`. Authors will be notified within one month of submission of the abstracts.

May 2004

*19–23 **2004 ASL Annual Meeting**, Carnegie Mellon Univ., Pittsburgh, Pennsylvania.

Local Organizing Committee: J. Avigad (chair), S. Awodey, L. Blum, J. Cummings, E. Schimmerling, and W. Sieg.

Information: The 2004 Mathematical Foundations of Programming Semantics (MFPS) Meeting, to begin on May 23, 2004, will co-locate with the ASL Annual Meeting. For more information about MFPS, visit `http://www.math.tulane.edu/MFPS.html`.

September 2004

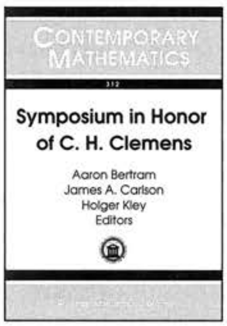
*1–6 **Sixth Pan-African Congress of Mathematicians**, Institute National des Sciences Appliquees et del la Technologie, Tunis, Tunisia.

Theme: Mathematical Sciences and the Development of Africa—Challenges for Building a Knowledge Society in Africa. The scientific program will include plenary lectures, invited lectures, contributed research papers, a symposium, and exhibitions.

Information: Please submit curriculum vitae and abstract to: Prof. J. Persens, Pres., African Mathematical Union, Univ. of the Western Cape, Private Bag X17, Belville 7535, South Africa; `jpersens@uwc.ac.za`; and copies to: Prof. J.-P. Ezin, Sec. General, African Mathematical Union, Institut de Mathematiques et de Sciences Physiques, BP613, Porto Novo, Benin; `jpezin@syfed.bj.refer.org`.

New Publications Offered by the AMS

Algebra and Algebraic Geometry



Symposium in Honor of C. H. Clemens

Aaron Bertram and **James A. Carlson**, *University of Utah, Salt Lake City,* and **Holger Kley**, *Colorado State University, Fort Collins,* Editors

This volume honors Herb Clemens and his contributions to algebraic geometry. The exceptional gathering of mathematicians at the symposium attest to his remarkable career. Papers in the book address topics in which Clemens has been active: the geometry of threefolds, enumerative geometry, Hodge theory, and higher-order methods for attacking deformation problems.

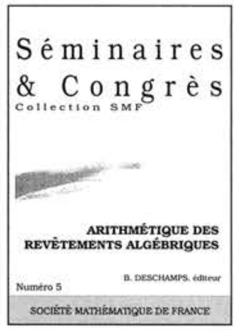
The volume is suitable for graduate students and research mathematicians interested in algebraic geometry.

Contents: D. Allcock, J. A. Carlson, and **D. Toledo**, Orthogonal complex hyperbolic arrangements; **E. Arbarello**, Sketches of KdV; **A. Beauville**, Vector bundles on the cubic threefold; **A. Bertram**, Using symmetry to count rational curves; **R. Friedman** and **J. W. Morgan**, Exceptional groups and del Pezzo surfaces; **M. Green** and **P. Griffiths**, The regulator map for a general curve; **S. Katz**, Versal deformations and superpotentials for rational curves in smooth threefolds; **J. Kollár**, The Nash conjecture for nonprojective threefolds; **Y. Lee**, Bounds and $\mathbb{Q}$-Gorenstein smoothings of smoothable stable log surfaces; **M. V. Nori**, The integral of powers of a function; **Z. Ran**, On semipositivity of sheaves of differential operators and the degree of a unipolar $\mathbb{Q}$-Fano variety; **Y. Ruan**, Stringy geometry and topology of orbifolds; **R. Smith** and **R. Varley**, The Prym Torelli problem: An update and a reformulation as a question in birational geometry; **C. Voisin**, On the punctual Hilbert scheme of a symplectic fourfold.

Contemporary Mathematics, Volume 312

December 2002, 291 pages, Softcover, ISBN 0-8218-2152-0, LC 2002034253, 2000 *Mathematics Subject Classification*: 14C05, 14C34, 14H40, 14J10, 14J17, 14J26, 14J30, 14J32, 14J45, 14J60, **Individual member $47**, List $79, Institutional member $63, Order code CONM/312N

Independent Study



Arithmétique des Revêtements Algébriques

B. Deschamps, *Université Jean Monnet, St. Etienne, France,* Editor

A publication of the Société Mathématique de France.

This book presents articles from the conference on algebraic coverings held in March 2000 in St. Etienne (France). The goal of the conference was to introduce the algebraic bases of this theory and to give a survey of the research tools. These proceedings reflect the spirit of the conference.

The book includes widely accessible survey and research papers on a range of topics, including inverse Galois theory, moduli spaces, problems of descent, rigid geometry, the language of stacks and gerbs and its applications, Galois modules, and morphisms of curves. There is also an appendix with a short lecture on topological and algebraic covers that will make a good introduction to the subject for the non-specialist.

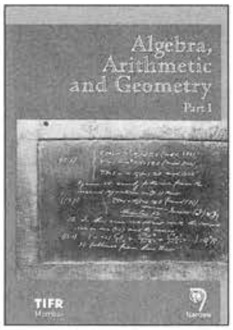
The volume is intended for advanced graduate students and researchers. It would make a nice addition to a seminar on algebraic coverings.

Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: P. Dèbes, Thèorie de Galois et géométrie: une introduction; **P. Dèbes**, Méthodes topologiques et analytiques en théorie inverse de Galois: Théorème d'existence de Riemann; **Q. Liu**, Une mini introduction à la géométrie analytique rigide; **M. Emsalem**, Espaces de Hurwitz; **S. Flon**, Corps des modules et bonnes places; **J.-C. Douai**, Descente, champs et gerbes de Hurwitz; **Ph. Satgé**, Morphismes d'une courbe de genre 2 vers une courbe de genre 1; **N. Borne**, Modules galoisiens sur les courbes: une introduction; **P. Dèbes**, Annexe: Revêtements topologiques.

Séminaires et Congrès, Number 5

May 2002, 214 pages, Softcover, ISBN 2-85629-116-3, 2000 *Mathematics Subject Classification*: 12F12, 14H30, 14G32, 12E30, 14D15, 14D10, 14H05, 14H10, 30F10, 14G27, 14D22, 14E22, 14G22, 18G50, 14E20, 11G99, 14H37, 14C40, **Individual member $50**, List $56, Order code SECO/5N



Algebra, Arithmetic and Geometry Mumbai 2000 (Parts I and II)

R. Parimala, *Tata Institute of Fundamental Research, Mumbai, India*, Editor

A publication of the Tata Institute of Fundamental Research.

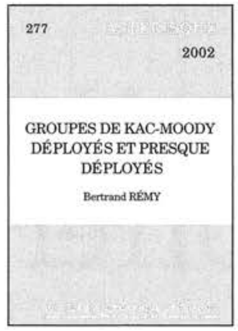
This volume contains papers by invited speakers at the International Colloquium on Algebra, Arithmetic and Geometry, held at the Tata Institute of Fundamental Research (Mumbai, India) in January 2000. The articles present the latest developments in a broad variety of topics from algebraic geometry, group theory, and K-theory. It is suitable for graduate students and research mathematicians interested in those areas.

Distributed worldwide except in India, Bangladesh, Bhutan, Maldavis, Nepal, Pakistan, and Sri Lanka.

Contents: *Part I:* **S. S. Abhyankar**, Symplectic groups and permutation polynomials; **L. L. Avramov** and **S. Iyengar**, Homological criteria for regular homomorphisms and for locally complete intersection homomorphisms; **P. Barquero** and **A. Merkurjev**, Norm principle for reductive algebraic groups; **S. M. Bhatwadekar** and **R. Sridharan**, On Euler classes and stably free projective modules; **J. Biswas**, **G. Dayal**, **K. H. Paranjape**, and **G. V. Ravindra**, Higher Abel-Jacobi maps; **S. Bloch** and **V. Srinivas**, Enriched Hodge structures; **J.-L. Colliot-Thélène**, **M. Ojanguren**, and **R. Parimala**, Quadratic forms over fraction fields of two-dimensional Henselian rings and Brauer groups of related schemes; **E. M. Friedlander** and **M. E. Walker**, Semi-topological K-theory of real varieties; *Part II:* **J. Herzog** and **E. Sbarra**, Sequentially Cohen-Macaulay modules and local cohomology; **W. van der Kallen**, From Mennicke symbols to Euler class groups; **M.-A. Knus**, **R. Parimala**, and **R. Sridharan**, On generic triality; **V. B. Mehta** and **S. Subramanian**, On the Harder-Narasimhan filtration of principal bundles; **V. B. Mehta** and **A. J. Parameswaran**, Geometry of low height representations; **M. Miyanishi** and **K. Masuda**, Generalized Jacobian conjecture and related topics; **N. M. Kumar**, Construction of rank two vector bundles on projective spaces; **M. V. Nori**, Constructible sheaves; **M. P. Murthy**, Cancellation problem for projective modules over certain affine algebras; **V. L. Popov**, Self-dual algebraic varieties and nilpotent orbits; **P. C. Roberts**, Intersection multiplicities and dimension inequalities; **P. Russell**, Some formal aspects of the theorems of Mumford-Ramanujam; **R. Sujatha**, Euler-Poincaré characteristics of p-adic Lie groups and arithmetic; **A. Suslin**, On the vanishing of $H_3(SL_2(A,I),\mathbb{Z}/l)$.

Tata Institute of Fundamental Research

May 2002, 651 pages, Hardcover, ISBN 81-7319-476-9, 2000 *Mathematics Subject Classification*: 11-XX, 13-XX, 14-XX; 11Exx, 11Gxx, 13Cxx, 13Dxx, 14Cxx, 14Fxx, **All AMS members $52**, List $65, Order code TIFR/5N



Groupes de Kac-Moody Déployés et Presque Déployés

Bertrand Rémy, *Université de Grenoble, Saint-Martin d'Héres, France*

A publication of the Société Mathématique de France.

There are two main parts to this book. The first part deals with combinatorial and geometric objects, namely a class of groups defined by a certain set of abstract axioms. The class includes (isotropic) reductive algebraic groups and (split) Kac-Moody groups. A twin building is attached to each group, which enables the use of notions of negative curvature and convexity. The author proves amalgam theorems, as well as Levi decompositions for some subgroups.

The second part is relevant to Kac-Moody theory. In particular, the author formulates a relative theory for Kac-Moody groups. The goal is to obtain a Galois descent theorem, i.e., to prove the persistence of the group combinatorics after passing to the rational points. The main tools are algebraic group arguments and the use of an adjoint representation as a functorial substitute for a global algebro-geometric structure.

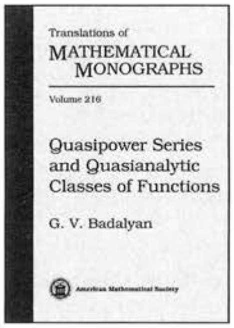
Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; *Partie I. Données radicielles jumelées:* Combinatoire des groupes; Immeubles (jumelés) abstraits; Ensembles ordonnés et amalgames de groupes; Courbure négative dans les immeubles généraux; Géométrie conique des jumelages; Décompositions de Lévi dans les données radicielles jumelées; *Partie II. Foncteurs de Tits, groupes de Kac-Moody déployés et presque déployés:* Algèbres de type Kac-Moody; Foncteurs de Tits. Groupes de Kac-Moody; Représentation adjointe des foncteurs de Tits; Groupes de Kac-Moody déployés en caractéristique quelconque; $\mathbb{K}$-Formes des foncteurs de Tits; Descente galoisienne; Constructions de formes. Actions galoisiennes. Formes quasidéployées. Descente dans un immeuble hyperbolique; Index des définitions; Index des axiomes et conditions; Bibliographie.

Astérisque, Number 277

June 2002, 348 pages, Softcover, ISBN 2-85629-114-7, 2000 *Mathematics Subject Classification*: 20E42, 51E24, 20G15, 20F05, 20F55, 17B67, 54E35, **Individual member $68**, List $76, Order code AST/277N

Analysis



Quasipower Series and Quasianalytic Classes of Functions

G. V. Badalyan, *Armenian Academy of Sciences, Armenia*

In this book, G.V. Badalyan addresses the fundamental problems of the theory of infinitely-differentiable functions using the theory of functions of quasianalytic classes.

A certain class of functions C on an interval is called quasianalytic if any function in C is uniquely determined by the values of its derivatives at any point. The obvious question, then, is how to reconstruct such a function from the sequence of values of its derivatives at a certain point. In order to answer that question, Badalyan combines a study of expanding functions in generalized factorial series with a study of quasipower series.

The theory of quasipower series and its application to the reconstruction problem are explained in detail in this research monograph. Along the way other, related problems are solved, such as Borel's hypothesis that no quasianalytic function can have all positive derivatives at a point.

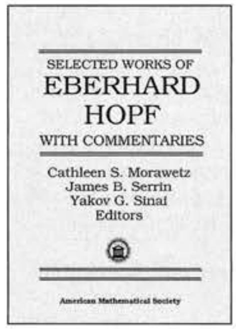
Originally published in Russian, this English translation contains additional materials that treat the problems of classification of infinitely-differentiable functions, conditions for absolute convergence of quasipower series in terms of the functions that generate them, and the possibility of representing analytic functions by quasipower series in non-circular domains.

While the treatment is technical, the theory is developed chapter by chapter in detail, and the first chapter is of an introductory nature. The quasipower series technique explained here provides the means to extend the previously known results and elucidates their nature in the most relevant manner. This method also allows for thorough investigation of numerous problems of the theory of functions of quasianalytic classes by graduate students and research mathematicians.

Contents: Quasianalytic classes of functions; Generalizations of the Taylor formula. Quasipower series; Functions of Carleman's classes: Expansion in quasipower series; Criteria for the possibility of expanding functions in quasipower and factorial series; Generalized completely monotone functions and the condition for absolute convergence of a quasipower series (in the basic interval); On the use of quasipower series for representation of analytic functions in non-circular domains; Some applications of quasipower series to the theory of functions of quasianalytic classes; Bibliography.

Translations of Mathematical Monographs, Volume 216

December 2002, 183 pages, Hardcover, ISBN 0-8218-2943-2, LC 2002034246, 2000 *Mathematics Subject Classification*: 30Bxx, 30D60, **Individual member $47**, List $79, Institutional member $63, Order code MMONO/216N



Selected Works of Eberhard Hopf with Commentaries

Cathleen S. Morawetz, *New York University-Courant Institute*, **James B. Serrin**, *University of Minnesota, Minneapolis*, and **Yakov G. Sinai**, *Princeton University, NJ*, Editors

This work celebrates the work of Eberhard Hopf, a founding father of ergodic theory, a mathematician who produced many beautiful, elegantly written, and now classical results in integral equations and partial differential equations. Hopf's results remain at the core of these fields, and the title includes Hopf's original mathematical papers, still notable for their elegance and clarity of the writing, with accompanying summaries and commentary by well-known mathematicians.

Today, ergodic theory and P.D.E. continue to be active, important areas of mathematics. In this volume the reader will find the roots of many ergodic theory concepts and theorems. Hopf authored fundamental results for P.D.E., such as the maximum principle of elliptic equations and the complete solution of Burger's equation. The familiar properties of elliptic equations were proved for the first time in his earliest work and are included here. His bifurcation theorem, still used over and over again, is a particular gem. The proof of the Wiener-Hopf Theorem is a stunning application of deep analysis.

The volume is presented in two main parts. The first section is dedicated to classical papers in analysis and fluid dynamics, and the second to ergodic theory.

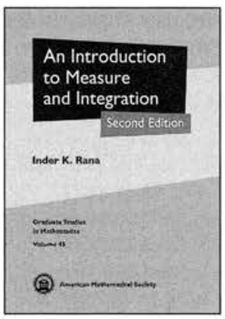
These works and all the others in the Selected Works carry commentaries by a stellar group of mathematicians who write of the origin of the problems, the important results that followed. Many a mathematical researcher and graduate student will find these collected works to be an excellent resource.

Contents: *Part I:* **E. Hopf**, Elementare Bemerkungen über die Lösungen partieller Differentialgleichungen zweiter Ordnung vom elliptischen Typus; **J. B. Serrin**, Commentary; **E. Hopf**, A remark on linear elliptic differential equations of second order; **J. B. Serrin**, Commentary; **E. Hopf**, Zum analytischen Charakter der Lösungen regulärer zweidimensionaler Variationsprobleme; **H. Weinberger**, Commentary; **N. Wiener** and **E. Hopf**, Über eine Klasse singulärer Integralgleichungen; **H. Widom**, Commentary; **E. Hopf**, Über den funktionalen, insbesondere den analytischen Charakter der Lösungen elliptscher Differentialgleichungen zweiter Ordnung; **H. Weinberger**, Commentary; **E. Hopf**, Abzweigung einer periodischen Lösung von einer stationären Lösung eines Differentialsystems; **M. Golubitsky** and **P. H. Rabinowitz**, Commentary; **E. Hopf**, Repeated branching through loss of stability. An example; **E. Hopf**, A mathematical example displaying features of turbulence; **R. Temam**, Commentary; **E. Hopf**, On S. Bernstein's theorem on surfaces $z(x,y)$ of nonpositive curvature; **L. Nirenberg**, Commentary; **E. Hopf**, The partial differential equation $u_t + uu_x = \mu_{xx}$; **P. D. Lax**, Commentary; **E. Hopf**, Über die Anfangswertaufgabe für die hydrodynamischen Grundgleichungen; **J. B. Serrin**, Commentary; **E. D. Conway** and **E. Hopf**, Hamilton's theory and generalized solutions of the Hamilton-Jacobi equation; **C. S. Morawetz**, Commentary; *Part II:* **E. Hopf**, Statistik der geodätischen Linien in Mannigfaltigkeiten negativer Krümmung; **E. Hopf**, Statistik der Lösungen geodätischer Probleme vom unstabilen Typus. II; **Ya. G. Sinai**, Commentary; **E. Hopf**, Closed surfaces without conjugate points; **Ya. G. Sinai**, Commentary; **E. Hopf**, Statistical hydromechanics and functional calculus; **Ya. G. Sinai**, Commentary; **E. Hopf**, On the ergodic theorem for positive linear operators; **D. Ornstein**, Commentary; Acknowledgments.

Collected Works, Volume 17

January 2003, 396 pages, Hardcover, ISBN 0-8218-2077-X, LC 2002033244, 2000 *Mathematics Subject Classification*: 30-XX, 34-XX, 35-XX, 37-XX; 34C23, 35Q30, 45-XX, 47-XX, **All AMS members $79**, List $99, Order code CWORKS/17N

Recommended Text



An Introduction to Measure and Integration
Second Edition

Inder K. Rana, *Indian Institute of Technology, Powai, Mumbai, India*

From reviews for the first edition:

Distinctive features include: 1) An unusually extensive treatment of the historical developments leading up to the Lebesgue integral ... 2) Presentation of the standard extension of an abstract measure on an algebra to a sigma algebra prior to the final stage of development of Lebesgue measure. 3) Extensive treatment of change of variables theorems for functions of one and several variables ... the conversational tone and helpful insights make this a useful introduction to the topic ... The material is presented with generous details and helpful examples at a level suitable for an introductory course or for self-study.

—Zentralblatt MATH

A special feature [of the book] is the extensive historical and motivational discussion ... At every step, whenever a new concept is introduced, the author takes pains to explain how the concept can be seen to arise naturally ... The book attempts to be comprehensive and largely succeeds ... The text can be used for either a one-semester or a one-year course at M.Sc. level ... The book is clearly a labor of love. The exuberance of detail, the wealth of examples and the evident delight in discussing variations and counter examples, all attest to that ... All in all, the book is highly recommended to serious and demanding students.

—Resonance

Integration is one of the two cornerstones of analysis. Since the fundamental work of Lebesgue, integration has been interpreted in terms of measure theory. This introductory text starts with the historical development of the notion of the integral and a review of the Riemann integral. From here, the reader is naturally led to the consideration of the Lebesgue integral, where abstract integration is developed via measure theory. The important basic topics are all covered: the Fundamental Theorem of Calculus, Fubini's Theorem, L_p spaces, the Radon-Nikodym Theorem, change of variables formulas, and so on.

The book is written in an informal style to make the subject matter easily accessible. Concepts are developed with the help of motivating examples, probing questions, and many exercises. It would be suitable as a textbook for an introductory course on the topic or for self-study.

For this edition, more exercises and four appendices have been added.

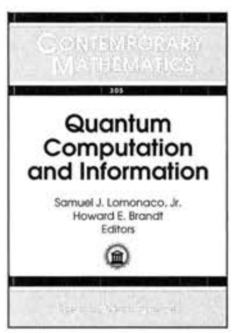
The AMS maintains exclusive distribution rights for this edition in North America and nonexclusive distribution rights worldwide, excluding India, Pakistan, Bangladesh, Nepal, Bhutan, Sikkim, and Sri Lanka.

Contents: Prologue: The length function; Riemann integration; Recipes for extending the Riemann integral; General extension theory; The Lebesgue measure on ℝ and its properties; Integration; Fundamental theorem of calculus for the Lebesgue integral; Measure and integration on product spaces; Modes of convergence and L_p-spaces; The Radon-Nikodym theorem and its applications; Signed measures and complex measures; Extended real numbers; Axiom of choice; Continuum hypotheses; Urysohn's lemma; Singular value decomposition of a matrix; Functions of bounded variation; Differentiable transformations; References; Index; Index of notations.

Graduate Studies in Mathematics, Volume 45

November 2002, approximately 459 pages, Hardcover, ISBN 0-8218-2974-2, LC 2002018244, 2000 *Mathematics Subject Classification*: 28-01; 28A05, 28A10, 28A12, 28A15, 28A20, 28A25, 28A33, 28A35, 26A30, 26A42, 26A45, 26A46, **All AMS members $47**, List $59, Order code GSM/45N

Applications



Quantum Computation and Information

Samuel J. Lomonaco, Jr., *University of Maryland, Baltimore*, and **Howard E. Brandt**, *Army Research Lab, Adelphi, MD*, Editors

This book is a collection of papers given by invited speakers at the first AMS Special Session on Quantum Computation and Information held at the January 2000 Annual Meeting of the AMS in Washington, DC.

The papers in this volume give readers a broad introduction to the many mathematical research challenges posed by the new and emerging field of quantum computation and quantum information. Of particular interest is a long paper by Lomonaco and Kauffman discussing mathematical and computational aspects of the so-called hidden subgroup algorithm.

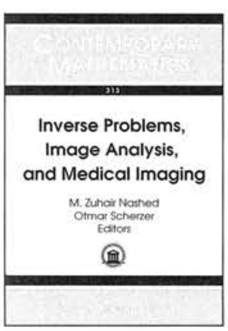
This book is intended to help readers recognize that, as a result of this new field of quantum information science, mathematical research opportunities abound in such diverse mathematical fields as algebraic coding theory, algebraic geometry, algebraic topology, communication theory, control theory, cryptography, differential geometry, differential topology, dynamical systems, game theory, group theory, information theory, number theory, operator theory, robotics, theory of computation, mathematical logic, mathematical physics, and more. It is hoped that this book will act as a catalyst to encourage members of the mathematical community to take advantage of the many mathematical research opportunities arising from the "grand challenge" of Quantum Information Science.

This book is the companion volume to *Quantum Computation: A Grand Mathematical Challenge for the Twenty-First Century and the Millennium*, PSAPM/58, Volume 58 in the Proceedings of Symposia in Applied Mathematics series.

Contents: P. Benioff, Space searches with a quantum robot; **G. P. Berman**, **G. D. Doolen**, **D. I. Kamenev**, **G. V. López**, and **V. I. Tsifrinovich**, Perturbation theory and numerical modeling of quantum logic operations with a large number of qubits; **H. E. Brandt**, Inconclusive rate with a positive operator valued measure; **G. Brassard**, **P. Høyer**, **M. Mosca**, and **A. Tapp**, Quantum amplitude amplification and estimation; **L. Hardy**, Manipulating the entanglement of one copy of a two-particle pure entangled state; **T. F. Havel** and **C. J. L. Doran**, Geometric algebra in quantum information processing; **L. H. Kauffman**, Quantum computing and the Jones polynomial; **S. J. Lomonaco, Jr.** and **L. H. Kauffman**, Quantum hidden subgroup algorithms: A mathematical perspective; **E. N. Maneva** and **J. A. Smolin**, Improved two-party and multi-party purification protocols; **D. A. Meyer**, Quantum games and quantum algorithms; **J. M. Myers** and **F. H. Madjid**, A proof that measured data and equations of quantum mechanics can be linked only by guesswork; **J. Pachos**, Quantum computation by geometrical means; **M. B. Ruskai**, Pauli exchange and quantum error correction; **B. Schumacher** and **M. D. Westmoreland**, Relative entropy in quantum information theory; **N. R. Wallach**, An unentangled Gleason's theorem; **W. K. Wootters**, Entangled chains.

Contemporary Mathematics, Volume 305

November 2002, 310 pages, Softcover, ISBN 0-8218-2140-7, LC 2002026239, 2000 *Mathematics Subject Classification*: 81P68, 94-02; 68Q05, 81-01, 81R99, 94A60, 94A99, **Individual member $47**, List $79, Institutional member $63, Order code CONM/305N



Inverse Problems, Image Analysis, and Medical Imaging

M. Zuhair Nashed, *University of Central Florida, Orlando*, and **Otmar Scherzer**, *University of Innsbruck, Austria*, Editors

This book contains the proceedings of the Special Session, Interaction of Inverse Problems and Image Analysis, held at the January 2001 meeting of the AMS in New Orleans, LA.

The common thread among inverse problems, signal analysis, and image analysis is a canonical problem: recovering an object (function, signal, picture) from partial or indirect information about the object. Both inverse problems and imaging science have emerged in recent years as interdisciplinary research fields with profound applications in many areas of science, engineering, technology, and medicine. Research in inverse problems and image processing shows rich interaction with several areas of mathematics and strong links to signal processing, variational problems, applied harmonic analysis, and computational mathematics.

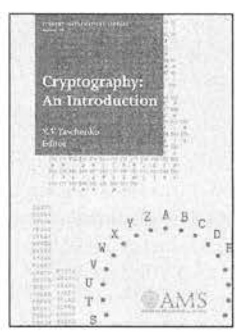
This volume contains carefully refereed and edited original research papers and high-level survey papers that provide overview and perspective on the interaction of inverse problems, image analysis, and medical imaging.

The book is suitable for graduate students and researchers interested in signal and image processing and medical imaging.

Contents: R. B. Alexeev and **A. B. Smirnova**, Regularization of nonlinear unstable operator equations by secant methods with application to gravitational sounding problem; **J. J. Benedetto** and **S. Sumetkijakan**, A fractal set constructed from a class of wavelet sets; **M. Boutin**, Joint invariant signatures for curve recognition; **T. F. Chan** and **J. Shen**, Inpainting based on nonlinear transport and diffusion; **U. Clarenz**, **M. Droske**, and **M. Rumpf**, Towards fast non-rigid registration; **C. De Mol** and **M. Defrise**, A note on wavelet-based inversion algorithms; **M. El-Gamel** and **A. I. Zayed**, A comparison between the wavelet-Galerkin and the Sinc-Galerkin methods in solving nonhomogeneous heat equations; **B. Fischer** and **J. Modersitzki**, Fast diffusion registration; **C. W. Groetsch** and **O. Scherzer**, Iterative stabilization and edge detection; **F. A. Grünbaum**, Backprojections in tomography, spherical functions and addition formulas: A few challenges; **B. A. Mair** and **J. A. Zahnen**, Mathematical models for 2d positron emission tomography; **O. Scherzer**, Explicit versus implicit relative error regularization on the space of functions of bounded variations; **F. Stenger**, **A. R. Naghsh-Nilchi**, **J. Niebsch**, and **R. Ramlau**, Sampling methods for approximate solution of pde; **J. Weickert** and **T. Brox**, Diffusion and regularization of vector- and matrix-valued images; **I. Yamada**, **N. Ogura**, and **N. Shirakawa**, A numerically robust hybrid steepest descent method for the convexly constrained generalized inverse problems.

Contemporary Mathematics, Volume 313

December 2002, 303 pages, Softcover, ISBN 0-8218-2979-3, LC 2002034298, 2000 *Mathematics Subject Classification*: 00Bxx, 45Q05, 65Jxx, 65Rxx, 65Kxx, 65T60, 34G20, 35A15, 41-XX, 42-XX, **Individual member $47**, List $79, Institutional member $63, Order code CONM/313N



Recommended Text

Cryptography: An Introduction

V. V. Yaschenko, *Moscow Center for Continuous Mathematics Education, Russia*, Editor

Learning about cryptography requires examining fundamental issues about information security. Questions abound, ranging from "Whom are we protecting ourselves from?" and "How can we measure levels of security?" to "What are our opponent's capabilities?" and "What are their goals?" Answering these questions requires an understanding of basic cryptography. This book, written by Russian cryptographers, explains those basics.

Chapters are independent and can be read in any order. The introduction gives a general description of all the main notions of modern cryptography: a cipher, a key, security, an electronic digital signature, a cryptographic protocol, etc. Other chapters delve more deeply into this material. The final chapter presents problems and selected solutions from "Cryptography Olympiads for (Russian) High School Students".

This is an English translation of a Russian textbook. It is suitable for advanced high school students and undergraduates studying information security. It is also appropriate for a general mathematical audience interested in cryptography.

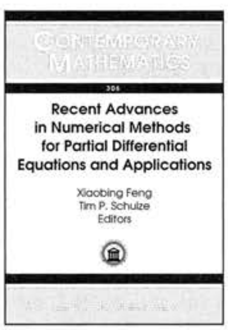
This item will also be of interest to those working in number theory.

Also on cryptography and available from the AMS is *Codebreakers: Arne Beurling and the Swedish Crypto Program during World War II*, SWCRY.

Contents: Main notions; Cryptograpy and complexity theory; Cryptographic protocols; Algorithmic problems of number theory; Mathematics of secret sharing; Cryptography olympiads for high school students; Bibliography.

Student Mathematical Library, Volume 18

December 2002, approximately 234 pages, Softcover, ISBN 0-8218-2986-6, LC 2002027740, 2000 *Mathematics Subject Classification*: 94-01, 94A60; 11T71, 68P25, **All AMS members $31**, List $39, Order code STML/18N



Recent Advances in Numerical Methods for Partial Differential Equations and Applications

Xiaobing Feng, *University of Tennessee, Knoxville*, and **Tim P. Schulze**, *New York University-Courant Institute*, Editors

This book is derived from lectures presented at the 2001 John H. Barrett Memorial Lectures at the University of Tennessee, Knoxville. The topic was computational mathematics, focusing on parallel numerical algorithms for partial differential equations, their implementation and applications in fluid mechanics and material science. Compiled here are articles from six of nine speakers. Each of them is a leading researcher in the field of computational mathematics and its applications.

A vast area that has been coming into its own over the past 15 years, computational mathematics has experienced major developments in both algorithmic advances and applications to other fields. These developments have had profound implications in mathematics, science, engineering and industry. With the aid of powerful high performance computers, numerical simulation of physical phenomena is the only feasible method for analyzing many types of important phenomena, joining experimentation and theoretical analysis as the third method of scientific investigation.

The three aspects: applications, theory, and computer implementation comprise a comprehensive overview of the topic. Leading lecturers were Mary Wheeler on applications, Jinchao Xu on theory, and David Keyes on computer implementation.

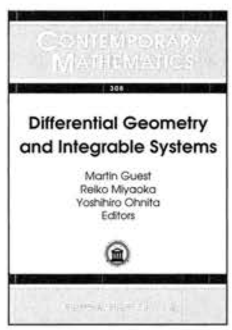
Following the tradition of the Barrett Lectures, these in-depth articles and expository discussions make this book a useful reference for graduate students as well as the many groups of researchers working in advanced computations, including engineering and computer scientists.

Contents: J. Xu and **A. Zhou**, Some multiscale methods for partial differential equations; **D. E. Keyes**, Terascale implicit methods for partial differential equations; **M. Peszyńska**, **E. W. Jenkins**, and **M. F. Wheeler**, Boundary conditions for fully implicit two-phase flow models; **G. B. McFadden**, Phase-field models of solidification; **Q. Nie**, **S. Tanveer**, **T. F. Dupont**, and **X. Li**, Singularity formation in free-surface Stokes flows; **C. C. Douglas** and **D. T. Thorne**, A note on cache memory methods for multigrid in three dimensions.

Contemporary Mathematics, Volume 306

November 2002, 177 pages, Softcover, ISBN 0-8218-2970-X, LC 2002028160, 2000 *Mathematics Subject Classification*: 65F10, 65M55, 65M60, 65M70, 65Y05, 68U20, 76S05, 74N20, 80A22, 86A10, **Individual member $29**, List $49, Institutional member $39, Order code CONM/306N

Differential Equations



Differential Geometry and Integrable Systems

Martin Guest, *Tokyo Metropolitan University, Japan*, **Reiko Miyaoka**, *Sophia University, Tokyo, Japan*, and **Yoshihiro Ohnita**, *Tokyo Metropolitan University, Japan*, Editors

Ideas and techniques from the theory of integrable systems are playing an increasingly important role in geometry. Thanks to the development of tools from Lie theory, algebraic geometry, symplectic geometry, and topology, classical problems are investigated more systematically. New problems are also arising in mathematical physics. A major international conference was held at the University of Tokyo in July 2000. It brought together scientists in all of the areas influenced by integrable systems. This book is the first of three collections of expository and research articles.

This volume focuses on differential geometry. It is remarkable that many classical objects in surface theory and submanifold theory are described as integrable systems. Having such a description generally reveals previously unnoticed symmetries and can lead to surprisingly explicit solutions. Surfaces of constant curvature in Euclidean space, harmonic maps from surfaces to symmetric spaces, and analogous structures on higher-dimensional manifolds are some of the examples that have broadened the horizons of differential geometry, bringing a rich supply of concrete examples into the theory of integrable systems.

Many of the articles in this volume are written by prominent researchers and will serve as introductions to the topics. It is intended for graduate students and researchers interested in integrable systems and their relations to differential geometry, topology, algebraic geometry, and physics.

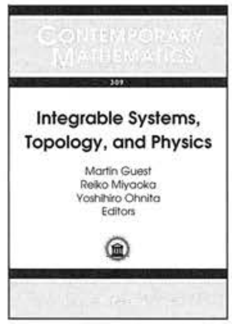
The second volume from this conference also available from the AMS is *Integrable Systems, Topology, and Physics*, Volume 309 CONM/309in the Contemporary Mathematics series. The forthcoming third volume will be published by the Mathematical Society of Japan and will be available outside of Japan from the AMS in the Advanced Studies in Pure Mathematics series.

This item will also be of interest to those working in geometry and topology and mathematical physics.

Contents: N. Ando, The index of an isolated umbilical point on a surface; **J. Bolton**, The Toda equations and equiharmonic maps of surfaces into flag manifolds; **J.-M. Burel** and **E. Loubeau**, p-harmonic morphisms: The $1 < p < 2$ case and some non-trivial examples; **F. Burstall**, **F. Pedit**, and **U. Pinkall**, Schwarzian derivatives and flows of surfaces; **V. De Smedt** and **S. Salamon**, Anti-self-dual metrics on Lie groups; **J. Dorfmeister**, **J.-i. Inoguchi**, and **M. Toda**, Weierstraß-type representation of timelike surfaces with constant mean curvature; **N. Ejiri**, A differential-geometric Schottky problem, and minimal surfaces in tori; **E. V. Ferapontov**, Surfaces in 3-space possessing nontrivial deformations which preserve the shape operator; **F. Hélein** and **P. Romon**, Hamiltonian stationary Lagrangian surfaces in Hermitian symmetric spaces; **H. Hu**, Line congruences and integrable systems; **X. Jiao**, Factorizations of harmonic maps of surfaces into Lie groups by singular dressing actions; **H. Jin** and **X. Mo**, On submersive p-harmonic morphisms and their stability; **K. Kiyohara**, On Kähler-Liouville manifolds; **M. Kokubu**, **M. Umehara**, and **K. Yamada**, Minimal surfaces that attain equality in the Chern-Osserman inequality; **V. S. Matveev**, Low dimensional manifolds admitting metrics with the same geodesics; **Y. Ohnita** and **S. Udagawa**, Harmonic maps of finite type into generalized flag manifolds, and twistor fibrations; **J. Park**, Submanifolds associated to Grassmannian systems; **Y. Sakane** and **T. Yamada**, Harmonic cohomology groups of compact symplectic nilmanifolds; **B. A. Springborn**, Bonnet pairs in the 3-sphere; **M. S. Tanaka**, Subspaces in the category of symmetric spaces; **H. Tasaki**, Integral geometry of submanifolds of real dimension two and codimension two in complex projective spaces; **J. C. Wood**, Jacobi fields along harmonic maps; **H. Wu**, Denseness of plain constant mean curvature surfaces in dressing orbits.

Contemporary Mathematics, Volume 308

November 2002, 349 pages, Softcover, ISBN 0-8218-2938-6, LC 2002028162, 2000 *Mathematics Subject Classification*: 35Q53, 37K05, 37K10, 53A05, 53A07, 53A10, 58D25, 58D27, 58E20, 70H06, **Individual member $51**, List $85, Institutional member $68, Order code CONM/308N



Integrable Systems, Topology, and Physics

Martin Guest, *Tokyo Metropolitan University, Japan*, **Reiko Miyaoka**, *Sophia University, Tokyo, Japan*, and **Yoshihiro Ohnita**, *Tokyo Metropolitan University, Japan*, Editors

Ideas and techniques from the theory of integrable systems are playing an increasingly important role in geometry. Thanks to the development of tools from Lie theory, algebraic geometry, symplectic geometry, and topology, classical problems are investigated more systematically. New problems are also arising in mathematical physics. A major international conference was held at the University of Tokyo in July 2000. It brought together scientists in all of the areas influenced by integrable systems. This book is the second of three collections of expository and research articles.

This volume focuses on topology and physics. The role of zero curvature equations outside of the traditional context of differential geometry has been recognized relatively recently, but it has been an extraordinarily productive one, and most of the articles in this volume make some reference to it. Symplectic geometry, Floer homology, twistor theory, quantum cohomology, and the structure of special equations of mathematical physics, such as the Toda field equations—all of these areas have gained from the integrable systems point of view and contributed to it.

Many of the articles in this volume are written by prominent researchers and will serve as introductions to the topics. It is intended for graduate students and researchers interested in integrable systems and their relations to differential geometry, topology, algebraic geometry, and physics.

The first volume from this conference also available from the AMS is *Differential Geometry and Integrable Systems*, Volume 308 CONM/308 in the Contemporary Mathematics series. The forthcoming third volume will be published by the Mathematical Society of Japan and will be available outside of Japan from the AMS in the Advanced Studies in Pure Mathematics series.

This item will also be of interest to those working in geometry and topology and mathematical physics.

Contents: L. Casian and **Y. Kodama**, Twisted Tomei manifolds and the Toda lattices; **J.-H. Chang**, Quantization of Benney hierarchies; **K. Fukaya**, Floer homology for families–A progress report; **R. Goto**, Rozansky-Witten invariants of log symplectic manifolds; **M. A. Guest**, An update on harmonic maps of finite uniton number, via the zero curvature equation; **R. Inoue**, The lattice Toda field theory for simple Lie algebras; **H. Konno**, On the cohomology ring of the hyperKähler analogue of the polygon spaces; **A.-L. Mare**, On the theorem of Kim concerning $QH^*(G/B)$; **Y. Nagatomo**, Geometry of the twistor equation and its applications; **A. Nakayashiki**, On the cohomology of theta divisors of hyperelliptic Jacobians; **Y. Ohyama**, Isomonodromy deformations and twistor theory; **K. Ono**, Simple singularities and symplectic fillings; **T. Otofuji**, Quantum cohomology of infinite dimensional flag manifolds; **S. Saito**, **N. Suzuki**, and **H. Yamaguchi**, Discrete conjugate nets of strings; **B. A. Shipman**, Nongeneric flows in the full Kostant-Toda lattice; **I. A. B. Strachan**, Frobenius manifolds and bi-Hamiltonian structures on discriminant hypersurfaces; **T. Taniguchi**, Periodicity conditions for harmonic maps associated to spectral data; **Y. Terashima**, Higher dimensional parallel transports for Deligne cocycles; **H.-Y. Wang**, Geometric nonlinear Schrödinger equations.

Contemporary Mathematics, Volume 309

December 2002, approximately 344 pages, Softcover, ISBN 0-8218-2939-4, 2000 *Mathematics Subject Classification*: 35Q53, 37K05, 37K10, 53A05, 53A07, 53A10, 58D25, 58D27, 58E20, 70H06, **Individual member $51**, List $85, Institutional member $68, Order code CONM/309N

Optique Géometrique pour des Systèmes Semi-Linéaires avec Invariance de Jauge

Pierre-Yves Jeanne, *Université Paris-Sud, Orsay, France*

A publication of the Société Mathématique de France.

The goal of this memoir is to justify the use of methods of "geometric optics" type for a large class of semilinear systems that remain invariant under gauge and Lorentz transformations. The author explicitly constructs families of approximate solutions of a model system coupling a gauge field (Yang-Mills equation) with a scalar field (wave equation) and a spinor field (Dirac equation) in the form of single phase expansions oscillating at high frequency and with maximal amplitude. Further, the author proves the existence of exact solutions that remain asymptotic to the expansions already obtained. There is a stability result in the case where oscillatory solutions are obtained as high-frequency perturbations of a given smooth solution of the system. It shows that the system can keep a stable nonlinear behavior, even fields with very weak regularity, where nonlinear terms usually lead to destructive interactions.

The book is of interest to graduate students and research mathematicians in partial differential equations and their applications.

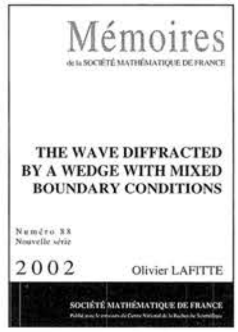
This item will also be of interest to those working in mathematical physics.

Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Construction de familles de solutions approchées de (YM) sous forme de développements oscillant à haute fréquence, monophasés, et d'amplitude maximale; Prolongement asymptotique des familles de solutions approchées par des familles de solutions exactes; Appendice A; Appendice B; Bibliographie.

Mémoires de la Société Mathématique de France, Number 90

0249-633X, July 2002, 160 pages, ISBN 2-85629-123-6, 2000 *Mathematics Subject Classification*: 78A05, 81T13, 35L70, 35Q75, **Individual member $30**, List $33, Order code SMFMEM/90N



The Wave Diffracted by a Wedge with Mixed Boundary Conditions

Olivier Lafitte, *Massachusetts Institute of Technology, Cambridge*

A publication of the Société Mathématique de France.

This monograph studies the diffraction of a wave by a curved wedge on the plane in the case where each side of the wedge is characterized by a mixed boundary condition of impedance type.

This book is suitable for graduate students and researchers interested in partial differential equations, in particular in diffraction theory and its applications to problems in physics.

Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

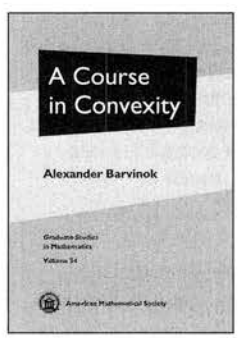
Contents: Introduction; Existence, uniqueness, and regularity of the solution; Diffraction by a straight wedge; Microlocal propagation of singularities for the mixed problem; Reduced system on the boundary; Calculus of the diffraction coefficient; Appendix; Bibliography.

Mémoires de la Société Mathématique de France, Number 88

0249-633X, June 2002, 167 pages, Softcover, ISBN 2-85629-118-X, 2000 *Mathematics Subject Classification*: 35L05, 35A21; 35Q60, 78A25, **Individual member $30**, List $33, Order code SMFMEM/88N

Discrete Mathematics and Combinatorics

Recommended Text



A Course in Convexity

Alexander Barvinok, *University of Michigan, Ann Arbor*

Convexity is a simple idea that manifests itself in a surprising variety of places. This fertile field has an immensely rich structure and numerous applications. Barvinok demonstrates that simplicity, intuitive appeal, and the universality of applications make teaching (and learning) convexity a gratifying experience. The book will benefit both teacher and student: It is easy to understand, entertaining to the reader, and includes many exercises that vary in degree of difficulty. Overall, the author demonstrates the power of a few simple unifying principles in a variety of pure and applied problems.

The notion of convexity comes from geometry. Barvinok describes here its geometric aspects, yet he focuses on applications of convexity rather than on convexity for its own sake. Mathematical applications range from analysis and probability to algebra to combinatorics to number theory. Several important areas are covered, including topological vector spaces, linear programming, ellipsoids, and lattices. Specific topics of note are optimal control, sphere packings, rational approximations, numerical integration, graph theory, and more. And of course, there is much to say about applying convexity theory to the study of faces of polytopes, lattices and polyhedra, and lattices and convex bodies.

The prerequisites are minimal amounts of linear algebra, analysis, and elementary topology, plus basic computational skills. Portions of the book could be used by advanced undergraduates. As a whole, it is designed for graduate students interested in mathematical methods, computer science, electrical engineering, and operations research. The book will also be of interest to research mathematicians, who will find some results that are recent, some that are new, and many known results that are discussed from a new perspective.

This item will also be of interest to those working in analysis and geometry and topology.

Contents: Convex sets at large; Faces and extreme points; Convex sets in topological vector spaces; Polarity, duality and linear programming; Convex bodies and ellipsoids; Faces of polytopes; Lattices and convex bodies; Lattice points and polyhedra; Bibliography; Index.

Graduate Studies in Mathematics, Volume 54

December 2002, 366 pages, Hardcover, ISBN 0-8218-2968-8, LC 2002028208, 2000 *Mathematics Subject Classification*: 52-01, 52-02, 52B45, 52C07, 46A20, 46N10, 90C05, 90C08, 90C22, 49N15, **All AMS members $47**, List $59, Order code GSM/54N

General and Interdisciplinary

Combined Membership List 2002–2003

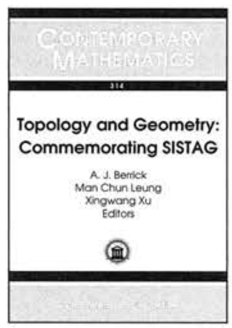
The *Combined Membership List* (CML) is a comprehensive directory of the membership of the American Mathematical Society, the American Mathematical Association of Two-Year Colleges, the Association for Women in Mathematics, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics.

There is a complete alphabetical list of all individual members in all five organizations. For each member, the CML provides an address, title, department, institution, telephone number (if available), and electronic address (if indicated), and also indicates membership in the five participating societies. In addition, the CML lists academic, institutional, and corporate members of the five participating societies providing addresses and telephone numbers of mathematical sciences departments.

The CML is distributed on request to AMS members in even-numbered years. MAA members can request the CML in odd-numbered years from the MAA. The CML is an invaluable reference for keeping in touch with colleagues and for making connections in the mathematical sciences community in the United States and abroad.

December 2002, approximately 304 pages, Softcover, ISBN 0-8218-3263-8, **Individual member $41**, List $68, Institutional member $54, Order code CML/2002/2003N

Geometry and Topology



Topology and Geometry: Commemorating SISTAG

A. J. Berrick, **Man Chun Leung**, and **Xingwang Xu**, *National University of Singapore*, Editors

This book presents nineteen refereed articles written by participants in the Singapore International Symposium in Topology and Geometry (SISTAG), held July 2-6, 2001, at the National University of Singapore. Beyond being a simple snapshot of the meeting in the form of a proceedings, it serves as a commemorative volume consisting of papers selected to show the diversity and depth of the mathematics presented at SISTAG.

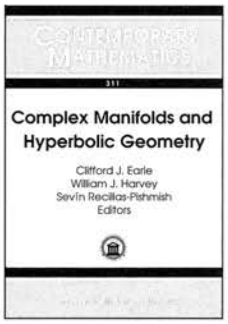
The book presents articles on low-dimensional topology, algebraic, differential and symplectic geometry, and algebraic topology. While papers reflect the focus of the conference, many documents written after SISTAG and included in this volume represent the latest thinking in the fields of topology and geometry. While representation from Pacific Rim countries is strong, the list of contributors is international in scope and includes many recognized experts.

This volume is of interest to graduate students and mathematicians working in the fields of algebraic geometry, differential geometry, geometric topology, low-dimensional topology, algebraic topology, symplectic geometry and mathematical physics.

Contents: **A. G. Aleksandrov**, Moduli of logarithmic connections along a free divisor; **S. Altinok**, **G. Brown**, and **M. Reid**, Fano 3-folds, K3 surfaces and graded rings; **I. Bokor**, A notion of connected sum for certain *CW*-complexes; **Y. S. Cho**, The cohomology ring of S^2-fibrations; **C. M. Gordon**, Links and their complements; **B. Hassett** and **Y. Tschinkel**, On the effective cone and the moduli space of pointed rational curves; **J. A. Hillman**, On 4-dimensional mapping tori; **W. Jaco**, **D. Letscher**, and **J. H. Rubinstein**, Algorithms for essential surfaces in 3-manifolds; **D. Joyce**, On counting special Lagrangian homology 3-spheres; **Y. Kamiya** and **K. Shimomura**, E_*-homology spheres for a connective spectrum E; **B. H. Lian**, **K. Liu**, and **S.-T. Yau**, Some applications of mirror principle; **R. Mazzeo** and **F. Pacard**, Bifurcating nodoids; **M. McQuillan**, Formal formal schemes; **Y.-G. Oh**, Holomorphic volume preserving maps and special Lagrangian submanifolds; **S. Pan**, On a new curve evolution problem in the plane; **C. Shen** and **F. Wang**, Some applications of the theory of critical points; **Y.-B. Shen**, On complete submanifolds with parallel mean curvature in R^{n+p}; **Y. Yuand** and **J. Zhou**, Semi-classical asymptotics; **D.-Q. Zhang**, On endomorphisms of algebraic surfaces.

Contemporary Mathematics, Volume 314

December 2002, 263 pages, Softcover, ISBN 0-8218-2820-7, LC 2002034243, 2000 *Mathematics Subject Classification*: 14-XX, 35-XX, 53-XX, 55-XX, 57-XX, 58-XX, **Individual member $41**, List $69, Institutional member $55, Order code CONM/314N



Complex Manifolds and Hyperbolic Geometry

Clifford J. Earle, *Cornell University, Ithaca, NY*, **William J. Harvey**, *King's College, London, England*, and **Sevín Recillas-Pishmish**, Editors

This volume derives from the second Iberoamerican Congress on Geometry, held in 2001 in Mexico at the Centro de Investigación en Matemáticas A.C., an internationally recognized program of research in pure mathematics. The conference topics were chosen with an eye toward the presentation of new methods, recent results, and the creation of more interconnections between the different research groups working in complex manifolds and hyperbolic geometry. This volume reflects both the unity and the diversity of these subjects.

Researchers around the globe have been working on problems concerning Riemann surfaces, as well as a wide scope of other issues: the theory of Teichmüller spaces, theta functions, algebraic geometry and classical function theory.

Included here are discussions revolving around questions of geometry that are related in one way or another to functions of a complex variable. There are contributors on Riemann surfaces, hyperbolic geometry, Teichmüller spaces, and quasiconformal maps.

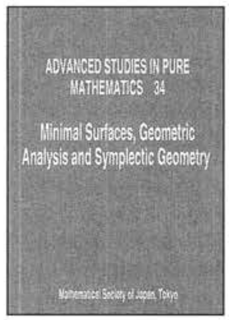
Complex geometry has many applications—triangulations of surfaces, combinatorics, ordinary differential equations, complex dynamics, and the geometry of special curves and jacobians, among others. In this book, research mathematicians in complex geometry, hyperbolic geometry and Teichmüller spaces will find a selection of strong papers by international experts.

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

Contents: A. M. Bonifant and **M. Dabija**, Self-maps of $\mathbb{P}^2$ with invariant elliptic curves; **J. F. Brock**, Pants decompositions and the Weil-Petersson metric; **A. Carocca**, **S. Recillas**, and **R. E. Rodríguez**, Dihedral groups acting on Jacobians; **C. J. Earle**, Schwarz's lemma and Teichmüller contraction; **C. J. Earle**, **V. Markovic**, and **D. Saric**, Barycentric extension and the Bers embedding for asymptotic Teichmüller space; **A. L. Epstein**, Symmetric rigidity for real polynomials with real critical points; **H. M. Farkas** and **I. Kra**, On theta constant identities and the evaluation of trigonometric sums; **A. Gamburd** and **E. Makover**, On the genus of a random Riemann surface; **F. P. Gardiner**, **J. Hu**, and **N. Lakic**, Earthquake curves; **F. P. Gardiner** and **N. Lakic**, Efficient smooth quasiconformal mappings; **T. M. Gendron**, The Ehrenpreis conjecture and the moduli-rigidity gap; **J. Gilman** and **L. Keen**, Word sequences and intersection numbers; **L. Giraldo** and **X. Gómez-Mont**, A law of conservation of number for local Euler characteristics; **G. González-Díez** and **W. J. Harvey**, On families of algebraic curves with automorphisms; **R. A. Hidalgo**, Real surfaces, Riemann matrices and algebraic curves; **N. Lakic** and **S. Mitra**, Approximation by meromorphic quadratic differentials; **B. Maskit**, On the topology of classical Schottky space; **R. Silhol**, Hyperbolic lego and algebraic curves in genus 2 and 3; **P. Susskind**, The Margulis region and continued fractions.

Contemporary Mathematics, Volume 311

December 2002, 343 pages, Softcover, ISBN 0-8218-2957-2, LC 2002034250, 2000 *Mathematics Subject Classification*: 11F12, 14H15, 14H40, 30F10, 30F40, 32G15, 32H50, 32S65, 37E10, 37F10, **Individual member $53**, List $89, Institutional member $71, Order code CONM/311N



Minimal Surfaces, Geometric Analysis and Symplectic Geometry

Kenji Fukaya, *Kyoto University, Japan*, **Seiki Nishikawa**, *Tohoku University, Sendai, Japan*, and **Joel Spruck**, *Johns Hopkins University, Baltimore, MD*, Editors

A publication of the Mathematical Society of Japan.

The 1998–1999 program year of the Japan-U.S. Mathematics Institute at the Johns Hopkins University (Baltimore, MD) was devoted to minimal surfaces, geometric analysis, and symplectic geometry. The program culminated in a week-long workshop and conference to discuss recent developments.

This volume is a collection of articles written by the speakers. It presents extended or modified versions of the lectures delivered at the meeting. Each article provides a vivid account of current research. The information given ranges from introductory-level to the most recent results. Of special interest is a long survey article by K. Fukaya on applications of Floer homology to mirror symmetry. Also discussed are new developments on the geometry of constant mean curvature one surfaces in hyperbolic 3-spaces of finite total curvature.

The range of topics covered in the volume provides direction for further research in these rapidly developing areas. The book is suitable for graduate students and researchers interested in differential and symplectic geometry.

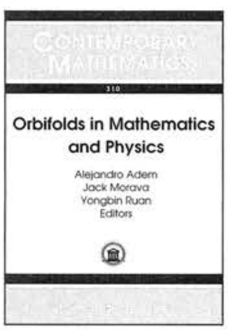
Published for the Mathematical Society of Japan by Kinokuniya, Tokyo, and distributed worldwide, except in Japan, by the AMS.

Contents: M. Cai, Volume minimizing hypersurfaces in manifolds of nonnegative scalar curvature; **P. Collin**, **L. Hauswirth**, and **H. Rosenberg**, The Gaussian image of mean curvature one surfaces in $\mathbb{H}^3$ of finite total curvature; **H. Donnelly**, Behavior of eigenfunctions near the ideal boundary of hyperbolic space; **K. Fukaya**, Floer homology and mirror symmetry II; **M. Ghomi**, Solution to the shadow problem in 3-space; **H. Hashimoto**, **K. Mashimo**, and **K. Sekigawa**, On 4-dimensional CR-submanifolds of a 6-dimensional sphere; **M. Kokubu**, On isotropic minimal surfaces in Euclidean space; **H. Konno**, The topology of toric hyper-Kähler manifolds; **R. López**, Cyclic hypersurfaces of constant curvature; **J. McCuan**, A generalized height estimate for *H*-graphs, Serrin's corner lemma, and applications to a conjecture of Rosenberg; **J. Masamune** and **W. Rossman**, Discrete spectrum and Weyl's asymptotic formula for incomplete manifolds; **H. Ohta**, Brieskorn manifolds and metrics of positive scalar curvature; **K. Ono**, Space of geodesics on Zoll three-spheres; **W. Rossman**, **M. Umehara**, and **K. Yamada**, Constant mean curvature 1 surfaces with low total curvature in hyperbolic 3-space; **T. Takakura**, A note on the symplectic volume of the moduli space of spatial polygons.

Advanced Studies in Pure Mathematics, Volume 34

June 2002, 259 pages, Hardcover, ISBN 4-931469-18-3, 2000 *Mathematics Subject Classification*: 53-06; 53A05, 53A10, 53B25, 53C21, 53C26, 53D05, 53D20, 53D40, 57R57, 58J50, **All AMS members $63**, List $79, Order code ASPM/34N

Mathematical Physics



Orbifolds in Mathematics and Physics

Alejandro Adem, *University of Wisconsin, Madison*, **Jack Morava**, *Johns Hopkins University, Baltimore, MD*, and **Yongbin Ruan**, *University of Wisconsin, Madison*, Editors

This book publishes papers originally presented at a conference on the Mathematical Aspects of Orbifold String Theory, hosted by the University of Wisconsin-Madison. It contains a great deal of information not fully covered in the published literature and showcases the current state of the art in orbital string theory. The subject of orbifolds has a long prehistory, going back to the work of Thurston and Haefliger, with roots in the theory of manifolds, group actions, and foliations. The recent explosion of activity on the topic has been powered by applications of orbifolds to moduli problems and quantum field theory. The present volume presents an interdisciplinary look at orbifold problems. Topics such as stacks, vertex operator algebras, branes, groupoids, K-theory and quantum cohomology are discussed.

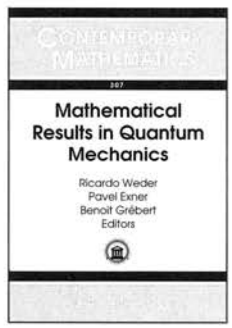
The book reflects the thinking of distinguished investigators working in the areas of mathematical physics, algebraic geometry, algebraic topology, symplectic geometry and representation theory. By presenting the work of a broad range of mathematicians and physicists who use and study orbifolds, it familiarizes readers with the various points of view and types of results the researchers bring to the subject.

This item will also be of interest to those working in geometry and topology and algebra and algebraic geometry.

Contents: D. Abramovich, **T. Graber**, and **A. Vistoli**, Algebraic orbifold quantum products; **W. Chen** and **Y. Ruan**, Orbifold Gromov-Witten theory; **C. Dong**, **K. Liu**, and **X. Ma**, On orbifold elliptic genus; **T. Graber** and **E. Zaslow**, Open-string Gromov-Witten invariants: Calculations and a mirror "theorem"; **T. J. Jarvis** and **T. Kimura**, Orbifold quantum cohomology of the classifying space of a finite group; **R. M. Kaufmann**, Orbifold Frobenius algebras, cobordisms and monodromies; **E. Lupercio** and **B. Uribe**, Loop groupoids, Gerbes, and twisted sectors on orbifolds; **M. Mariño** and **C. Vafa**, Framed knots at large *N*; **I. Moerdijk**, Orbifolds as groupoids: An introduction; **M. Poddar**, Orbifold cohomology group of toric varieties; **Z. Qin** and **W. Wang**, Hilbert schemes and symmetric products: A dictionary; **Y. Ruan**, Stringy orbifolds; **E. Sharpe**, Discrete torsion, quotient stacks, and string orbifolds; **K. Wendland**, Orbifold constructions of $K3$: A link between conformal field theory and geometry.

Contemporary Mathematics, Volume 310

December 2002, approximately 368 pages, Softcover, ISBN 0-8218-2990-4, 2000 *Mathematics Subject Classification*: 81T30, 55N91, 17B69, 19M05, **Individual member $53**, List $89, Institutional member $71, Order code CONM/310N



Mathematical Results in Quantum Mechanics

Ricardo Weder, *IIMAS-UNAM, Mexico City, Mexico*, **Pavel Exner**, *Czech Academy of Sciences, Prague, Czech Republic*, and **Benoit Grébert**, *University of Nantes, France*, Editors

This book contains contributions presented at the conference, "QMath-8: Mathematical Results in Quantum Mechanics", held at Universidad Nacional Autónoma de México in December 2001.

The articles cover a wide range of mathematical problems and focus on various aspects of quantum mechanics, quantum field theory, and nuclear physics. Topics vary from spectral properties of the Schrödinger equation of various quantum systems to the analysis of quantum computation algorithms.

The book is suitable for graduate students and research mathematicians interested in the mathematical aspects of quantum mechanics.

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

Contents: R. Adami, Blow-up for Schrödinger equation with pointwise nonlinearity; **J.-M. Barbaroux**, **M. Dimassi**, and **J.-C. Guillot**, Quantum electrodynamics of relativistic bound states with cutoffs. II; **F. Bentosela** and **M. Tater**, Scattering by a slab: An exact calculation; **X. Blanc** and **C. Le Bris**, Crystalline order in one dimensional Thomas-Fermi type models; **J. Bourgain**, New results on the spectrum of lattice Schrödinger operators and applications; **A. L. Bukhgeĭm**, **G. V. Dyatlov**, and **G. Uhlmann**, Reconstruction of the memory from partial boundary measurements; **R. E. Cardiel** and **P. I. Naumkin**, Asymptotics for nonlinear dissipative equations in the super critical case; **J.-M. Combes**, **P. D. Hislop**, and **E. Soccorsi**, Edge states for quantum Hall Hamiltonians; **M. Combescure** and **D. Robert**, A semiclassical approach in linear response theory; **J. Cruz-Sampedro**, Wigner-von Neumann-like potentials; **M. Demuth** and **A. Noll**, Equilibrium potentials in scattering theory; **J. Dittrich** and **J. Kříž**, Straight quantum waveguides with combined boundary conditions; **V. Enss**, **V. Kostrykin**, and **R. Schrader**, Perturbation theory for the quantum time-evolution in rotating potentials; **L. Erdős** and **V. Vougalter**, Two dimensional Pauli operator via scalar potential; **M. J. Esteban** and **E. Séré**, A max-min principle for the ground state of the Dirac-Fock functional; **S. Fournais**, **M. Hoffmann-Ostenhof**, **T. Hoffmann-Ostenhof**, and **T. Ø. Sørensen**, On the regularity of the density of electronic wave functions; **C. Hainzl**, Enhanced binding through coupling to a photon field; **B. C. Hall** and **J. J. Mitchell**, The large radius limit for coherent states on spheres; **I. Herbst** and **E. Skibsted**, Quantum scattering for potentials homogeneous of degree zero; **W. Kirsch** and **I. Veselić**, Existence of the density of states for one-dimensional alloy-type potentials with small support; **V. Kostrykin** and **R. Schrader**, Statistical ensembles and density of states; **M. Kudryavtsev**, The Cauchy problem for the Toda lattice with a class of non-stabilized initial data; **A. Laptev**, **S. Naboko**, and **O. Safronov**, Absolutely continuous spectrum of Jacobi matrices; **E. H. Lieb** and **M. Loss**, Stability of matter in relativistic quantum electrodynamics; **M. Măntoiu** and **R. Purice**, The algebra of observables in a magnetic field; **D. B. Pearson**, Recent developments in value distribution theory for Schrödinger operators on the half line; **D. Robert**, Long time propagation results in quantum mechanics; **M. B. Ruskai**, Comments on adiabatic quantum algorithms; **A. Sacchetti**, Tunneling destruction for a nonlinear Schrödinger equation; **R. Seiringer**, Symmetry breaking in a model of a rotating Bose gas; **S. B. Sontz**, Euler's constant in Segal-Bargmann analysis; **A. Tip**, Maxwell with a touch of Schrödinger; **J. H. Toloza**, Exponentially accurate semiclassical asymptotics; **C. van der Mee** and **V. Pivovarchik**, Some properties of the eigenvalues of a Schrödinger equation with energy-dependent potential; **C. Villegas-Blas**, The Bargmann transform for $L^2(S^3)$ and regularization of the Kepler problem; **K. Yajima** and **G. Zhang**, Schrödinger equations with superquadratic potentials; **K. Yoshitomi**, Band spectrum of the Laplacian on a slab with the Dirichlet boundary condition on a grid; Other talks; Participants.

Contemporary Mathematics, Volume 307

December 2002, approximately 360 pages, Softcover, ISBN 0-8218-2900-9, 2000 *Mathematics Subject Classification*: 35-06, 81-06, 92E99, 82D99, 81T99, 35P15, 35P25, 81Q10, 81Q15, 81U40, **Individual member $53**, List $89, Institutional member $71, Order code CONM/307N

Number Theory

Cohomologies p-Adiques et Applications Arithmétiques (I)

Pierre Berthelot, *Université de Rennes, France*, **Jean-Marc Fontaine** and **Luc Illusie**, *Université de Paris-Sud, Orsay, France*, **Kazuya Kato**, *Kyoto University, Japan*, and **Michael Rapoport**, *Universität zu Köln, Germany*, Editors

A publication of the Société Mathématique de France.

This volume is the first of three dealing with p-adic methods in arithmetic geometry. Topics in this volume include the theory of formal groups and their deformations, the p-adic Langlands program, and p-adic hyperbolic geometry. The material is suitable for graduate students and research mathematicians interested in number theory and arithmetic algebraic geometry.

Books in the Asterisque series consist of high-quality long papers, lecture notes, and conference or seminar proceedings. They are distributed in the U.S., Canada, and Mexico by the AMS and published by the Société Mathématique de France. Also available from the AMS is *Cohomologies p-adiques et applications arithmétiques, II*, Volume 279 in the Asterisque series.

This item will also be of interest to those working in algebra and algebraic geometry.

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Contents: S. Mochizuki, An introduction to p-adic Teichmüller theory; **P. Schneider** and **J. Teitelbaum**, p-adic boundary values; **T. Zink**, The display of a formal p-divisible group.

Astérisque, Number 278

248 pages, Softcover, ISBN 2-85629-115-5, 2000 *Mathematics Subject Classification*: 11F85, 14F30, 14F40, 14H10, 14L05, 22E50, **Individual member $50**, List $56, Order code AST/278N

Cohomologies p-Adiques et Applications Arithmetiques (II)

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A publication of the Société Mathématique de France.

This volume is the second of three dealing with p-adic methods in arithmetic geometry. Topics in this volume include the construction of p-adic cohomology theories and comparison theorems between these cohomologies: logarithmic geometry, crystalline cohomology, arithmetic D-modules, p-adic differential equations, and comparison theorems of Faltings and Tsuji. The material is suitable for graduate students and research mathematicians interested in number theory and arithmetic algebraic geometry.

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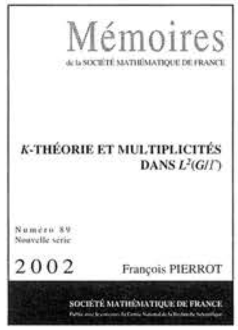
Contents: P. Berthelot, Introduction à la théorie arithmétique des $\mathcal{D}$-modules; **C. Breuil** and **W. Messing**, Torsion étale and crystalline cohomologies; **G. Christol** and **Z. Mebkhout**, Équations différentielles p-adiques et coefficients p-adiques sur les courbes; **G. Faltings**, Almost étale extensions; **L. Illusie**, An overview of the work of K. Fujiwara, K. Kato, and C. Nakayama on logarithmic étale cohomology; **T. Tsuji**, Semi-stable conjecture of Fontaine-Jannsen: a survey.

Astérisque, Number 279

370 pages, Softcover, ISBN 2-85629-117-1, 2000 *Mathematics Subject Classification*: 11G10, 11G25, 11S20, 12H25, 13N10, 14A99, 14D05, 14D06, 14D10, 14E05, 14E20, 14E22, 14F10, 14F20, 14F30, 14F35, 14F40, 14G20, 14G22, 16S32, 32C38, **Individual member $90**, List $100, Order code AST/279N



K-Théorie et Multiplicités Dans $L^2(G/\Gamma)$

François Pierrot, *École Normale Supérieure, Paris, France*

A publication of the Société Mathématique de France.

This monograph discusses an important topic in number theory. The author proves a generalized version of the L^2-index theorem of Atiyah concerning equivariant elliptic operators on coverings of compact manifolds in the context of the Baum-Connes conjecture. Using recent results on the K-theory of group algebras, he computes the multiplicities of integrable discrete series in the homogeneous spaces of discrete torsionless and cocompact subgroups in the case of semisimple Lie groups (a result due to R. P. Langlands), as well as in the p-adic case. The book is intended for researchers interested in number theory.

This item will also be of interest to those working in algebra and algebraic geometry.

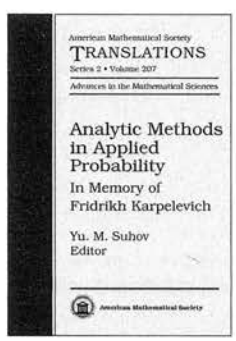
Distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents: Introduction; Traces densément définies et K-théorie; Γ-trace; Une généralisation en K-théorie du théorème d'indice L^2 d'Atiyah; Propriétés de fonctorialité pour les sous-groupes discrets cocompacts et théorème à la Langlands en K-théorie; Conjecture de Bost et formule de Langlands; Bibliographie.

Mémoires de la Société Mathématique de France, Number 89

0249-633X, June 2002, 85 pages, ISBN 2-85629-119-8, 2000 *Mathematics Subject Classification*: 11F72, 19K14, 19K35, 22D10, 46L08, **Individual member $30**, List $33, Order code SMFMEM/89N

Probability



Analytic Methods in Applied Probability

Yu. M. Suhov, *University of Cambridge, England,* and *Institute for Information Transmission Problems, Moscow, Russia*, Editor

This volume is dedicated to F. I. Karpelevich, an outstanding Russian mathematician who made important contributions to applied probability theory. The book contains original papers focusing on several areas of applied probability and its uses in modern industrial processes, telecommunications, computing, mathematical economics, and finance.

It opens with a review of Karpelevich's contributions to applied probability theory and includes a bibliography of his works. Other articles discuss queueing network theory, in particular, in heavy traffic approximation (fluid models).

The book is suitable for graduate students, theoretical and applied probabilists, computer scientists, and engineers.

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

Contents: A. Ya. Kreinin and **Y. Suhov**, Karpelevich's contribution to applied probability; **O. J. Boxma**, **S. Schlegel**, and **U. Yechiali**, A note on an $M/G/1$ queue with a waiting server, timer, and vacations; **S. Foss** and **S. Zachary**, Asymptotics for the maximum of a modulated random walk with heavy-tailed increments; **J. M. Harrison**, Stochastic networks and activity analysis; **V. Kalashnikov**, Stability bounds for queueing models in terms of weighted metrics; **F. I. Karpelevich**, **V. A. Malyshev**, **A. I. Petrov**, **S. A. Pirogov**, and **A. N. Rybko**, Context-free evolution of words; **M. Kelbert**, **S. Rachev**, and **Y. Suhov**, The maximum of a tree-indexed random process, with applications; **J. Martin**, Stochastic bounds for fast Jackson networks; **M. Menshikov** and **D. Petritis**, Markov chains in a wedge with excitable boundaries; **M. Mitzenmacher** and **B. Vöcking**, Selecting the shortest of two queues, improved; **A. N. Rybko**, **A. L. Stolyar**, and **Y. M. Suhov**, Stability of global LIFO networks; **S. Shakkottai** and **A. L. Stolyar**, Scheduling for multiple flows sharing a time-varying channel: The exponential rule; **M. G. Shur**, New ratio limit theorems for Markov chains; **E. J. Thomas**, Stability of patchwork-JSQ feedback networks.

American Mathematical Society Translations—Series 2 (*Advances in the Mathematical Sciences*), Volume 207

January 2003, 217 pages, Hardcover, ISBN 0-8218-3306-5, LC 91-640741, 2000 *Mathematics Subject Classification*: 60Jxx, 60K20, **Individual member $59**, List $99, Institutional member $79, Order code TRANS2/207N

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Department of Mathematics

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Auburn University has over 50 mathematicians engaged in research in a wide variety of disciplines including algebra, analysis, linear algebra, numerical analysis, probability, topology, geometry, and dynamical systems. In addition to an expanding undergraduate program, there is an active graduate program with approximately 60 graduate students studying in various areas of mathematical science. The mathematics department is part of the College of Science and Mathematics, which includes strong research departments in biology, chemistry, geology and physics; additionally, the Colleges of Engineering and of Business have research programs in disciplines that require the use of the mathematical sciences.

An application, transcript(s), a curriculum vitae, and a description of the candidate's research interests and teaching philosophy should be sent to the address below. In addition, applicants should arrange for four letters of recommendation (at least one of which should address teaching) to be sent to the same address. Review of applications will begin February 1, 2003, and continue until the position is filled.

Send information in care of:
Dr. Michel Smith
Professor and Chair
Department of Mathematics
Auburn University
Auburn, AL 36849
Phone: 334-844-4290;
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Department of Mathematics
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All positions: Expected to serve on dept. and university committees, engage in scholarly activities. Required: Evidence

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STANFORD UNIVERSITY
Department of Mathematics

The department is considering applications for tenure-track or tenured faculty appointments. The research fields to be considered are: (1) analysis, (2) algebra, number theory or logic, (3) geometry or topology, (4) combinatorics, (5) applied mathematics or probability; in the last case there are also possibilities for joint appointments with other departments.

Candidates should send a letter of application with a curriculum vitae, a list of publications, and a cover sheet clearly stating the following information: name, area of specialization, institution, date of Ph.D., and Ph.D. advisor. Also, the candidate should arrange to have at least three letters of recommendation (junior candidates only) and evidence of commitment to excellence in teaching sent to: Search Committee, Department of Mathematics, Stanford University, Stanford, CA 94305, by January 1, 2003. Stanford is an Affirmative Action/Equal Opportunity Employer. Women and minorities are particularly encouraged to apply.

UNIVERSITY OF CALIFORNIA, DAVIS
Department of Mathematics
Regular and Visiting Faculty Positions in Mathematics

The Department of Mathematics at the University of California, Davis, is soliciting applications for two tenure-track/tenured positions and several Visiting Research Assistant Professor (VRAP) positions starting July 1, 2003.

For the tenure-track/tenured positions, appointments at the assistant professor level are preferred, but unusually well-qualified candidates may be considered for an associate or full professorship. The department will consider applications in all of its focus research areas: applied mathematics including mathematical biology, geometry and topology, numerical analysis and scientific computation, analysis and partial differential equations, mathematical physics, discrete mathematics and combinatorics. However, priority will be given to making one appointment in the area of geometry and topology. Minimum qualifications for the position include a Ph.D. degree or its equivalent in the mathematical sciences and great promise in research and teaching. Duties include mathematical research, undergraduate and graduate teaching (four quarter-courses per year), and departmental and university service. Candidates for an associate or full professorship must have demonstrated outstanding attainment in research and teaching.

The VRAP positions are renewable for up to a total of three years, assuming satisfactory performance in research and teaching. The VRAP applicants are required to have completed their Ph.D. by the time of their appointment, but not earlier than July 1, 1999. The department is interested in applicants with excellent research potential in any of the focus research areas listed above and excellent teaching skills. The department has a number of VIGRE postdoctoral positions. Recipients must be U.S. citizens, nationals, or permanent residents and have received their Ph.D. after January 1, 2002. All applicants for a VRAP position who are eligible for a VIGRE postdoctoral position will automatically be considered for one.

Applications will be accepted until the positions are filled. To receive full consideration, the application should be received by November 30, 2002. To initiate an application, please either: (a) submit an electronic version of the AMS cover sheet, together with any supporting documents, from the MathJobs.org website at `http://www.mathjobs.org/`; or (b) write to the Chair of Search Committee, Department of Mathematics, University of California, One Shields Avenue, Davis, CA 95616-8633.

Additional information on the department may be found on the World Wide Web at `http://math.ucdavis.edu/`.

The University of California, Davis, is an Affirmative Action/Equal Opportunity Employer. The university undertakes affirmative action to assure equal employment opportunity for minorities and women, for persons with disabilities, and for special disabled veterans, Vietnam-era veterans, and any other veterans who served on active duty during a war or in a campaign or expedition for which a campaign badge has been authorized.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Department of Mathematics

Subject to availability of resources and administrative approval, the following positions are available for the 2003–04 academic year.

1. Several tenure-track and senior positions in all areas of mathematics.

2. Several E. R. Hedrick Assistant Professorships. Salary is $53,200. Three-year appointment. Teaching load: four quarter-courses per year, which may include one advanced course in the candidate's field.

3. Several Research Assistant Professorships in Computational and Applied Mathematics (CAM). Salary is $53,200. Three-year appointment. Teaching load: normally reduced to two or three quarter-courses per year by research funding as available; may include one advanced course in the candidate's field.

4. Several Adjunct Assistant Professorships or Lectureships in the Program in Computing (PIC). Applicants for the adjunct position must show very strong promise in teaching and research in an area related to computing. Teaching load: four one-quarter programming courses each year and one seminar every two years. One-year initial appointment, with the option of applying for renewal for a second year and possibly longer, up to a maximum service of four years. Salary is $56,800. Applicants for the lectureship must show very strong promise in the teaching of programming. An M.S. in computer science or equivalent degree is preferred. Teaching load: six one-quarter programming courses per year. One-year appointment, probably renewable one or more times, depending on the needs of the program. Salary is $43,152 or more, depending on experience.

5. Several VIGRE Assistant Professorships. Hedrick, CAM, or PIC applicants who are U.S. citizens or permanent residents may also apply for a VIGRE Assistant Professor position. Three-year appointment. Salary is $53,200. The successful recipient will receive a summer stipend of $6,500 for two summers and $2,500 per year for travel, equipment, and supplies for three years. Teaching load: 3 courses per year.

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7. Several visiting instructorships.

For more details, see `http://www.math.ucla.edu/~search/`. To apply, complete the application on the website, or send e-mail to `search@math.ucla.edu`, or write to: Staff Search, Department of Mathematics, University of California, Los Angeles, CA 90095-1555. Preference will be given to applications completed by January 6, 2003.

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UNIVERSITY OF CALIFORNIA, RIVERSIDE
Department of Mathematics
F. Burton Jones Chair in Topology

Applications and nominations are invited for the F. Burton Jones Chair in Topology. The university seeks a distinguished scholar recognized for outstanding research in topology. This prestigious chair was established with the generous endowment by the late emeritus professor F. Burton Jones, the first in the history of UC Riverside fully endowed by an emeritus professor. The holder of the Jones

Chair will be expected to play a leading role in maintaining first-rate teaching and research programs in the department, and consequently the appointee will be a person of great distinction, with national or international recognition for scholarly achievement. It is hoped to have the position filled by July 1, 2003. It is expected that the appointment will be with tenure at the rank of full professor and that the appointee will perform all the duties thereof. Established criteria of the University of California determine rank and salary. Initial review of applications will begin on December 1, 2002, and will continue until the position is filled.

Please send nominations, applications (curriculum vitae, publications list, and the names of at least five references), and supporting materials to:

Professor Reinhard Schultz
Chair, Selection Committee
F. Burton Jones Chair/Topology
Department of Mathematics
University of California, Riverside
Riverside, CA 92521-0135

The University of California, Riverside, is an Affirmative Action/Equal Opportunity Employer.

UNIVERSITY OF CALIFORNIA, SAN DIEGO
Department of Mathematics
Professorships

The Department of Mathematics of the University of California, San Diego (`http://math.ucsd.edu/`) is seeking outstanding candidates for up to six faculty positions to start July, 2003. One of these positions is for a very senior Full Professor with a distinguished record of research and teaching and is open to applicants in all areas of mathematics. The strongly preferred level for the other positions is at the Assistant Professor level, but applicants with all levels of experience from Assistant Professor to Full Professor will be considered.

Applicants should hold a Ph.D. in mathematics or a related field and should show outstanding promise and/or accomplishments in both research and teaching. Areas of special interest in applied mathematics include statistics, biostatistics, bioinformatics and logic. Areas of special interest in pure mathematics include geometry, number theory, probability, representation theory and topology. However, we encourage applications from any area of pure or applied mathematics. Level of appointment will be based on qualifications with appropriate salary per UC pay scales. To apply for any of these positions, please submit your placement file including vitae and publications, and arrange for three letters of reference to be sent under separate cover to the "Faculty Search Committee", Department of Mathematics, University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92093-0112G. Please indicate primary research area (field and #) using the AMS Mathematical Review Classification List. All applications received by January 3, 2003, will receive thorough consideration. All supporting material must be received no later than January 9, 2003. In compliance with the Immigration Reform and Control Act of 1986, individuals offered employment by the University of California will be required to show documentation to prove identity and authorization to work in the United States before hiring can occur. UCSD is an Equal Opportunity/Affirmative Action Employer with a strong institutional commitment to the achievement of diversity among its faculty and staff.

UNIVERSITY OF CALIFORNIA, SAN DIEGO
Department of Mathematics
Stefan E. Warschawski Assistant Professorship Recruitment–7/1/2003

The Department of Mathematics of the University of California, San Diego (`http://math.ucsd.edu/`) is seeking outstanding candidates for a special two year assistant professorship, the S. E. Warschawski Assistant Professorship. The nine-month salary is $48,000. Applicants (of any age) should possess a recent Ph.D. degree (received no earlier than 2000) in mathematics or expect to receive one prior to July 2003, and should show outstanding promise in both research and teaching. To apply for this position, please submit your placement file including vitae and publications, and arrange for three letters of reference to be sent to the "SEW Search Committee", Department of Mathematics, University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92093-0112G. Please indicate primary research area (field and #) using the AMS Mathematical Review Classification List. All applications received by January 3, 2003, will receive thorough consideration. All supporting material must be received no later than January 9, 2003. In compliance with the Immigration Reform and Control Act of 1986, individuals offered employment by the University of California will be required to show documentation to prove identity and authorization to work in the United States before hiring can occur. UCSD is an Equal Opportunity/Affirmative Action Employer with a strong institutional commitment to the achievement of diversity among its faculty and staff.

CONNECTICUT

YALE UNIVERSITY
Department of Mathematics

Yale University applications accepted for Gibbs Instructorships/Assistant Professorships for Ph.D. with outstanding promise in research in pure mathematics. Appointments are for two/three years, starting July 2003. The teaching load for Gibbs Instructors/Assistant Professors will be kept light so as to allow ample time for research. This will consist of 3 one-semester courses per year. Part of the duties may consist of a one-semester course at the graduate level in the general area of the instructor's research. Applications and supporting materials must be received by January 1, 2003. Offers will be made during February. Salary at least $51,800. Applications are available at: `http://www.math.yale.edu/`. Applications and supporting materials may be sent via U.S. mail to: The Gibbs Committee, Department of Mathematics, Yale University, P.O. Box 208283, New Haven, CT 06520-8283; or via email to: `gibbs.committee@math.yale.edu`. Applications from women and members of minority groups are welcome. Yale is an Affirmative Action/Equal Opportunity Employer.

FLORIDA

FLORIDA ATLANTIC UNIVERSITY
Department of Mathematical Sciences
Department Chair Position

The Department of Mathematical Sciences at Florida Atlantic University invites applications for the position of department chair and professor of mathematical sciences. We are looking for an effective administrator with a distinguished record in research and leadership who is dedicated to promoting research as well as graduate and undergraduate education. The chair is expected to promote the acquisition of external funding.

Florida Atlantic University is one of the fastest growing universities in the United States. The Department of Mathematical Sciences offers a full range of academic degrees through the Ph.D., including a new Master of Science Program in Applied Mathematics and Statistics. The department has 25 professorial faculty and four instructors and is recruiting additional faculty. Research areas include algebra, combinatorics, constructive mathematics, control theory, cryptology, differential equations, dynamical systems, functional analysis, numerical methods, probability, and statistics.

Applicants should send a curriculum vitae, together with the names, addresses, and phone numbers of three references to: Search Committee Chair, Department of Mathematical Sciences, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431.

Consideration of applications will begin in January 2003 and will continue until the position is filled. Florida Atlantic University is an Equal Opportunity/Access/Affirmative Action Employer.

FLORIDA ATLANTIC UNIVERSITY
Department of Mathematical Sciences
Tenure-Track Positions

The Department of Mathematical Sciences at Florida Atlantic University invites applications for several tenure-track positions at the assistant professor level or higher. Appointments are to be made starting in fall 2003.

The primary areas of interest are statistics, cryptology, dynamical systems, and computational mathematics. These areas form the basis of a Master of Science Program in Applied Mathematics and Statistics that was recently inaugurated by the department and approved by the university's Board of Trustees. Florida Atlantic University is one of the fastest growing U.S. universities, and its mathematical sciences department offers academic degrees from the Bachelor of Science to the Ph.D.

Applicants should have earned a Ph.D. degree in mathematics or statistics and are expected to have demonstrated outstanding potential in both research and teaching. Applicants should send a curriculum vitae, reprints/preprints and/or a dissertation abstract, and at least three letters of recommendation. All applicants are requested to use the AMS standardized application form and indicate their subject area using the AMS subject classification numbers.

The department will also have two full-time renewable instructor positions. Applicants should indicate whether they would like to be considered for an instructor position. For more information on available positions, go to `http://www.math.fau.edu/hiring/`.

Applicants should address all application materials to:

Search Committee Chair,
Department of Mathematical Sciences
Florida Atlantic University
777 Glades Road
Boca Raton, FL 33431

Preference will be given to applications received by January 1, 2003. Women and minorities are strongly encouraged to apply. Florida Atlantic University is an Equal Opportunity/Access/Affirmative Action Employer.

UNIVERSITY OF SOUTH FLORIDA
Department of Mathematics

The Department of Mathematics at the University of South Florida has two tenure-track, nine-month assistant professor positions in analysis available on our main (Tampa) campus starting in August 2003. Minimum qualifications include Ph.D. or equivalent in mathematics or a closely related field by the time of appointment as assistant professor. Demonstrated achievement or potential for excellence in research and teaching is required. An application consisting of an AMS cover sheet, curriculum vitae, and at least three letters of recommendation addressing teaching and research experience must be received by February 1, 2003. These materials should be mailed to: Analysis Search Committee, Department of Mathematics, University of South Florida, 4202 East Fowler Avenue, PHY114, Tampa, FL 33620-5700.

The University of South Florida is an Affirmative Action/Equal Opportunity/ Equal Access Employer. Applications from women and minorities are encouraged. According to Florida law, all applications and meetings regarding them are open to the public. For disability accommodations, please contact the department at 813-974-2643 at least five days in advance.

UNIVERSITY OF WEST FLORIDA
Department of Mathematics and Statistics

Applications are invited for the position of chairperson, Department of Mathematics and Statistics, University of West Florida. Seeking applicants with strong leadership, administrative, and interpersonal skills, with a commitment to quality undergraduate and graduate education who will serve as a visionary leader and spokesperson for the department. The ideal candidate will have a strong record of teaching and research, and support a collegial culture of academic innovation and progress. Rank would be at full or advanced associate professor, tenure-earning.

Candidates must hold a doctoral degree in mathematics or statistics. The area of specialization is open, and candidates with teaching and research interests that complement current departmental programs and initiatives are invited to apply. The department is among the largest in the university, with 17 full-time faculty. A detailed department description is available on the website `http://uwf.edu/`. Applications from minorities and women are especially encouraged.

Persons interested in applying should send a vita, copies of transcripts, and three letters of reference to: Dr. David L. Sherry, Chairperson, Department of Mathematics and Statistics, University of West Florida, 11000 University Parkway, Pensacola, FL 32514. Active review of candidate materials will begin January 18 and will continue until the position is filled. UWF is an Equal Opportunity/ACCESS/Affirmative Action Employer.

UNIVERSITY OF WEST FLORIDA
Department of Mathematics & Statistics

The University of West Florida, Department of Mathematics and Statistics, invites applications for two tenure-track positions at the assistant professor rank and one lecturer position, ABD preferred, beginning August 2003. Positions are in both mathematics and statistics. Salary commensurate with experience. Record of excellent teaching, advising and scholarly activity are required. Responsibilities include teaching undergraduate and master's levels, research, and service.

Interested persons should send a letter of interest, vita, transcripts, and at least three letters of reference to: Dr. David L. Sherry, Chairperson, Department of Mathematics and Statistics, University of West Florida, 11000 University Parkway, Pensacola, FL 32514. Active review of candidate materials will begin January 18 and will continue until the position is filled. Applications from minorities and females are especially encouraged. UWF is a state university and an Equal Opportunity/ACCESS/Affirmative Action Employer.

GEORGIA

NORTH GEORGIA COLLEGE & STATE UNIVERSITY
Department of Mathematics

North Georgia College & State University invites applications for one or more tenure-track assistant professor positions in mathematics, beginning August 2003. A Ph.D. in mathematics or a closely related field is required. Excellence in teaching is essential. Preference may be given to candidates with the additional ability to teach introductory computer science or introductory statistics courses.

Located north of Atlanta, NGCSU is a state-supported four-year liberal arts institution known for its academic excellence and military program. The Department of Mathematics and Computer Science offers undergraduate degrees in computer science, computer information systems, mathematics and mathematics with teacher certification in addition to dual degrees with the Georgia Institute of Technology and Clemson University.

Responsibilities include teaching undergraduate mathematics and possibly introductory computer science or statistics courses, scholarly activity, and institutional service. The teaching load is twelve to thirteen hours per semester. For consideration send a letter of application, curriculum vitae, unofficial undergraduate and graduate transcripts, a statement of teaching philosophy, and three letters of recommendation by December 2, 2002, to: Department of Human Resources, ATTN: Mathematics Position Search, North Georgia College & State University, Dahlonega, GA 30597. See: http://www.ngcsu.edu/adminsrv/hr/positions.htm.

ILLINOIS

ILLINOIS WESLEYAN UNIVERSITY
Bloomington, IL 61701
Department of Mathematics and Computer Science

The Department of Mathematics and Computer Science at Illinois Wesleyan University invites applications for a tenure-track assistant professor in mathematics. Employment would begin in August 2003, and the teaching load would be six courses per year. All candidates should have a Ph.D. in statistics or probability and a dedication to excellent teaching in a liberal arts environment where undergraduate research is encouraged. We are seeking candidates who have an interest in working with students who want to become actuaries. The opportunity to participate in university-wide general education programs is available for interested faculty.

Illinois Wesleyan University is a highly selective undergraduate university of approximately 2,000 students located in Bloomington, Illinois, a community of about 120,000. This year the average ACT for Illinois Wesleyan's entering class of freshmen was 28. In recent years as many as 4% of the undergraduate population at Illinois Wesleyan University have declared majors in mathematics. The department maintains a healthy balance between applied mathematics and pure mathematics. Faculty areas of professional expertise include algebra, approximation theory, differential equations, number theory, dynamical systems, electrical engineering, linear algebra, logic, operations research, topology, topos theory, numerical analysis and wavelet analysis. The Department of Mathematics and Computer Science is located in the Center for Natural Science Learning and Research, a $25,000,000 facility opened in 1995. The department operates five computer labs for students, which have around 80 SunSPARC and iMac computers. For additional information on the mathematics curriculum, facilities, and faculty interests, see http://www.iwu.edu/~mathcs/.

Candidates for the position should submit a letter of application, a curriculum vitae, an AMS Standard Cover Sheet, a teaching statement and a research statement, and have three letters of recommendation sent separately to: Melvyn Jeter, Department of Mathematics and Computer Science, Illinois Wesleyan University, P.O. Box 2900, Bloomington, IL 61702-2900. Preliminary interviews for this position will be held at the Joint Mathematics Meetings in Baltimore, Maryland (January 2003). Applications received after December 13, 2002, may not receive full consideration. Women and minorities are encouraged to apply. Illinois Wesleyan is an Equal Opportunity Employer. For further information see our Jobs webpage at http://www.iwu.edu/~iwujobs/.

INDIANA

UNIVERSITY OF NOTRE DAME
Notre Dame, IN 46556
Department of Mathematics
Regular Position in Stochastic Analysis

The Department of Mathematics of the University of Notre Dame invites applications for a position in the field of applied stochastic analysis to start on August 24, 2003. The position is at the tenure-track level, but a tenured appointment may be possible for an exceptional candidate. The teaching load is one course one semester and two courses the other semester. The salary is competitive. Applications, including a curriculum vitae, a letter of application, and a completed AMS Standard Cover Sheet, should be sent to Steven A. Buechler, Chair, at the above address. Applicants should also arrange for at least three letters of recommendation to be sent to the chair. These letters should address the applicant's research accomplishments and supply evidence that the applicant has the ability to communicate articulately and teach effectively. Notre Dame is an Equal Opportunity Employer. Women and minorities are urged to apply. The evaluation of candidates will begin December 1, 2002. Information about the department is available at http://www.math.nd.edu/math/.

IOWA

GRINNELL COLLEGE
Department of Mathematics and Computer Science
2 Tenure-Track Positions in Mathematics

Two tenure-track positions as assistant professor of mathematics starting fall 2003. Ph.D. in mathematics expected. For one of these positions, we seek applicants whose specialty is an area of analysis; for the other position, all specialties will be considered. Grinnell College is a highly selective liberal arts college that seeks outstanding teacher-scholars for its faculty, rewards excellence in teaching, and is generous in its support of scholarship. For more information see http://www.math.grinnell.edu/2002-math.html. Please include a statement describing your interests in teaching and research in an undergraduate liberal arts environment that emphasizes close student-faculty interaction and values diversity. Send AMS cover sheet, curriculum vitae, undergraduate and graduate transcripts (copies acceptable), and three letters of recommendation to: Mathematics Search Committee, Department of Mathematics and Computer Science, 1116 8th Avenue, Grinnell College, Grinnell, IA 50112. Review of applications will continue until positions are filled.

Grinnell College is an Equal Opportunity/Affirmative Action Employer committed to attracting and retaining highly qualified individuals who collectively reflect the diversity of the nation. No applicant shall be discriminated against on the basis of race, national or ethnic origin, age, gender, sexual orientation, marital status, religion, creed, or disability.

IOWA STATE UNIVERSITY
Department of Mathematics

The Department of Mathematics anticipates several tenure-track positions. Most positions will be at the assistant professor level, though it is possible that more experienced candidates could be hired at the associate level. We are interested in hiring mathematicians whose research programs are complementary to the existing strengths in the department and who can interact with current faculty in the department as well as with faculty in other units of the university. The department has active research groups in applied mathematics and partial differential equations, algebra and combinatorics, functional analysis, linear algebra, logic and universal algebra, numerical analysis, and probability and stochastic processes. For further information about the department, visit the department's website at http://www.math.iastate.edu/.

The teaching load for untenured faculty is three courses per year. For assistant professor a Ph.D. in mathematics or related discipline by the start date of the position and an excellent record in research and teaching are required. We prefer applicants with two to four years of experience beyond the Ph.D., normally achieved through a postdoctoral position. For associate professor, in addition to the above, a superior record in research and teaching is expected.

Applicants must submit a vita and a brief statement describing their research accomplishments and plans. They must also arrange for four (4) letters of recommendation, one (1) of which must address the applicant's teaching ability and experience. Mail to: Dr. Justin R. Peters, Chair, Department of Mathematics, 400 Carver, Iowa State University, Ames, IA 50011-2064. Iowa State University is an Affirmative Action/Equal Opportunity Employer and strongly encourages women and members of underrepresented groups to apply.

UNIVERSITY OF IOWA
Department of Statistics & Actuarial Science
Tenure-Track Assistant Professor

Tenure-track assistant professor in actuarial science starting 08/03. Promise for teaching excellence and creative research; Ph.D.; fellowship or associateship in professional actuarial society. Expected to conduct research in actuarial science/financial mathematics, assist in building Ph.D. program in this area, supervise Ph.D. students. Selection begins 12/01/02 and continues until filled. CV and three reference letters to: Actuarial Search, Statistics & Actuarial Science, Univ. of Iowa, Iowa City, IA 52242; `http://www.stat.uiowa.edu/`.

Women and minorities encouraged to apply. The Univ. of Iowa is an Affirmative Action/Equal Opportunity Employer.

UNIVERSITY OF NORTHERN IOWA
Department of Mathematics
Head

Applications are invited for the position of head of the Department of Mathematics to begin on or about July 1, 2003. We are seeking an effective leader of a diverse department. The ideal candidate will be capable of leading a large department consisting of mathematicians, applied mathematicians, statisticians, and mathematics educators.

Required: Doctorate in mathematics, applied mathematics, statistics, or mathematics education, with a strong background in mathematics, excellence in communication and administration, qualifications to teach all levels of undergraduate mathematics, credentials warranting a senior-level position, substantial evidence of excellent undergraduate- and/or graduate-level teaching.

Duties: Leading and serving the department; some teaching, advising, and scholarly activity; budgeting and planning; assigning and evaluating faculty; facilitating faculty development; conducting external relations; recruiting mathematics majors.

The Department of Mathematics consists of 26 tenured and tenure-track faculty members and offers undergraduate degrees with concentrations in mathematics, applied mathematics, statistics and actuarial science, and mathematics education (both elementary and secondary). The department offers master's degrees in mathematics and mathematics education (both elementary and secondary).

The University of Northern Iowa is one of three state universities in Iowa and has the principal mission of providing high-quality education to undergraduates. Located in a metropolitan area with a population of about 125,000, the university serves a student population of approximately 14,000.

Complete applications received by January 6, 2003, will be given full consideration. Salary will be commensurate with qualifications and experience. The department encourages applications from minority persons, women, disabled veterans, and Vietnam-era veterans. Send a letter describing in pertinent detail how your qualifications and experience match our mission and requirements; a curriculum vitae; and the names, mail addresses, email addresses, and telephone numbers of three references to: Mathematics Head Search, Committee Chair, BRC 50, University of Northern Iowa, Cedar Falls, IA 50614-0181. Email inquiries may be sent to `math_head_search@uni.edu`. See our website at `http://www.math.uni.edu/`. Applications by email will not be accepted.

The University of Northern Iowa is an Equal Opportunity Employer with a comprehensive plan for affirmative action.

KANSAS

KANSAS STATE UNIVERSITY
Department of Mathematics

Subject to budgetary approval, applications are invited for tenure-track and visiting positions commencing August 3, 2003; rank and salary commensurate with qualifications. The department seeks candidates whose research interests mesh well with current faculty. The department has research groups in the areas of analysis, algebra, geometry/topology, and differential equations. Applicants must have strong research credentials and a commitment to excellence in teaching. A Ph.D. in mathematics or a Ph.D. dissertation accepted with only formalities to be completed is required. Letter of application, current vita, description of research, and at least three letters of reference evaluating research should be sent to:

Louis Pigno
Department of Mathematics
Cardwell Hall 138
Kansas State University
Manhattan, KS 66506

The department also requires that the candidate arrange for letters to be submitted evaluating teaching potential. Offers may begin by December 2, 2002, but applications for positions will be reviewed until February 1, 2003, or until positions are closed. AA/EOE.

MARYLAND

UNITED STATES NAVAL ACADEMY
Mathematics Department

The USNA mathematics department anticipates at least two tenure-track positions (subject to approval and funding) at the assistant professor or associate professor level, depending on qualifications, to start in August 2003. See website `http://www.usna.edu/MathDept/website/Hire.htm`. For full information; tel: 410-293-6700; fax: 410-293-4883; email: `amg@usna.edu`. The United States Naval Academy is an Affirmative Action/Equal Employment Opportunity Employer and provides reasonable accommodations to applicants with disabilities.

MASSACHUSETTS

BOSTON UNIVERSITY
Center for BioDynamics
Predoctoral and Postdoctoral Positions

The Center for BioDynamics (CBD) at Boston University has predoctoral and postdoctoral positions available. The CBD is a multidisciplinary center devoted to research and training at the interfaces of dynamical systems, biology and engineering. Current research themes include computational neurobiology, gene regulatory networks, fluid and solid mechanics, and applied biodynamics. We seek candidates interested in working across disciplinary boundaries with multiple members of the CBD.

The CBD is connected to many departments and other research centers at Boston University, providing a stimulating research environment. Associated senior faculty members are T. Kaper, N. Kopell, G. Wayne (math), J. Collins, K. Sen, J. White (biomedical engineering), M. Hasselmo (psychology), P. Barbone and J. Baillieul (aerospace and mechanical engineering), and S. Redner (physics). For further information about the CBD, please see our webpage at `http://cbd.bu.edu/`.

To apply for a postdoctoral fellowship, please send (1) a statement that includes your background, career goals, how this position satisfies those goals, and your suitability for this position; (2) your CV and (3) three letters of recommendation to:

Ms. Geri Duffy
Center for BioDynamics
Department of Mathematics
Boston University
111 Cummington Street
Boston, MA 02215

Applications will be reviewed starting January 10, 2003. Interested Ph.D. candidates should apply to one of the associated departments and mention interest in the CBD. Please refer to the BU Graduate School Admissions Office (http://www.bu.edu/apply/#graduate/) for all application materials.

Related predoctoral and postdoctoral positions are available in the Program in Mathematical and Computational Neuroscience (PMCN); see ad #000166.

BOSTON UNIVERSITY
Predoctoral and Postdoctoral Fellowship
Burroughs Wellcome Training Program in Mathematical and Computational Neuroscience (PMCN)

The goal of PMCN is to facilitate the transition of a small and outstanding set of predoctoral and postdoctoral fellows from the mathematical and physical sciences to a range of areas in neuroscience. Financial support for both Ph.D. candidates and postdoctoral fellows is available. The program features special seminars, mentoring by faculty and advanced trainees, and a dynamic and well-networked intellectual life provided by multiple supporting institutional modules. These include a new degree-granting Program in Neuroscience (PIN, http://www.bu.edu/pin/), the graduate program of the biomedical engineering department (BME, http://bme.bu.edu/) and the Center for BioDynamics (CBD, http://cbd.bu.edu/).

Predoctoral fellows will enroll in one of two Ph.D. programs (PIN or BME) that focus on the combination of experimental and computational neuroscience. Burroughs Wellcome Postdoctoral Fellows will design individualized programs that include neuroscience courses and one or more research projects that emphasize combined computational and experimental approaches to neuroscience. In addition, fellows may participate in the CBD, which helps physical scientists and engineers to address research problems at the interfaces among mathematics, physics, biology, and engineering.

PMCN is directed by H. Eichenbaum and N. Kopell. The senior faculty members are P. Cook (biology); M. Hasselmo, H. Eichenbaum, D. Somers, C. Stern (psychology); S. Colburn, J. Collins, J. White (biomedical engineering); T. Kaper, N. Kopell, G. Wayne (math); B. Shinn-Cunningham (cognitive and neural systems, biomedical engineering). For further information and instructions about applications, see our website at http://pmcn.bu.edu/, or email pmcn@bu.edu. Our mailing address is: PMCN, c/o G. Duffy, Department of Mathematics, Boston University, 111 Cummington St., Boston, MA 02215. Applications will be reviewed starting January 10, 2003.

Related predoctoral and postdoctoral positions are available at the Center for BioDynamics (CBD); see ad #000165.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics
Applied Mathematics

Applications are invited for a limited number of positions in applied mathematics, including numerical analysis, scientific computation, and physical applied mathematics, starting fall 2003. Available positions include instructorships, lectureships, assistant professorships, and possibly higher levels. Appointments will be made mainly on the basis of demonstrated research accomplishments and potential. Complete applications must be received by January 6. To apply, please send a vita with a description of your recent research and research plans, and arrange to have three letters of reference sent to: Committee on Applied Mathematics, Massachusetts Institute of Technology, Room 2-345, 77 Massachusetts Ave., Cambridge, MA 02139-4307. M.I.T. is an Equal Opportunity/Affirmative Action Employer. (For more information about the position and institution: http://www-math.mit.edu/.)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics
C.L.E. Moore Instructorships in Mathematics

These positions are open to mathematicians with doctorates who show definite promise in research. The teaching load will be nine hours for the academic year. Applications should be complete by January 6. Applicants should arrange to have sent (a) a vita, (b) three letters of reference, (c) a description of the research in their thesis, and (d) a research plan for the next year to: Pure Mathematics Committee, Massachusetts Institute of Technology, Room 2-263, 77 Massachusetts Ave., Cambridge, MA 02139-4307. M.I.T. is an Equal Opportunity/Affirmative Action Employer. (For more information about the position or institution: http://www-math.mit.edu/.)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mathematics

The Department of Mathematics may make appointments, at the level of lecturer and assistant professor or higher, in pure mathematics for the year 2003–2004. The teaching load will be nine hours for the academic year (eight hours for assistant professor appointments). These positions are open to mathematicians with doctorates who show definite promise in research. Applications should be complete by January 6. Applicants should arrange to have sent (a) vita, (b) three letters of reference, (c) a description of their most recent research, and (d) a research plan for the immediate future to: Pure Mathematics Committee, Massachusetts Institute of Technology, Room 2-263, 77 Massachusetts Ave., Cambridge, MA 02139-4307. M.I.T. is an Equal Opportunity/Affirmative Action Employer. (For more information about the position or institution: http://www-math.mit.edu/.)

UNIVERSITY OF MASSACHUSETTS AMHERST
Department of Mathematics & Statistics

The Department of Mathematics & Statistics (http://www.math.umass.edu/) invites applications for tenure-track positions at the assistant professor level. The search will encompass the following areas: analysis, applied and computational mathematics, dynamical systems, geometry and topology, representation and Lie theory, number theory, partial differential equations, probability, and statistics. Exceptional promise in research and teaching (at all levels of the curriculum) is required. Although this search focuses on junior-level appointments, candidates for more senior-level appointments will be considered. In addition, visiting assistant professor/lecturer positions might be available. Applicants should send a curriculum vitae and arrange to have at least three letters of recommendation sent to: Search Committee, Department of Mathematics & Statistics, University of Massachusetts, 710 North Pleasant St., Amherst, MA 01003-9305. Review of applications will begin on November 1. Applications will continue to be accepted until all positions are filled. Please include the AMS Application Cover Sheet. Women and members of minority groups are encouraged to apply. Equal Opportunity/Affirmative Action Employer.

WILLIAMS COLLEGE
Department of Mathematics and Statistics

The department invites applications for two positions in mathematics and one position in statistics, beginning fall 2003, all at the rank of assistant professor (in exceptional cases, more advanced appointments may be considered). We are seeking highly qualified candidates who have demonstrated excellence in teaching and research and who will have a Ph.D. by the time of appointment.

Williams College is a private, residential, highly selective liberal arts college with an undergraduate enrollment of approximately 2,000 students. The teaching load is two courses per 12-week semester and a winter-term course every other January. In addition to excellence in teaching, an active and successful research program is expected.

To apply, please send a vita and have three letters of recommendation on teaching and research sent to the Hiring Committee, Department of Mathematics and Statistics, Williams College, Williamstown, MA 01267. Teaching and research statements are also welcome. Evaluations of applications will begin on or after November 25 and will continue until the positions are filled. Williams College is dedicated to providing a welcoming intellectual environment for all of its faculty, staff, and students; as an EEO/AA Employer, Williams especially encourages applications from women and underrepresented minorities. For more information on the Department of Mathematics and Statistics, visit http://www.williams.edu/Mathematics/.

MICHIGAN

MICHIGAN TECHNOLOGICAL UNIVERSITY
Department of Mathematical Sciences
Combinatorics Search Committee
Tenure-Track Assistant Professor
1400 Townsend Drive
Houghton, MI 49931-1295

Applications are invited for a tenure-track position in the Department of Mathematical Sciences in the area of Combinatorics starting August 2003. We are especially interested in the areas of combinatorial optimization, cryptography, data compression, combinatorial algorithms, and combinatorial designs as well as individuals who will be able to interact with faculty in the area of combinatorics. Candidates should have completed their Ph.D. degree by the beginning of the 2003/2004 academic year and must demonstrate evidence of excellence in teaching and outstanding research potential. Review process begins January 15, 2003. Send vitae and 3 letters of reference to: Combinatorics Search Committee, Department of Mathematical Sciences, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295. Michigan Technological University is an Equal Opportunity Educational Institution/Equal Opportunity Employer/Affirmative Action Employer.

UNIVERSITY OF MICHIGAN
Department of Mathematics

The department seeks candidates for lecturer positions beginning September 2003, involving the operation of its Introductory Program in precalculus and calculus. Duties include teaching in the program and, depending on the candidate's experience, possibly one or more of the following: general help with the administration of the Introductory Program, assistance with training and supervising new teachers, or direction of a large multi-section course. Applicants should have demonstrated excellence in the teaching of precalculus and calculus. Experience in directing other instructors and expertise in modern pedagogical methods are also desirable. A Ph.D. in mathematics or a closely related area is preferred, but all strong candidates will be considered. Salary commensurate with experience.

Applicants should send a CV/bibliography, description of experience, a statement on teaching, and three letters of recommendation to: Chair, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109-1109; email: math-fac-search@umich.edu. Further information on the Introductory Program is available on our webpage (http://www.math.lsa.umich.edu/). Applicants will be considered on a continuing basis. The University of Michigan is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF MICHIGAN
Department of Mathematics

The department seeks candidates for a tenured or tenure-track position whose primary responsibility is the direction and administration of its Introductory Program. Duties include addressing curricular issues and serving as liaison with other departments, directing a large multisection precalculus or calculus course per semester, teaching one section of the course being directed, assisting to train and supervise new teachers in the Introductory Program, and providing general leadership to the program. Applicants should hold a Ph.D. in mathematics, have demonstrated excellence in the teaching of precalculus and calculus, have experience directing other instructors, and expertise in modern pedagogical issues and methods. Outstanding research and scholarly contributions in mathematics and/or pedagogy of mathematics and a developing national recognition of educational issues are required for tenure.

Applicants should send a CV/bibliography, description of experience, a statement on teaching, and three letters of recommendation to: Search Chair, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109-1109; email: math-fac-search@umich.edu. Details on qualifications for hiring and tenure are available upon request. Further information about the Introductory Program can be found on our home page (http://www.math.lsa.umich.edu/). Applicants will be considered on a continuing basis. The University of Michigan is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF MICHIGAN
Department of Mathematics

The department has several openings at the tenure-track or tenured level. Candidates should hold a Ph.D. in mathematics or a related field and should show outstanding promise and/or accomplishments in both research and teaching. Applications are encouraged from any area of pure, applied, computational, or interdisciplinary mathematics, including mathematical biology, theoretical computer science, and actuarial or financial mathematics. Salaries are competitive and are based on credentials. Applicants should send a CV; bibliography; descriptions of research and teaching experience; and three or four letters of recommendation, at least one of which addresses the candidate's teaching experience and capabilities, to: Personnel Committee, University of Michigan, Department of Mathematics, 2074 East Hall, Ann Arbor, MI 48109-1109. Applications are considered on a continuing basis, but candidates are urged to apply by November 1, 2002. Inquiries may be made by email to math-facsearch@umich.edu. More detailed information regarding the department may be found on our webpage: http://www.math.lsa.umich.edu/. The University of Michigan is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF MICHIGAN-DEARBORN
Tenure-Track Position in
Applied Mathematics

University of Michigan-Dearborn (http://www.umd.umich.edu/casl/math/) plans to fill a tenure-track position starting in September 2003 at the assistant professor level. The position requires a Ph.D. in an area of applied or computational mathematics by September 2003. Candidates in all areas of applied mathematics are encouraged to apply, with preference given to those in applied discrete mathematics. Teaching capability in applied mathematics is required. Excellence in research and teaching are required for tenure. Interest in developing undergraduate and graduate curricula in applied mathematics, especially computational mathematics, is desired. The teaching load is 18 credit hours per academic year. To apply, send vita, transcript, and three letters of recommendation to: Professor Margret Höft, Chair, Department of Mathematics and Statistics, University of Michigan-Dearborn, 4901 Evergreen Rd., Dearborn, MI 48128-1491.

To ensure full consideration, all application materials must be received by January 27, 2003. However, the department will continue to accept application materials until the position is filled. A representative of the department will be at the annual meeting of the AMS in Baltimore in January to discuss the position with those interested.

The University of Michigan-Dearborn is dedicated to the goal of building a culturally diverse and pluralistic faculty committed to teaching and working in a multicultural environment and strongly encourages applications from minorities and women. The University of Michigan-Dearborn is an Equal Opportunity/Affirmative Action Educator and Employer.

MISSOURI

HILLSDALE COLLEGE
Mathematics and Computer Science
Two positions available: (1) Applied Mathematics and (2) Mathematics

Applications are invited for positions in applied mathematics and in mathematics. Entry-level, tenure-track positions with initial appointments made at the assistant professor level beginning in August 2003.

1. Candidates for applied mathematics position required to have a Ph.D. in mathematics with specialty in applied mathematics and to be willing to teach especially mathematical modeling, differential equations, numerical analysis, and vector analysis, in addition to other undergraduate mathematics courses.

2. Candidates for mathematics position required to have a Ph.D. in mathematics and to be willing to teach various undergraduate mathematics courses.

Candidates for either position must have a strong commitment to excellence in teaching undergraduate mathematics. Duties for each position include a 12-hour (3 course) teaching load per semester, which will include teaching all levels of undergraduate mathematics, academic advising, college service, and continued mathematical activity.

Hillsdale College, founded in 1844, is an independent, coeducational, four-year liberal arts college of 1,200 students. Hillsdale has traditionally upheld two concepts: academic excellence and institutional independence. For additional college information check our website: `http://www.hillsdale.edu/`.

Send a letter of application, which should include a personal statement addressing the applicant's teaching philosophy and qualifications for the position; curriculum vitae; graduate transcript; a short summary of teaching evaluations; and at least three letters of recommendation to: Professor Mark J. Watson, Chair, Department of Mathematics and Computer Science, Hillsdale College, Hillsdale, MI 49242. Review of applications will begin November 1, 2002, and will continue until the positions are filled. EOE.

UNIVERSITY OF MISSOURI-KANSAS CITY
Department of Mathematics

The University of Missouri-Kansas City announces openings for mathematics faculty at both the assistant professor and associate professor levels. The department has needs in all areas of mathematics, but at least one of the appointments will be made in each of the core disciplines of analysis and algebra; the other offers will be made to the best-qualified applicants, regardless of specialty.

Duties include teaching mathematics courses at both the undergraduate and graduate levels and research of a quality sufficient to enable the successful applicant to participate in the department's doctoral and master's programs. The applicant must have a Ph.D. in mathematics and have strong potential for successful research and excellence in teaching. Applicants for the associate professor positions should have well-established research programs and experience in teaching graduate courses; in addition, at least one of the successful applicants should have the qualities needed in a potential department chair.

Applications should include a vita and three letters of recommendation and should be sent to:

Search Committee
Department of Mathematics
and Statistics
206 Haag Hall
University of Missouri-Kansas City
Kansas City, MO 64110-2499

The salary is competitive at both the assistant professor and associate professor levels. UMKC is an Equal Opportunity/Affirmative Action Employer.

NEW HAMPSHIRE

DARTMOUTH COLLEGE
Department of Mathematics

The Department of Mathematics seeks to recruit at the senior level in applied mathematics with an initial appointment in the 2003–2004 academic year. The successful candidate will be an acknowledged leader in his/her field with proven ability to work across disciplines and attract outside funding. Applicants with any of a wide variety of interests ranging from traditional applied fields and backgrounds—e.g. signal processing, mathematical statistics, PDE's, as well as new application areas such as informatics, quantum computing, or applied algebra—are encouraged to apply. Various projects are currently funded by the NSF, NIH, NIMH, and DoD. Active collaborations with the medical and engineering schools, and programs in computer science and cognitive neuroscience exist. Collaborations and/or appointments in Dartmouth's M.D./Ph.D. program, as well as Dartmouth's Institute for Secure Technologies Studies, are also possible. Lab space in the new mathematics building will also be available, and future hirings in applied mathematics are anticipated.

Candidates must be committed to outstanding teaching and interaction with students at all levels of undergraduate and graduate study and be willing to advance applied mathematics across campus. To create an atmosphere supportive of research, Dartmouth offers new faculty members grants for research-related expenses, a quarter of sabbatical leave for each three academic years in residence, and flexible scheduling of teaching responsibilities. The teaching responsibility in mathematics is two courses per quarter for two 10-week quarters or one course for each of two quarters and two courses for one quarter. The combination of committed colleagues and talented, responsive students encourages excellence in teaching at all levels.

To apply, a copy of the application information and required response form may be obtained online from our website at `http://www.math.dartmouth.edu/recruiting/`. Or send a letter of application; curriculum vitae; a brief statement of research results and interests; and four letters of reference, at least one of which specifically addresses teaching, to: Donna Black, Recruiting Secretary, Department of Mathematics, Dartmouth College, 6188 Bradley Hall, Hanover, NH 03755-3551. Applications received by December 6, 2002, will receive first consideration. Dartmouth College is committed to diversity and strongly encourages applications from women and minorities. Inquiries about the progress of the selection process may be directed to: Dan Rockmore, Professor of Mathematics and Computer Science, Dartmouth College, Hanover, NH 03755, or via email at `Daniel.Rockmore@Dartmouth.edu`.

DARTMOUTH COLLEGE
Department of Mathematics

The Department of Mathematics anticipates a tenure-track opening with initial appointment in the 2003–2004 academic year. The position is an assistant professorship in number theory or "applicable mathematics". The work of candidates in applicable mathematics should straddle the line of pure and applied mathematics. The successful candidate will be a researcher working in core mathematics who has a proven track record in pursuing both the theoretical development of his/her subject, as well as potential applications. Examples would include (but are not limited to) number theorists with interests in cryptography or coding theory, representation theorists who work in signal processing, combinatorialists with interests in computing, probabilists with interests in statistics, as well as more classical applied mathematicians. Various projects are currently funded by the NSF and DoD. Active collaborations with the medical and engineering schools, and programs in computer science and cognitive neuroscience exist. Collaborations and/or appointments in Dartmouth's M.D./Ph.D. program, as well as Dartmouth's Institute for Secure Technologies Studies, are also possible. In number theory, we have interests in both algebraic and analytic number theory.

Candidates for the position must be committed to outstanding teaching and interaction with students at all levels of undergraduate and graduate study, and must demonstrate an exceptional potential for research. Candidates with several years of experience should be able to give evidence of a research program that has achieved peer recognition and which promises future research leadership in the mathematical community. Candidates who do not have this level of experience must have demonstrated the potential for future mathematical research leadership in their Ph.D. work. To create an atmosphere supportive of research, Dartmouth offers new faculty members grants for research-related expenses, a quarter of sabbatical leave for each three academic years in residence, and flexible scheduling of teaching responsibilities. The teaching responsibility in mathematics is two courses per quarter for two 10-week quarters or one course for each of two quarters and two courses for one quarter. The combination of committed colleagues and bright, responsive students encourages excellence in teaching at all levels.

To apply, get a copy of the application information and the required response form at `http://www.math.dartmouth.edu/recruiting/`. Or send a letter of application; curriculum vitae; a brief statement of research results and interests; and four letters of reference, at least one of which specifically addresses teaching, to: Donna Black, Recruiting Secretary, Department of Mathematics, Dartmouth College, 6188 Bradley Hall, Hanover, NH 03755-3551. Applications received by January 5, 2003, will receive first consideration. Dartmouth College is committed to Affirmative Action and encourages applications from African Americans, Asian Americans, Hispanics, Native Americans, and women. Inquiries about the progress of the selection process may be directed to Dwight Lahr, Recruiting Chair.

DARTMOUTH COLLEGE
John Wesley Young
Research Instructorship

The John Wesley Young Instructorship is a two-year postdoctoral appointment intended for promising Ph.D.'s whose research interests overlap a department member's. Current departmental interests include areas in algebra, analysis, algebraic geometry, combinatorics, differential geometry, logic and set theory, number theory, probability, and topology. Instructors teach four 10-week courses distributed over three terms, though one of these terms in residence may be free of teaching. The assignments normally include introductory, advanced undergraduate, and graduate courses. Instructors usually teach at least one course in their own specialty. Nine-month salary of $43,800 supplemented by summer research stipend of $9,733 for instructors in residence for two months in summer.

To be eligible for a 2003–2005 instructorship, candidate must be able to complete all requirements for the Ph.D. degree before September 2003. Applicants should get a copy of the application information and the required response form at `http://www.math.dartmouth.edu/recruiting/`. Or submit a letter of application; curriculum vitae; graduate school transcript; thesis abstract; statement of research plans and interests; and at least three, preferably four, letters of recommendation to: Donna Black, Department of Mathematics, Dartmouth College, 6188 Bradley Hall, Hanover, NH 03755-3551. Applications received by January 5, 2003, will receive first consideration; applications will be accepted until position is filled. Dartmouth College is committed to diversity and strongly encourages applications from women and minorities.

NEW JERSEY

RUTGERS UNIVERSITY–NEWARK
Department of Mathematics and Computer Science
Assistant Professor

The Department of Mathematics and Computer Science invites applications for a tenure-track assistant professor position in mathematics to begin September 2003. Candidates must have a Ph.D., a strong research record, and show outstanding promise for future research. Candidates should also demonstrate a commitment to effective teaching in mathematics and in computer science.

Applicants should arrange for (1) an AMS Standard Cover Sheet; (2) a curriculum vitae; (3) a research statement; and (4) at least four letters of recommendation, one of which addresses teaching, to be sent to: Personnel Committee, Department of Mathematics and Computer Science, Rutgers University, Newark, NJ 07102

The review process will begin January 15, 2003. Applications may be accepted until the position is filled.

Rutgers University is an Equal Opportunity/Affirmative Action Employer.

NEW YORK

BINGHAMTON UNIVERSITY
Department of Mathematical Sciences

The Department of Mathematical Sciences at Binghamton University (The State University of New York at Binghamton) invites applications for a Riley Assistant Professorship. This is a three-year non-tenure-track position in mathematics. The position is contingent upon university funding. Qualifications: A recent Ph.D. in mathematics or Ph.D. expected by summer 2003, evidence of teaching ability, and outstanding research potential. Research areas near those of current faculty will have priority. Applications will be accepted until the teaching position is filled. Send CV, evidence of research, and teaching credentials to: Ben Brewster, Chair, Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902-6000. Binghamton University is an Equal Opportunity/Affirmative Action Employer.

BROOKLYN COLLEGE OF THE CITY UNIVERSITY OF NEW YORK
Department of Mathematics

The Department of Mathematics of Brooklyn College of the City University of New York announces a tenure-track assistant or associate professor position in mathematics/mathematics education beginning in fall 2003. Duties will include curriculum development and teaching in the programs for mathematics teachers, grades 7–12; and helping coordinate those programs. The successful applicant will possess the Ph.D. degree in mathematics or mathematics education and will have relevant experience. Commitments to scholarship, teaching, and curriculum development are essential. Rank and salary are commensurate with qualifications and experience.

Candidates should send a résumé and three letters of recommendation to: Dr. Edna Chun, Assistant Vice President for Human Resources, Brooklyn College, 2900 Bedford Avenue, Brooklyn, NY 11210. Review of applications will begin on November 12, 2003, and will continue until the position is filled.

An EO/AA/IRCA/ADA Employer.

SUNY POTSDAM
Department of Mathematics

SUNY Potsdam invites applications for one anticipated full-time tenure-track position effective September 1, 2003, at the rank of assistant professor. Responsibilities of the position include teaching twelve hours per semester of undergraduate through first-year graduate courses. Required qualifications are a Ph.D. in any area of mathematics, with a strong interest in and preparation for teaching undergraduate major mathematics courses. Candidates from all areas of mathematics are encouraged to apply.

Applications, which must include a letter of interest; a teaching statement; a curriculum vitae; three letters of recommendation, at least one of which addresses teaching experience and abilities; and a transcript (a copy is acceptable), should be sent to: Dr. Victoria Klawitter, Staffing Committee Chair, Department of Mathematics, SUNY Potsdam, Potsdam, NY 13676; or email at klawitv@potsdam.edu. To ensure full consideration, complete applications must be received by January 22, 2003. For information about the college and the department, you may go to http://www.potsdam.edu/. SUNY Potsdam is an Equal Opportunity Employer committed to excellence through diversity.

NORTH CAROLINA

WAKE FOREST UNIVERSITY
Department of Mathematics

Applications are invited for two tenure-track positions in mathematics at the assistant professor level beginning August 2003. We seek one person whose research is in analysis and one person whose research is in combinatorics or number theory. Duties include teaching at the undergraduate and graduate levels and continuing research. A Ph.D. in mathematics or equivalent is required. The department has 18 members and offers a B.A., B.S., and M.A. in mathematics and a B.S. in each of mathematical business and mathematical economics. Send letter of application and résumé to: R. D. Carmichael, Department of Mathematics, Wake Forest University, P.O. Box 7388, Winston-Salem, NC 27109-7388. AA/EO Employer.

OREGON

PORTLAND STATE UNIVERSITY
Department of Mathematics and Statistics

The Department of Mathematics and Statistics anticipates two tenure-track positions at the assistant professor level beginning fall 2003. Candidates must hold a Ph.D. in mathematics or statistics, have excellent communication skills, and a strong commitment to excellence in teaching and research.

Computational position: Preference given to applicants with strong academic training and research interests in numerical analysis or computational mathematics. Successful candidates must be able to contribute also to the research life of the department in one or more of the following areas: scientific computing, numerical analysis, control theory, dynamical systems, applied analysis or partial differential equations, graph theory, applied probability or applied statistics.

Open position: Preference given to candidates in mathematics or statistics with demonstrated capability for original research of high quality in an area of interest in the department and a strong interest in interdisciplinary research in computer science, engineering, a physical or life science, financial mathematics, or economics.

Portland State University is an Affirmative Action/Equal Opportunity Institution and, in keeping with the president's diversity initiative, welcomes applications from diverse candidates and candidates who support diversity. Positions open until finalists are identified. Applicants should send AMS cover sheet, a curriculum vitae, summaries of research and teaching objectives, and three letters of recommendation to: Search Committee, Department of Mathematics and Statistics, Portland State University, Portland, OR 97207. Questions? Call 503-725-3621 or send email to search@mth.pdx.edu. Candidates can also visit the PSU website, http://www.mth.pdx.edu/, for more information.

UNIVERSITY OF OREGON
Department of Mathematics

Applications are invited for one tenure-track assistant or associate professor in the Department of Mathematics, beginning September 2003. Qualifications are a Ph.D. in the mathematical sciences, an excellent record of research accomplishment, and evidence of teaching ability. Applicants from all parts of the mathematical sciences are encouraged to apply. See http://darkwing.uoregon.edu/~math/employment.html.

Competitive salary with excellent fringe benefits. Mail complete vita and at least three letters of recommendation to: Search Committee, 1222 Department of Mathematics, University of Oregon, Eugene, OR 97403-122, Attention: J. Perkins. Application materials may NOT be submitted electronically.

Closing date is January 6, 2003. Women and minorities are encouraged to apply. The University of Oregon is an EO/AA/ADA Institution committed to diversity.

UNIVERSITY OF OREGON
Department of Mathematics

Applications are invited for one tenure-track assistant or associate professor in the Department of Mathematics in the areas of numerical analysis and/or applied analysis, beginning September 2003. Qualifications are a Ph.D. in the mathematical sciences, an excellent record of research accomplishment in the required fields, and evidence of teaching ability. See http://darkwing.uoregon.edu/~math/employment.html.

Competitive salary with excellent fringe benefits. Mail complete vita and at least three letters of recommendation to: Professor Yuan Xu, Chair of Applied Analysis Search Committee, 1222 Department of Mathematics, University of Oregon, Eugene, OR 97403-122. Application materials may NOT be submitted electronically.

Closing date is January 6, 2003. Women and minorities are encouraged to apply. The University of Oregon is an EO/AA/ADA Institution committed to diversity.

UNIVERSITY OF OREGON
Department of Mathematics

The Department of Mathematics at the University of Oregon announces a tenure-track position in mathematics education at the assistant or associate professor level, starting fall 2003. Qualifications: either a Ph.D. in mathematics and documented interest in mathematics education at the elementary or secondary level or a Ph.D. or Ed.D. in mathematics education with a very strong background and interest in mathematics. In addition the candidate must have some involvement in the education of future school teachers and excellence in teaching undergraduate mathematics. See http://darkwing.uoregon.edu/~math/employment.html.

Please send your application materials, including full CV and at least three letters of recommendation from people well acquainted with your qualifications, to: Professor J. Brundan, Mathematics Education Hiring Committee, Department of Mathematics, 1222 University of Oregon, Eugene, OR 97403-1222. Application materials may NOT be submitted electronically.

Closing date for applications is January 13, 2003. Women and minorities are encouraged to apply. The University of Oregon is an EO/AA/ADA Institution committed to diversity.

PENNSYLVANIA

CARNEGIE MELLON UNIVERSITY
Center for Nonlinear Analysis
Department of Mathematical Sciences

The Center for Nonlinear Analysis expects to make several postdoctoral appointments for 2002-03 in the area of applied analysis. These will be one- or two-year joint appointments by the Center and Department of Mathematical Sciences. Recipients will teach at most two courses per year. Applicants should send a vita, list of publications, a statement describing current and planned research, and at least three letters of recommendation to the committee. The deadline for applications is January 17, 2003. All communications should be addressed to: Postdoctoral Appointments Committee, Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213. Carnegie Mellon University is an Affirmative Action/Equal Opportunity Employer.

CARNEGIE MELLON UNIVERSITY
Department of Mathematical Sciences
Zeev Nehari Visiting Assistant Professorship

The position is available for a period of three years, beginning in September 2003, and carries a teaching load of three courses during the academic year. Applicants are expected to show exceptional research promise, as well as clear evidence of achievement, and should have research interests which intersect those of current faculty of the department. Applicants should send a curriculum vitae, list of publications, a statement describing current and planned research, and at least three letters of recommendation to: Appointments Committee, Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213. The deadline for applications is January 17, 2003.

The Department of Mathematical Sciences is committed to increasing the number of women and minority faculty. Carnegie Mellon University is an Affirmative Action/Equal Opportunity Employer and encourages applications from women and minorities.

GETTYSBURG COLLEGE
Tenure-Track Assistant Professor Position in Mathematics

Gettysburg College invites applications for a tenure-track assistant professor position in mathematics beginning August 2003. Applicants must have a Ph.D. in mathematics, applied mathematics, or statistics or expect to complete all requirements for the degree by September 2003. Promise of excellence in teaching and commitment to a vigorous research program are essential. Applicants from all branches in the mathematical sciences will be considered; applicants who have an active interest and demonstrated expertise in applied or computational mathematics or statistics are especially encouraged to apply. Preference will be given to an individual who is willing to teach a broad range of undergraduate mathematics courses and who has the desire to involve undergraduate students in mathematical activity outside the classroom.

Gettysburg College is a highly selective liberal arts college located within 90 minutes of the Baltimore/Washington metropolitan area. Established in 1832, the college has a rich history and is situated on a 220-acre campus with an enrollment of 2,400 students. Gettysburg College is committed to creating a more diverse campus environment. As a part of that process, the college gives strong consideration to candidates from historically underrepresented groups. The position includes an attractive benefits package.

Please send a letter of application explaining your interest in our department, a curriculum vitae, a brief description of your teaching methods and objectives, and a summary of your research goals to:

Mathematics Search Committee
Department of Mathematics
Gettysburg College
Gettysburg, PA 17325

Also arrange for the committee to receive three letters of recommendation addressing teaching effectiveness and research potential. Completed applications received by December 31, 2002, will receive full consideration.

MILLERSVILLE UNIVERSITY OF PENNSYLVANIA
Department of Mathematics

Full-time, tenure-track assistant professorship to begin August 2003 in a department of 20 faculty and approximately 175 majors in mathematics and mathematics education. Area of expertise in discrete mathematics with specialization in computational or applied aspects of finite fields, geometry, or number theory is required. Ph.D. (or completion by second year reappointment) in mathematics is required. Must exhibit evidence of strong commitment to excellence in teaching and continued scholarly activity. Must be prepared to teach a broad spectrum of undergraduate mathematics courses and have potential to contribute to the department's programs. Must provide evidence of teaching effectiveness and must complete a successful interview and teaching demonstration. Duties include an annual 24-hour teaching load, scholarly activity, student advisement, supervision of student research, curriculum development, and committee work. Salary/benefits are competitive.

Full consideration given to applications received by January 24, 2003. Email applications will not be accepted. Send letter of application addressing qualifications, curriculum vitae, copies of undergraduate and graduate transcripts, and three current letters of reference (at least two of which attest to recent teaching effectiveness) to: Dr. Hisa Tsutsui, Search Chair/AMS1202, Department of Mathematics, Millersville University of Pennsylvania, P. O. Box 1002, Millersville, PA 17551-0302. An AA/EO Institution.

PENN STATE UNIVERSITY/ COMMONWEALTH COLLEGE
Department of Mathematics

The Commonwealth College invites applications for tenure-track positions at the rank of assistant professor at three of its campuses beginning in August 2003. Tenure and promotion in the college are based on the following: innovative teaching of courses ranging primarily over the first two years of college mathematics; recognized research and scholarly contributions to mathematics and mathematics pedagogy; and service to the campus, college, university, and the community at large. Applicants must complete the Ph.D. degree in a mathematical science by the time the appointment begins and will be selected on the basis of their potential for achieving tenure and promotion. To learn more about the campuses and the positions, please visit `http://cwchome.psu.edu/` and choose the "Careers with Us" link.

Applicants should submit a résumé including a list of publications, a statement on teaching and research, and the complete contact information for three references, including email addresses, to:

The Pennsylvania State University
Commonwealth College
Faculty Searches
111 Old Main, Box NOTICES-TT
University Park, PA 16802

Applications will also be accepted via email at: `cwcsearch@psu.edu`. Review of applications will begin November 1, 2002, and will continue until the positions are filled. Penn State is committed to Affirmative Action, Equal Opportunity, and the diversity of its work force.

SOUTH CAROLINA

COLLEGE OF CHARLESTON
Department of Mathematics

Applications are invited for at least one tenure-track position at the assistant professor level starting in August 2003. The mathematics department at the College of Charleston has 34 full-time faculty members and offers the B.S. and M.S. degrees in mathematics. Candidates must have a Ph.D. in one of the mathematical sciences, a commitment to undergraduate and graduate teaching, and the potential for continuing research. Preference for one position will be given to applicants with the expertise to teach statistics or operations research. The normal teaching load is nine hours per week for those engaged in research. The salary is competitive.

Applicants should send a vita and three letters of recommendation to: Deanna Caveny, Chair, Department of Mathematics, College of Charleston, Charleston, SC 29424-0001. Additional information is available by visiting http://math.cofc.edu/ or emailing cavenyd@cofc.edu. Applications will be considered as they are received until the position is filled. The College of Charleston is an Equal Opportunity/Affirmative Action Employer and encourages applications from minority and women candidates.

TENNESSEE

UNIVERSITY OF TENNESSEE
Department of Mathematics

The mathematics department of the University of Tennessee seeks to fill tenure-track positions at the assistant professor level. A Ph.D. is required. Some postdoctoral experience is preferred but not required. Substantial research promise and dedication to teaching are paramount. Employment begins August 1, 2003.

Applicants with research experience in any area of mathematics are encouraged to apply, but preference will be shown to those in geometric topology and computational applied mathematics.

Interested applicants should arrange to have a vita, three reference letters, a research statement (including abstracts), and evidence of quality teaching sent to: Professor John B. Conway, Search, Mathematics Department, University of Tennessee, Knoxville, TN 37996-1300. Electronic applications are not acceptable. Use of the AMS application form is appreciated. Review of applications will begin December 1 and will continue until the positions are filled. Information about the department can be found at http://www.math.utk.edu/.

UT Knoxville is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA Institution in the provision of its education and employment programs and services.

VANDERBILT UNIVERSITY
Department of Mathematics
1326 Stevenson Center
Nashville, TN 37240

We invite applications for a non-tenure-track position in algebra and combinatorics beginning in fall 2003. This is a two-year appointment at the assistant professor level, normally renewable for a third year, with 2:1 teaching load. It is intended for a recent Ph.D. with demonstrated research potential and a strong commitment to excellence in teaching. Research areas of interest include, but are not limited to, geometric group theory, universal algebra, algebraic/geometric combinatorics, and graph theory. To apply, send the following materials to Algebra and Combinatorics Search: a letter of application (including email and fax number), the AMS standardized application form fully completed, a curriculum vitae and research summary, and at least 3 letters of recommendation (one of which should specifically address teaching effectiveness). Evaluation of applications will commence on January 7, 2003, and will continue until the position is filled.

Vanderbilt University is an Affirmative Action/Equal Opportunity Employer.

TEXAS

TEXAS TECH UNIVERSITY
Department of Mathematics and Statistics

Applications are invited for at least two tenure-track assistant professor positions beginning fall 2003. Higher-level appointments are possible in exceptional cases. Priority will be given to candidates in the areas of applied mathematics and computation, statistics, and mathematics education. Candidates whose mathematical background and scholarly activities have, or have shown, excellent potential for interdisciplinary collaboration are encouraged to apply.

Strong promise or accomplishment in teaching and scholarly activity and a Ph.D. degree at the time of appointment are required. Texas Tech University is committed to diversity among its faculty. Please send a résumé, a completed AMS Standard Cover Sheet, and three letters of recommendation to: Alex Wang, Hiring Chair, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409-1042. Review of applications will begin immediately. Additional information is available at http://ttmath.ttu.edu/~awang/employ/employ.html. Texas Tech is an AA/EO Employer.

THE UNIVERSITY OF TEXAS AT AUSTIN
Department of Mathematics
Austin, TX 78712

Openings for fall 2003 include: (a) instructorships, some that have R. H. Bing Faculty Fellowships attached to them and others that are VIGRE instructorships; and (b) four positions at the tenure-track/tenured level.

(a) Instructorships at The University of Texas at Austin are postdoctoral appointments, renewable for two additional years. It is assumed that applicants for instructorships will have completed all Ph.D. requirements by August 26, 2003. Other factors being equal, preference will be given to those whose doctorates were conferred in 2002 or 2003. Candidates should show superior research ability and have a strong commitment to teaching. Consideration will be given only to persons whose research interests have some overlap with those of the permanent faculty. Duties consist of teaching undergraduate or graduate courses and conducting independent research. The projected salary is $40,000 for the nine-month academic year.

Each R. H. Bing Fellow holds an instructorship in the mathematics department, with a teaching load of two courses in one semester and one course in the other. The combined instructorship-fellowship stipend for nine months is $44,000, which is supplemented by a travel allowance of $1,000. Pending satisfactory performance of teaching duties, the fellowship can be renewed for two additional years. Applicants must show outstanding promise in research. Bing Fellowship applicants will automatically be considered for other departmental openings at the postdoctoral level, so a separate application for such a position is unnecessary.

VIGRE instructorships are partially funded by an NSF VIGRE grant awarded to the department (in partnership with the Texas Institute for Computational and Applied Mathematics). The combined instructorship-VIGRE postdoctoral fellowship carries a nine month stipend of $40,000, with an annual allocation of $2,500 to cover equipment, supplies, and travel. The position also includes summer support in the amount of $6,500 for the first two summers of the appointment. The teaching load for VIGRE instructors is one course per semester. Only citizens, nationals, and permanent residents of the U.S. are eligible for VIGRE instructor appointments. Furthermore, a VIGRE instructor must have received the Ph.D. within eighteen months of the date the appointment becomes effective. All eligible applicants for postdoctoral positions in either the mathematics department or TICAM will automatically be considered for a VIGRE instructorship.

Those wishing to apply for Instructor positions are asked to send a vita and a brief research summary to the above address c/o Instructor Committee. Transmission of the preceding items via email (address: instructor@math.utexas.edu) is encouraged.

(b) An applicant for a tenure-track or tenured position must present a record of exceptional achievement in her or his research area and must demonstrate a proficiency at teaching. In addition to the duties indicated above for instructors, such an appointment will typically entail the supervision of M.A. or Ph.D. students. The salary will be commensurate with the level at which the position is filled and the qualifications of the person who fills it.

Those wishing to apply for tenure-track/tenured positions are asked to send a vitae and a brief research summary to the above address, c/o Recruiting Committee. Transmission of the preceding items via email (address: recruit@math.utexas.edu) is encouraged.

All applications must be supported by three or more letters of recommendation, at least one of which speaks to the applicant's teaching credentials. The screening of applications will begin on December 1, 2002. The University of Texas at Austin is an Equal Opportunity Employer.

WASHINGTON

WASHINGTON STATE UNIVERSITY
College of Sciences
Dean

The state's land-grant university invites nominations and applications for the position of dean of the College of Sciences. The College of Sciences has 150 faculty; 80 staff; 1,500 undergraduate and 400 graduate students. The college houses a large array of academic and research programs, with annual research expenditures of over $18 million. For more information see the college website at `http://www.sci.wsu.edu/`.

The Search Committee will begin reviewing candidates on October 31, 2002. Nominations and applications will be accepted until the position is filled. All nominations or letters of application with vita; and names, addresses, phone, and email of at least three references should be sent to: Dean Anjan Bose, Chair, Dean of Sciences Search Committee, College of Engineering & Architecture, Dana Hall Room 146, WSU, Pullman, Washington 99164-2714; (509) 335-5593. All inquiries, nominations, and applications will be held in strictest confidence. WSU is an Equal Opportunity/Affirmative Action Educator and Employer. Members of ethnic minorities, women, Vietnam-era or disabled veterans, persons of disability and/or persons between the ages of 40 and 70 are encouraged to apply.

WISCONSIN

UNIVERSITY OF WISCONSIN-MILWAUKEE
Milwaukee, WI 53201-0413
Department of Mathematical Sciences

The Department of Mathematical Sciences anticipates two openings for tenure-track assistant professorships, starting August 2003, pending budgetary approval. The department invites applications in algebra and statistics. Candidates must have a strong research record, evidence of or strong potential for extramural funding, and a demonstrated commitment to teaching excellence. Responsibilities include: teaching two courses per semester and taking an active role in the undergraduate, master's, and Ph.D. programs. Additional information is available at `http://www.math.uwm.edu/`.

Applicants should send the AMS Standard Cover Sheet, a vita, a description of their research, and a teaching statement to the Hiring Committee at the above address. Review of applications will begin December 6, 2002, and will continue until the position is filled. At least three letters of recommendation should be sent to the Hiring Committee; at least one letter should address the applicant's teaching experience and capabilities. UW-Milwaukee is an EEO/AA Employer. Applications from female and minority candidates are strongly encouraged.

WYOMING

UNIVERSITY OF WYOMING
Department of Mathematics

The Department of Mathematics at the University of Wyoming invites applications for a tenure-track position in high-performance computing of fluid dynamics in energy-related sciences. The appointment will be at the rank of assistant or associate professor, with an expected starting date of August 27, 2003. Qualifications include an earned doctorate, promise of excellence in teaching, research and service, and strong expertise in areas such as free-boundary problems, level set methods, and flow in heterogeneous media. The successful candidate is expected to develop an externally funded research program to support the Institute for Scientific Computation and also to explore collaborative research possibilities with the Institute for Energy Research (IER) at the University of Wyoming. Rank will depend on research and teaching experience.

Review of completed applications will begin on January 1, 2003. For informal inquiries please contact `sri@uwyo.edu`. Applicants should submit a letter explaining their interests, vita, and three letters of reference to: EPSCoR Search Committee, Department of Mathematics, University of Wyoming, Laramie, WY 82071-3036. UW is an AA/EEO Employer.

CANADA

UNIVERSITY OF TORONTO AT SCARBOROUGH
Canada Research Chair in Mathematics and Statistics at UTSC

The University of Toronto at Scarborough solicits applications for a tenured or tenure-track position in the Department of Mathematical Sciences, to begin July 1, 2003. The graduate appointment will be jointly to the Department of Mathematics and the Department of Statistics at the University of Toronto. Rank and salary will be commensurate with qualifications. The main areas of research interest are mathematical statistics, mathematical finance, or probability; however, exceptional candidates in other areas relevant to both mathematics and statistics are encouraged to apply.

It is intended that successful applicants will be nominated for a junior Canada Research Chair (Tier II). Accordingly, candidates are expected to be outstanding researchers whose scholarship and teaching will make major contributions to the quality and stature of the university.

Applicants should send their complete CV, including a list of publications, a short statement describing their research programme, and all appropriate material about their teaching. They should also arrange to have at least four letters of reference sent directly to:

Search Committee UTSC
Department of Mathematics
University of Toronto
100 St. George Street, Room 4072
Toronto, Ontario
Canada M5S 3G3.

Additional information is available at the webpage `http://www.math.toronto.edu/jobs/`.

Priority will be given to applications received by December 31, 2002. Applications after this date will be considered until the position has been filled.

The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas.

Any inquiries about the application should be sent to `ida@math.toronto.edu` or `laura@utstat.toronto.edu`.

YORK UNIVERSITY
Applied Mathematics

Applications are invited for an NSERC University Faculty Award at the assistant professor level in the Department of Mathematics and Statistics to commence July 1, 2003. Applications in the areas of applied or computational mathematics will be considered. The successful candidate must have a Ph.D. and is expected to have a proven record of research excellence and superior teaching. The position is subject to budgetary approval, and the selection process will begin immediately. Applicants should send résumés and arrange for three letters of recommendation (one of which should address teaching) to be sent directly to:

UFA Search Committee
Department of Mathematics
and Statistics
York University
4700 Keele Street

Toronto, Ontario
Canada M3J 1P3
Fax: 416-736-5757
email: ufa.recruit@mathstat.yorku.ca
http://www.math.yorku.ca/Hiring/

The UFA program is directed to women and aboriginal peoples. York University also has an Affirmative Action program with respect to its faculty and librarian appointments. The designated groups are: women, racial/visible minorities, persons with disabilities and aboriginal peoples. Persons in these groups must self-identify in order to participate in the Affirmative Action program. The Department of Mathematics and Statistics welcomes applications from persons in these groups. The Affirmative Action program can be found on York's website at http://www.yorku.ca/acadjobs/, or a copy can be obtained by calling the Affirmative Action office at 416-736-5713. The UFA program is restricted to Canadian citizens and permanent residents.

PORTUGAL

INSTITUTO SUPERIOR TÉCNICO
Department of Mathematics
Lisbon, Portugal

The Center for Mathematical Analysis, Geometry, and Dynamical Systems of the Department of Mathematics of Instituto Superior Técnico, Av. Rovisco Pais, 1049-001, Lisbon, Portugal, invites applications for postdoctoral positions for research in mathematics, subject to budgetary approval. Positions are for one year, with the possibility of extension for a second year upon mutual agreement. Selected candidates will be able to take up their position between September 1, 2003, and January 1, 2004.

Applicants should have a Ph.D. in mathematics preferably obtained after December 31, 2000. They must show very strong research promise in one of the areas in which the mathematics faculty of the center is currently active. There are no teaching duties associated with these positions.

Applicants should send a curriculum vitae; reprints, preprints and/or dissertation abstract; description of research project (of no more than 1,000 words); and three letters of reference directly to the director at the above address.

To insure full consideration, complete application packages should be received by **January 15, 2003.** Additional information about the center and the positions is available at http://www.math.ist.utl.pt/cam/.

SINGAPORE

NATIONAL UNIVERSITY OF SINGAPORE
Department of Mathematics

The Department of Mathematics at NUS invites applications for several tenure-track and visiting positions beginning in July 2003. We will consider outstanding researchers in any field of pure and applied mathematics, particularly those in the areas of scientific computing, optimization and operations research, as well as in financial mathematics, computational biology, mathematical modeling, approximation and simulations.

Application materials should be sent to:
Search Committee
Department of Mathematics
National University of Singapore
2 Science Drive 2, Singapore 117543
Republic of Singapore
Fax: +65 6779 5452

and should include: (1) an American Mathematical Society Standard Cover Sheet; (2) a detailed CV including publications list; (3) a statement of research accomplishments and plan; (4) at least three letters of recommendation, including one which indicates the candidate's effectiveness and commitment to teaching. Inquiries may be sent via email to search@math.nus.edu.sg. Review of applications will begin December 30, 2002, and will continue until positions are filled. For further information about the department, please see http://www.math.nus.edu.sg/.

TAIWAN

NATIONAL TSING-HUA UNIVERSITY
Department of Mathematics

The Department of Mathematics invites applications for faculty positions of (tenure-track) assistant professor or higher ranks, beginning fall 2003 or later. Applicants should have a Ph.D. degree in mathematical science, be research oriented, and have excellent teaching skills. The language of instruction is Mandarin. A cover letter, curriculum vitae (including plans, reprints, preprints), and three letters of professional reference should be sent to: Chairman, Department of Mathematics, National Tsing-Hua University, Hsin-Chu, 30043, Taiwan. For full consideration the application should be received by February 15, 2003. For more information on our department, visit the home page at http://www.math.nthu.edu.tw/.

Coming to a TV Screen near you!

N is a Number

Paul Erdős, the legend, is no stranger to mathematicians; Paul Erdős, the person, may be less familiar to a new generation. With his theorems, with his many conjectures, with every fiber of his being, he embodied the mathematical idea. The intensity and the selflessness of his search for mathematical truth were there for all of us to see and to emulate.

Over a four year period, George Csicsery followed Paul Erdős from Philadelphia to Poznań, from Berkeley to Budapest. His film, *N is a Number*, captures the spirit that has made so many of us so devoted to "Uncle Paul."

American Public Television is arranging showings of this documentary all over the country—we urge you to mention this fascinating glimpse of a mathematical life to others and to watch it yourself.

Joel Spencer, CIMS, NYU
Ron Graham, University of California, San Diego

Confirmed showings below. New stations added daily, check local listings.

October 18, 11 pm KLCS Los Angeles, CA
October 27, 6 pm KLRN San Antonio, TX
November 2, 10 pm KLCS Los Angeles, CA
November 13, 11 pm KCSM San Mateo, CA
December 19, 10 pm WYBE Philadelphia, PA

A quote from Erdős: "I have no home, the world is my home."

The complete video is available from A K Peters, Ltd. for $29.95 per copy, plus shipping & handling.

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Email:
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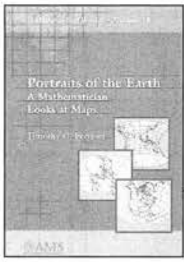
Web: www.akpeters.com

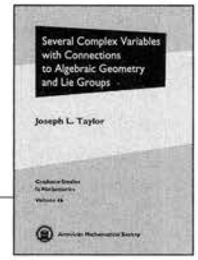
Recent AMS Titles
by Authors Speaking at the Joint Mathematics Meetings



Portraits of the Earth
A Mathematician Looks at Maps

Timothy G. Feeman, *Villanova University, PA*

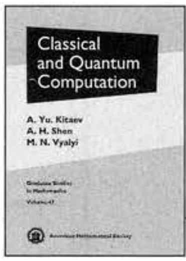
Mathematical World, Volume 18; 2002; ISBN 0-8218-3255-7; approximately 136 pages; Softcover; **All AMS members $21**, List $26, Order Code MAWRLD/18CT212



Several Complex Variables with Connections to Algebraic Geometry and Lie Groups

Joseph L. Taylor, *University of Utah, Salt Lake City*

Graduate Studies in Mathematics, Volume 46; 2002; ISBN 0-8218-3178-X; 507 pages; Hardcover; **All AMS members $59**, List $74, Order Code GSM/46CT212

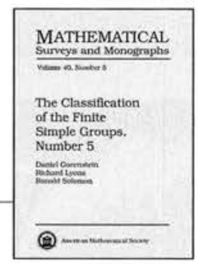


Classical and Quantum Computation

Available in Hardcover and Softcover

A. Yu. Kitaev, *California Institute of Technology, Pasadena*, and
A. H. Shen and **M. N. Vyalyi**, *Independent University of Moscow, Russia*

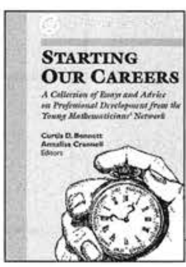
Graduate Studies in Mathematics, Volume 47; 2002; 257 pages
Hardcover: ISBN 0-8218-2161-X; **All AMS members $47**, List $59, Order Code GSM/47CT212
Softcover: ISBN 0-8218-3229-8; **All AMS members $29**, List $36, Order Code GSM/47.SCT212



The Classification of the Finite Simple Groups, Number 5

Daniel Gorenstein, **Richard Lyons**, *Rutgers University, Piscataway, NJ*, and **Ronald Solomon**, *Ohio State University, Columbus*

Mathematical Surveys and Monographs, Volume 40; 2002; ISBN 0-8218-2776-6; 467 pages; Hardcover; **Individual member $57**, List $95, Institutional member $76, Order Code SURV/40.5CT212



Starting Our Careers
A Collection of Essays and Advice on Professional Development from the Young Mathematicians' Network

Curtis D. Bennett, *Bowling Green State University, OH*,
and **Annalisa Crannell**, *Franklin & Marshall College, Lancaster, PA*, Editors

1999; ISBN 0-8218-1543-1; 116 pages; Softcover; **All AMS members $19**, List $24, Order Code SOCCT212

Ramanujan: Essays and Surveys

Bruce C. Berndt, *University of Illinois, Urbana-Champaign*,
and **Robert A. Rankin**, *University of Glasgow, Scotland*, Editors

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

History of Mathematics, Volume 22; 2001; ISBN 0-8218-2624-7; 347 pages; Hardcover; **All AMS members $63**, List $79, Order Code HMATH/22CT212

These are just a few of the AMS titles by authors speaking at the 2003 Joint Mathematics Meetings in Baltimore. Stop by the AMS booth or visit the AMS Bookstore to purchase these and other titles.

www.amsbookstore.org

AMS BOOKSTORE

1-800-321-4AMS (4267), in the US and Canada, or 1-401-455-4000; fax: 1-401-455-4046; email: cust-serv@ams.org.
American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294, USA

10/02

Cosponsored Conferences

AAAS Meeting to Offer Strong Mathematics Program

The 2003 Annual Meeting of the American Association for the Advancement of Science, February 13–18, in Denver, CO, will feature many outstanding expository talks by prominent mathematicians. These include the following three-hour symposia (and organizers) sponsored by Section A (Mathematics) of the AAAS:

- Predictability and Randomness in Weather Forecasting (Cecile Penland, Prashant Sardeshmukh, and Matthew Newman, NOAA-CIRES/Climate Diagnostics Center)
- Math Inside!... An Industrial View (Brenda Dietrich, IBM Research, and Fadil Santosa, University of Minnesota)
- Game Theoretic Aspect of Internet Computation (Joan Feigenbaum, Yale University)
- Mathematical Models for Traffic Flow: Phantom Jams and Real Data (Paul Nelson, Texas A&M University)
- Opening the Mind with Mathematics (Carson C. Chow, University of Pittsburgh)
- Modelling the Internet and the World Wide Web (Jennifer Tour Chayes and Christian Borgs, Microsoft Research)

Other symposia that will be of interest to the mathematical community include:

Challenges in the Statistical Analysis of Genome Data
Science and Mathematics Education of American Indians and Alaskan Natives
Face and Object Recognition in Man, Monkey, and Machine
The Physics of Extra Dimension
Security for Life: The Science behind Security Technologies

The above symposia are only a few of the 150 or so AAAS program offerings in the physical, life, social, and biological sciences. For further details about the 2003 AAAS program, see the November 1, 2002, issue of *Science*.

AAAS annual meetings are the showcases of American science, and they encourage participation by mathematicians and mathematics educators. (AAAS acknowledges the AMS for its generous support.) In presenting mathematics-related themes to the AAAS Program Committee, I have found the committee to be genuinely interested in offering symposia on mathematical topics of current interest. Thus, Section A's Committee seeks organizers and speakers who can present substantial new material in an accessible manner to a large scientific audience. Toward this end, I invite you to attend our Section A Committee business meeting 7:45 p.m.–10:45 p.m. Friday, February 14, 2003, in the Molly Brown Room of the Marriott. I invite you also to send me, and encourage your colleagues to send me, symposia proposals for future AAAS annual meetings.

—Warren Page, Secretary of Section A of the AAAS
`wxpny@aol.com`

Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices*. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See `http://www.ams.org/meetings/`. Programs and abstracts will continue to be displayed on the AMS website in the Meetings and Conferences section until about three weeks after the meeting is over. Final programs for Sectional Meetings will be archived on the AMS website in an electronic issue of the *Notices* as noted below for each meeting.

Orlando, Florida

University of Central Florida

November 9–10, 2002

Meeting #982

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: September 2002
Program first available on AMS website: September 26, 2002
Program issue of electronic *Notices*: November 2002
Issue of *Abstracts*: Volume 23, Issue 4

Deadlines

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

Invited Addresses

Steven J. Cox, Rice University, *Decoding the dance of your dendritic spines.*

James Haglund, University of Pennsylvania, *The q,t-Catalan numbers and the space of diagonal harmonics.*

Marius Mitrea, University of Missouri-Columbia, *Elliptic and parabolic boundary problems in Sobolev-Besov spaces on nonsmooth domains.*

Ricardo H. Nochetto, University of Maryland, College Park, *Basic principles for convergence of adaptive finite element methods and applications to the Stokes problem.*

Special Sessions

Algebraic and Enumerative Combinatorics, **James Haglund**, University of Pennsylvania, and **Jeff B. Remmel**, University of California San Diego.

Asymptotics of Integrable Partial Differential Equations, Riemann-Hilbert Problem and Related Topics, **Ken T. R. McLaughlin**, University of North Carolina at Chapel Hill and University of Arizona, and **Alexander Tovbis**, University of Central Florida.

Commutative Algebra, **Heath M. Martin**, University of Central Florida, and **Stephanie A. Fitchett**, Florida Atlantic University.

Computational Mathematics, **Ricardo H. Nochetto**, University of Maryland, and **Bernardo Cockburn**, University of Minnesota.

Computational Methods in Analysis, **George A. Anastassiou**, University of Memphis.

Financial Mathematics, **Craig A. Nolder** and **Alec N. Kercheval**, Florida State University.

Function Spaces, Singular Integrals and Applications to PDEs, **Marius Mitrea** and **Dorina Mitrea**, University of Missouri-Columbia.

Functional and Harmonic Analysis of Wavelets, Frames and Their Applications, **Deguang Han**, University of Central Florida, and **Manos I. Papadakis**, University of Houston.

Graph Theory, **Robert C. Brigham**, University of Central Florida, **Cun-Quan Zhang**, West Virginia University, and **Yue Zhao**, University of Central Florida.

Homotopy Theory and Geometric Topology, **Alexander N. Dranishnikov**, **James E. Keesling**, and **Yuli B. Rudyak**, University of Florida.

Invariants of Knots and Low-Dimensional Manifolds, **J. Scott Carter**, University of South Alabama, and **Masahico Saito**, University of South Florida.

The Likelihood Inferences in Statistics, **Jian-Jian Ren**, University of Central Florida.

Mathematical Neuroscience, **Steve J. Cox**, Rice University, and **Richard Bertram**, Florida State University.

Nonlinear Waves, **Min Chen**, Purdue University, and **Roy Choudhury** and **David J. Kaup**, University of Central Florida.

Baltimore, Maryland

Baltimore Convention Center

January 15–18, 2003

Meeting #983

Joint Mathematics Meetings, including the 109th Annual Meeting of the AMS, 86th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 2002
Program first available on AMS website: November 1, 2002
Program issue of electronic *Notices*: January 2003
Issue of *Abstracts*: Volume 24, Issue 1

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired
For summaries of papers to MAA organizers: Expired

AMS Program Updates

Graphic Depiction of Mathematics: Tips for Minimizing Hassles with Your Publisher, Thursday, 1:00 p.m. to 2:30 p.m., presented by **Stephen Moye** and **Tom Kacvinsky**, AMS. "Dear Author: Your paper is accepted for publication. but there are problems with your graphics." Have you ever received a note like this? Feeling discouraged? Then join the AMS experts for a session on how to prepare graphics for your publisher. Graphics, often an essential part of a document devoted to mathematics, are also the element of the publishing process most prone to headaches and hassles for authors and publishers alike. In this session we will talk about good practices for the creation of graphics and discuss commonly available software that can considerably ease the process of creating graphics. This presentation offers tips and information to avert problems before they happen, thus facilitating the publishing process for you and the publisher.

MAA Program Updates

Knowledge for Teaching Algebra: Issues from *The Mathematical Education of Teachers*, Wednesday, 9:00 a.m. to 10:20 a.m., organized by **Joan Ferrini-Mundy**, Michigan State University. The question of what mathematics teachers need to know for teaching is of interest to mathematicians, teacher-educators, those who are involved in the professional development of teachers, and researchers who study teacher education. The 2001 *CBMS Mathematical Education of Teachers Report* makes recommendations about the mathematics that teachers need for teaching. In this session we will focus on the mathematical preparation of teachers of secondary school mathematics, using the MET document as a framework for discussing issues in research, teacher education, and instructional materials for teachers. Panelists will discuss recent work in the MSU-based, NSF-funded Study of Algebra Knowledge for Teaching and the High School Mathematics from an Advanced Standpoint project, funded by the Stuart Foundation, in relationship to the MET report. We will focus specifically on issues concerning the education of teachers for teaching secondary school algebra. The panelists will include **Daniel Chazan**, University of Maryland; **Anthony L. Peressini**, University of Illinois at Urbana-Champaign; and **Joan Ferrini-Mundy**. The panel will be moderated by **Gail F. Burrill**, Michigan State University; **William G. McCallum**, University of Arizona, will serve as discussant.

Organizational Reception for the Proposed WEBSIGMAA, Wednesday, 7:00 p.m. to 8:15 p.m. This Special Interest Group will focus on the use of the World Wide Web for undergraduate mathematics instruction, whether for distance learning or as an adjunct to a traditional course. The reception will provide an opportunity for the organizers and potential members to meet each other and discuss plans for the group.

SIGMAA on Environmental Mathematics, Thursday, 5:45 p.m. to 7:15 p.m. This MAA Special Interest Group will hold its inaugural reception, including a talk by **William Rundell**, the new director of NSF's Division of Mathematical Sciences. If you have an interest in helping with the educational challenge of fusing together the most pressing problems of our time with the most potent technology of our time, please join us on Thursday evening.

Interdisciplinary Business Mathematics, Friday, 9:00 a.m. to 10:55 a.m., 1:00 p.m. to 3:00 p.m., and 5:00 p.m. to 7:00 p.m., organized by **Richard B. Thompson**, University of Arizona. Electronic texts for a new interdisciplinary program in mathematics for freshman business college majors will be demonstrated. This material, developed at the University of Arizona, is currently used by over 1,200 students in seven institutions. Participants will have an opportunity to engage in hands-on exploration of major business projects with Excel and PowerPoint tools. Richard B. Thompson, coauthor of the course, will preside. This course will be repeated in each of three different time frames for the convenience of participants (it is not a three-part course). Sponsored by the MAA and the University of Arizona.

The Role of Mathematics in the Professional Work of Mathematics Educators, Friday, 1:00 p.m. to 2:20 p.m., organized by **Joan Ferrini-Mundy**, Michigan State University. The professional work of mathematics educators spans many arenas of activity, including the design of instructional materials, the preservice and continuing education of teachers, and research about teaching and learning. In a study supported by the NSF, Developing Leadership for Mathematics and Science Education, a group of researchers at Michigan State University, is examining the roles played by background and preparation, including subject matter experience, in the professional work of educators. This panel discussion will open with a discussion of the issues and considerations that are emerging in this research. Panelists will speak to these issues from the vantage points of their own engagement in teaching prospective teachers of secondary school, developing secondary school instructional materials, and conducting research about the mathematical knowledge entailed in teaching. Commentators will discuss the implications of the panelists' comments for the design of doctoral programs in mathematics education and for the mathematical preparation of mathematics educators. Panelists include **Christian R. Hirsch**, Western Michigan University; **Bradford R. Findell**, University of Georgia; and **Deborah Loewenberg Ball**, University of Michigan. **Gail F. Burrill**, Michigan State University will serve as commentator.

Informal Session on Actuarial Education has been moved from Friday, 5:00 p.m. to 7:00 p.m., to Saturday, 4:15 p.m. to 6:15 p.m.

Other Organizations

The Association for Symbolic Logic will present these invited addresses: **Arthur W. Apter**, Baruch College of the City University of New York, *Some results concerning strong compactness and supercompactness.* **Krzysztof Ciesielski**, West Virginia University, *Set theoretical aspects of the Fubini theorem and separate continuity.* **Lou P. van den Dries**, University of Illinois, Urbana-Champaign, *Lower bounds in arithmetic complexity.* **Jeff L. Hirst**, Appalachian State University, *Hindman's theorem, ultrafilters, and reverse mathematics.* **Bjorn Kjos-Hanssen**, Ruprecht-Karls-Universität Heidelberg, *Initial segments of the Turing degrees with a view toward automorphisms.* **David E. Marker**, University of Illinois at Chicago, *Model theory and differential algebra.* **Timothy H. McNicholl**, University of Dallas, *Automorphisms of the c.e. weak truth-table degrees.* **Rahim Nazim Moosa**, Massachusetts Institute of Technology, *F-structures and semiabelian varieties over finite fields.* **Andrzej Roslanowski**, University of Nebraska at Omaha and University of Northern Iowa, *Proper forcing revisited.*

Summer Program for Women in Mathematics (SPWM) Reunion, Thursday, 2:00 p.m. to 4:00 p.m., organized by **Murli M. Gupta** and **E. Arthur Robinson Jr.**, George Washington University. SPWM program participants will describe their experiences.

Social Events

The Ohio State University Reception for Alumni and Friends, Thursday, 5:45 p.m. to 7:45 p.m.

The University of Wisconsin-Madison Department of Mathematics Reception, Friday, 5:30 p.m. to 7:00 p.m.

Ancillary Conference

Teaching an Introductory Statistics Course Based on Statistical Thinking, Tuesday, 8:30 a.m. to 5:00 p.m., presented by **Roger W. Hoerl** and **G. Rex Bryce**. This course is sponsored by the American Statistical Association. A great deal has been published recently about making fundamental changes to introductory statistics courses. Much of this discussion has centered around focusing more on conceptual understanding of key concepts (statistical thinking) and less on formulas and calculations, which can now be left to the computer. For example, the ASA/MAA Committee on Undergraduate Statistics recommends "...emphasize statistical thinking through active learning with more data and concepts, less theory and fewer recipes." A key barrier to change is that instructors would need to devote considerable time to redesigning introductory courses from scratch, since even the recently revised texts do not go far enough in the transition from calculations to statistical thinking. For example, few include interactive exercises or projects in the text itself or teach how to integrate the tools into an overall process of scientific discovery, provide sequential case studies involving integration of several tools, or stress a dynamic process versus static population context for data. This workshop will present a radically revised course based on statistical thinking, utilizing a new text published by Roger Hoerl and Ron Snee. This text is oriented towards a business context but with augmentation can be used for other contexts as well, such as general statistics. The workshop will also review results and lessons learned from two recent courses at Brigham Young University that used this approach and text. The course fee is $325. Registration deadline is December 15, 2002. Please see `learnstat@amstat.org` for information on how to register, or call 703-684-1221.

Baton Rouge, Louisiana

Louisiana State University

March 14–16, 2003

Meeting #984

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: January 2003
Program first available on AMS website: January 30, 2003
Program issue of electronic *Notices*: March 2003
Issue of *Abstracts*: Volume 24, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: November 26, 2002
For abstracts: January 22, 2003

Invited Addresses

Bruce K. Driver, University of California San Diego, *Title to be announced.*

Gunter Lumer, Université de Mons-Hainout, *Title to be announced.*

Barry M. McCoy, SUNY at Stony Brook, *Title to be announced.*

Stephen C. Milne, Ohio State University, *Title to be announced.*

Special Sessions

Algebraic Number Theory and K-Theory (Code: AMS SS A1), **Jurgen Hurrelbrink** and **Jorge F. Morales**, Louisiana State University, and **Robert Osburn**, McMaster University.

Applied Mathematics and Materials Science (Code: AMS SS B1), **Robert Lipton**, **Stephen Shipman**, **Blaise Bourdin**, and **Yuri Antipov**, Louisiana State University.

Arrangements in Topology and Algebraic Geometry (Code: AMS SS C1), **Daniel C. Cohen**, Louisiana State University, and **Alexander I. Suciu**, Northeastern University.

Asymptotic Analysis and Generalized Functions (Code: AMS SS M1), **Ricardo Estrada** and **Frank Neubrander**, Louisiana State University.

Commutative Ring Theory (Code: AMS SS D1), **James B. Coykendall**, North Dakota State University.

Frames, Wavelets, and Tomography (Code: AMS SS E1), **Gestur Olafsson**, Louisiana State University.

Graphs and Matroids (Code: AMS SS F1), **Bogdan S. Oporowski** and **James G. Oxley**, Louisiana State University.

Induced Representations: Connections to Graphs, Number Theory, Geometry (Code: AMS SS G1), **J. William Hoffman**, **Robert V. Perlis**, and **Neal W. Stoltzfus**, Louisiana State University.

Low Dimensional Topology (Code: AMS SS H1), **Oliver T. Dasbach**, **Patrick M. Gilmer**, and **Richard A. Litherland**, Louisiana State University.

Mathematical Techniques in Musical Analysis (Code: AMS SS J1), **Judith L. Baxter**, University of Illinois at Chicago, and **Robert Peck**, Louisiana State University.

Q-Series in Number Theory and Combinatorics (Code: AMS SS N1), **Mourad E. H. Ismail**, University of South Florida, and **Stephen C. Milne**, The Ohio State University.

The Role of Mathematics Departments in Secondary Education (Code: AMS SS P1), **James J. Madden** and **Frank Neubrander**, Louisiana State University.

Stochastic Analysis and Applications (Code: AMS SS K1), **H.-H. Kuo** and **P. Sundar**, Louisiana State University.

Stochastics, Quantization, and Segal-Bargmann Analysis (Code: AMS SS L1), **Bruce K. Driver**, University of California San Diego, **Brian C. Hall**, University of Notre Dame, and **Jeffrey J. Mitchell**, Baylor University.

Bloomington, Indiana

Indiana University

April 4–6, 2003

Meeting #985

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: February 2003
Program first available on AMS website: February 20, 2003
Program issue of electronic *Notices*: April 2003
Issue of *Abstracts*: Volume 24, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: December 17, 2002
For abstracts: February 11, 2003

Invited Addresses

Daniel J. Allcock, University of Texas, *Title to be announced.*

Brian D. Conrad, University of Michigan, *Title to be announced.*

Robin A. Pemantle, Ohio State University, *Title to be announced.*

Sijue Wu, University of Maryland, *Title to be announced.*

Special Sessions

Algebraic Topology (Code: AMS SS W1), **Randy McCarthy**, University of Illinois, Urban-Champaign, and **Ayelet Lindenstrauss**, Indiana University.

Applications of Teichmueller Theory to Dynamics and Geometry (Code: AMS SS K1), **Christopher M. Judge** and **Matthias Weber**, Indiana University.

Codimension One Splittings of Manifolds (Code: AMS SS U1), **James F. Davis**, Indiana University, and **Andrew A. Ranicki**, University of Edinburgh.

Cryptography and Computational and Algorithmic Number Theory (Code: AMS SS S1), **Joshua Holden** and **John Rickert**, Rose-Hulman Institute of Technology, **Jonathan Sorenson**, Butler University, and **Andreas Stein**, University of Illinois at Urbana-Champaign.

Differential Geometry (Code: AMS SS L1), **Jiri Dadok**, **Bruce Solomon**, and **Ji-Ping Sha**, Indiana University.

Ergodic Theory and Dynamical Systems (Code: AMS SS A1), **Roger L. Jones** and **Ayse A. Sahin**, DePaul University.

Extremal Combinatorics (Code: AMS SS R1), **Dhruv Mubayi**, University of Illinois at Chicago, and **Jozef Skokan**, University of Illinois at Urbana-Champaign.

Geometric Topology (Code: AMS SS D1), **Paul A. Kirk** and **Charles Livingston**, Indiana University.

Graph and Design Theory (Code: AMS SS N1), **Atif A. Abueida**, University of Dayton, and **Mike Daven**, Mount Saint Mary College.

Graph Theory (Code: AMS SS Q1), **Tao Jiang**, **Zevi Miller**, and **Dan Pritikin**, Miami University.

Harmonic Analysis in the 21st Century (Code: AMS SS E1), **Winston C. Ou** and **Alberto Torchinsky**, Indiana University.

Holomorphic Dynamics (Code: AMS SS B1), **Eric D. Bedford** and **Kevin M. Pilgrim**, Indiana University.

Mathematical and Computational Problems in Fluid Dynamics and Geophysical Fluid Dynamics (Code: AMS SS H1), **Roger Temam** and **Shouhong Wang**, Indiana University.

Operator Algebras and Free Probability (Code: AMS SS J1), **Hari Bercovici**, Indiana University, and **Marius Dadarlat**, Purdue University.

Operator Algebras and Their Applications (Code: AMS SS T1), **Jerry Kaminker**, Indiana University-Purdue University Indianapolis, and **Ronghui Ji**, Indiana University-Purdue University Indianapolis.

Particle Models and Their Fluid Limits (Code: AMS SS F1), **Robert T. Glassey** and **David C. Hoff**, Indiana University.

Probability (Code: AMS SS G1), **Russell D. Lyons**, Indiana University, and **Robin A. Pemantle**, Ohio State University.

Recent Trend in the Analysis and Computations of Functional Differential Equations (Code: AMS SS M1), **Paul W. Eloe** and **Qin Sheng**, University of Dayton.

Representations of Infinite Dimensional Lie Algebras and Mathematical Physics (Code: AMS SS P1), **Katrina Deane Barron**, University of Notre Dame, and **Rinat Kedem**, University of Illinois, Urbana.

Stochastic Analysis with Applications (Code: AMS SS V1), **Jin Ma** and **Frederi Viens**, Purdue University.

Weak Dependence in Probability and Statistics (Code: AMS SS C1), **Richard C. Bradley** and **Lanh T. Tran**, Indiana University.

New York, New York

Courant Institute

April 12–13, 2003

Meeting #986

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: February 2003
Program first available on AMS website: February 27, 2003
Program issue of electronic *Notices*: April 2003
Issue of *Abstracts*: Volume 24, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: December 24, 2002
For abstracts: February 18, 2003

Invited Addresses

Matthias Aschenbrenner, University of California Berkeley, *Title to be announced.*

John Etnyre, University of Pennsylvania, *Title to be announced.*

Hans Foellmer, Humboldt University Berlin, *Title to be announced.*

Wilfrid Gangbo, Georgia Institute of Technology, *Title to be announced.*

Special Sessions

Algebraic and Topological Combinatorics (Code: AMS SS E1), **Eva-Maria Feichtner**, ETH, Zürich, Switzerland; and **Dmitry N. Kozlov**, University of Bern, Switzerland, and KTH, Stockholm, Sweden.

Algebraic Geometry, Integrable Systems, and Gauge Theory (Code: AMS SS C1), **Marcos Jardim** and **Eyal Markman**, University of Massachusetts, Amherst.

Analytical and Computational Methods in Electromagnetics (Code: AMS SS G1), **Alexander P. Stone**, University of New Mexico, and **Peter A. McCoy**, U. S. Naval Academy.

Combinatorial and Statistical Group Theory (Code: AMS SS B1), **Alexei Myasnikov** and **Vladimir Shpilrain**, City College, New York.

Contact and Symplectic Geometry (Code: AMS SS K1), **John B. Etnyre** and **Joshua M. Sabloff**, University of Pennsylvania.

Galois Module Theory and Hopf Algebras (Code: AMS SS F1), **Daniel R. Replogle**, College of Saint Elizabeth, and **Robert G. Underwood**, Auburn University.

The History of Mathematics (Code: AMS SS D1), **Patricia R. Allaire**, Queensborough Community College, CUNY, and **Robert E. Bradley**, Adelphi University.

Hopf Algebras and Quantum Groups (Code: AMS SS A1), **M. Susan Montgomery**, University of Southern California, **Earl J. Taft**, Rutgers University, and **Sarah J. Witherspoon**, Amherst College.

Low-Dimensional Topology (Code: AMS SS M1), **James Conant**, Cornell University, **Slava Krushkal**, University of Virginia, and **Rob Schneiderman**, NYU-Courant Institute.

Nonlinear Partial Differential Equations in Differential Geometry (Code: AMS SS L1), **John C. Loftin** and **Mu-Tao Wang**, Columbia University.

Rigidity in Dynamics, Geometry, and Group Theory (Code: AMS SS J1), **David Fisher**, CUNY, Herbert H. Lehman College, and **Steven E. Hurder** and **Kevin M. Whyte**, University of Illinois at Chicago.

Topological Aspects of Complex Singularities (Code: AMS SS H1), **Sylvain E. Cappell**, NYU-Courant Institute, and

Walter D. Neumann and **Agnes Szilard**, Barnard College, Columbia University.

San Francisco, California

San Francisco State University

May 3–4, 2003

Meeting #987

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: March 2003
Program first available on AMS website: March 20, 2003
Program issue of electronic *Notices*: May 2003
Issue of *Abstracts*: Volume 24, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: January 14, 2003
For abstracts: March 11, 2003

Invited Addresses

Joe P. Buhler, Reed College, *A problem in symmetric functions arising from phase determination in crystallography.*

Raymond C. Heitmann, University of Texas at Austin, *Title to be announced.*

Alexei Y. Kitaev, California Institute of Technology, *Title to be announced.*

Arkady Vaintrob, University of Oregon, *Title to be announced.*

Special Sessions

Beyond Classical Boundaries of Computability (Code: AMS SS E1), **Mark Burgin**, University of California Los Angeles, and **Peter Wegner**, Brown University.

Combinatorial Commutative Algebra and Algebraic Geometry (Code: AMS SS C1), **Serkan Hosten**, San Francisco State University, and **Ezra Miller**, Mathematical Sciences Research Institute.

Geometry and Arithmetic over Finite Fields (Code: AMS SS G1), **Bjorn Poonen**, University of California Berkeley, and **Joe P. Buhler**, Reed College.

The History of Nineteenth and Twentieth Century Mathematics (Code: AMS SS A1), **Shawnee McMurran**, California State University, San Bernardino, and **James A. Tattersall**, Providence College.

Q-Series and Partitions (Code: AMS SS B1), **Neville Robbins**, San Francisco State University.

Qualitative Properties and Applications of Functional Equations (Code: AMS SS F1), **Theodore A. Burton**, Southern Illinois University at Carbondale.

Topological Quantum Computation (Code: AMS SS D1), **Alexei Kitaev**, California Institute of Technology, and **Samuel J. Lomonaco**, University of Maryland, Baltimore County.

Seville, Spain

June 18–21, 2003

Meeting #988

First Joint International Meeting between the AMS and the Real Sociedad Matematica Española (RSME).
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

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

Invited Addresses

Xavier Cabre, Universitat Politècnica de Catalunya, Barcelona, *Title to be announced.*

Charles Fefferman, Princeton University, *Title to be announced.*

Michael Hopkins, Massachusetts Institute of Technology, *Title to be announced.*

Ignacio Sols, Universidad Complutense, Madrid, *Title to be announced.*

Luis Vega, Universidad del Pais Vasco, Bilbao, *Title to be announced.*

Efim Zelmanov, Yale University, *Title to be announced.*

Special Sessions

Affine Algebraic Geometry, **Jaime Gutierrez**, University of Cantabria, **Vladimir Shpilrain**, City College of New York, and **Jie-Tai Yu**, University of Hong Kong.

Algebraic Geometry, **Felix Delgado**, Universidad de Valladolid, and **Andrey N. Todorov**, University of California Santa Cruz.

Algebraic Topology, **Alejandro Adem**, University of Wisconsin, **J. Aguade**, Universitat Autònoma de Barcelona, and **Eric M. Friedlander**, Northwestern University.

Banach Spaces of Analytic Functions, **Daniel Girela**, University of Malaga, and **Michael Stessin**, SUNY at Albany.

Biomolecular Mathematics, **Thomas J. Head** and **Fernando Guzman**, SUNY at Binghamton, **Mario Perez**, Universidad de Sevilla, and **Carlos Martin-Vide**, Rovira i Virgili University.

Classical and Harmonic Analysis, **Nets Katz**, Washington University, **Carlos Perez**, Universidad de Sevilla, and **Ana Vargas**, Universidad Autònoma de Madrid.

Combinatorics, **Joseph E. Bonin**, George Washington University, and **Marc Noy**, Universitat Politècnica de Catalunya.

Commutative Algebra: Geometric, Homological, Combinatorial and Computational Aspects, **Alberto Corso**, University of Kentucky, **Philippe Gimenez**, Universidad de Valladolid, and **Santiago Zarzuela**, Universitat de Barcelona.

Computational Methods in Algebra and Analysis, **Eduardo Cattani**, University of Massachusetts, Amherst, and **Francisco Jesus Castro-Jimenez**, Universidad de Sevilla.

Constructive Approximation Theory, **Antonio Duran**, Universidad de Sevilla, and **Edward B. Saff**, Vanderbilt University.

Control and Geometric Mechanics, **Manuel de Leon**, Instituto de Matemáticas y Física Fundamental, **Alberto Ibort**, Universidad Carlos III, and **Francesco Bullo**, University of Illinois, Urbana.

Differential Galois Theory, **Teresa Crespo** and **Zbigniew Hajto**, Universitat de Barcelona, and **Andy R. Magid**, University of Oklahoma.

Differential Structures and Homological Methods in Commutative Algebra and Algebraic Geometry, **Gennady Lyubeznik**, University of Minnesota, and **Luis Narvaez-Macarro**, Universidad de Sevilla.

Discrete and Computational Geometry, **Ferran Hertado**, Universitat Politècnica de Catalunya, and **William Steiger**, Rutgers University.

Dynamical Systems, **George Haller**, Massachusetts Institute of Technology, **Zbigniew H. Nitecki**, Tufts University, **Enrique Ponce**, Universidad de Sevilla, **Tere M. Seara**, Universitat Politècnica de Catalunya, and **Xavier Jarque**, Universitat Autònoma de Barcelona.

Effective Analytic Geometry over Complete Fields, **Luis-Miguel Pardos**, Universidad de Cantabria, and **J. Maurice Rojas**, Texas A&M University.

Geometric Methods in Group Theory, **José Burillo**, Universitat Politècnica de Catalunya, **Jennifer Tayback**, University of Albany, and **Enric Ventura**, Universitat Politècnica de Catalunya.

History of Modern Mathematics—Gauss to Wiles, **Jose Ferreiros**, Universidad de Sevilla, and **David Rowe**, Universitat Mainz.

Homological Methods in Banach Space Theory, **Jesus M. F. Castillo**, Universidad de Extremadura, and **N. J. Kalton**, University of Missouri.

Homotopy Algebras, **Pedro Real**, Universidad de Sevilla, **Thomas J. Lada**, North Carolina State University, and **James Stasheff**, University of North Carolina.

Interpolation Theory, Function Spaces and Applications, **Fernando Cobos**, University Complutense de Madrid, and **Pencho Petrushev**, University of South Carolina.

Lorentzian Geometry and Mathematical Relativity, **Luis J. Alias**, Universidad de Murcia, and **Gregory James Galloway**, University of Miami.

Mathematical Aspects of Semiconductor Modeling and Nano-technology, **Irene Martinez Gamba**, University of Texas, Austin, and **Jose Antonio Carrillo**, Universidad de Granada.

Mathematical Fluid Dynamics, **Diego Cordoba**, CSIC, Madrid, and Princeton University, **Susan Friedlander**, University of Illinois, Chicago, and **Marcos Antonio Fontelos**, Universidad Rey Juan Carlos.

Mathematical Methods in Finance and Risk Management, **Santiago Carrillo Menendez**, Universidad Autonoma de Madrid, **Antonio Falcos Montesinos**, Universidad Cardenal Herrera CEU, **Antonio Sanchez-Calle**, Universidad Autònoma de Madrid, and **Luis A. Seco**, University of Toronto at Mississauga.

The Mathematics of Electronmicroscopic Imaging, **Jose-Maria Carazo**, Centro Nacional de Biotecnologia-CSIC, and **Gabor T. Herman**, City University of New York.

Moduli Spaces in Geometry and Physics, **Steven B. Bradlow**, University of Illinois, Urbana-Champaign, and **Oscar Garcia-Prada**, Universidad Autònoma de Madrid.

Nonassociative Algebras and Their Applications, **Efim I. Zelmanov**, Yale University, **Santos Gonzalez**, Universidad de Oviedo, and **Alberto Elduque**, Universidad de Zaragoza.

Nonlinear Dispersive Equations, **Gustavo Ponce**, University of California Santa Barbara, and **Luis Vega**, Universidad del Pais Vascos.

Numerical Linear Algebra, **Lothar Reichel**, Kent State University, and **Francisco Marcellan**, University Carlos III de Madrid.

Operator Theory and Spaces of Analytic Functions, **Jose Bonet**, Universidad Politècnica de Valencia, **Pedro Paul**, Universidad de Sevilla, and **Cora S. Sadosky**, Howard University.

PDE Methods in Continuum Mechanics, **Juan L. Vazquez**, Universidad Autònoma de Madrid, and **J. W. Neuberger**, University of North Texas.

Polynomials and Multilinear Analysis in Infinite Dimensions, **Richard M. Aron**, Kent State University, **J. A. Jaramillo** and **Jose G. Llavona**, Universidad Complutense de Madrid, and **Andrew M. Tonge**, Kent State University.

Quantitative Results in Real Algebra and Geometry, **Carlos Andradas** and **Antonio Diaz-Cano**, Universidad Complutense, **Victoria Powers**, Emory University, and **Frank Sottile**, University of Massachusetts, Amherst.

Recent Developments in the Mathematical Theory of Inverse Problems, **Russell Brown**, University of Kentucky, **Alberto Ruiz**, Universidad Autònoma de Madrid, Spain, and **Gunther Uhlmann**, University of Washington.

Riemannian Foliations, **Jesus Antonio Alvarez Lopez**, Universidade de Santiago de Compostela, and **Efton L. Park**, Texas Christian University.

Ring Theory and Related Topics, **Jose Gomez-Torrecillas**, University of Granada, **Pedro Antonio Guil Asensio**, University of Murcia, **Sergio R. Lopez-Permouth**, Ohio University, and **Blas Torrecillas**, University of Almeria.

Variational Problems for Submanifolds, **Frank Morgan**, Williams College, and **Antonio Ros**, Universidad de Granada.

Boulder, Colorado

University of Colorado

October 2–4, 2003

Meeting #989

Western Section
Associate secretaries: Susan J. Friedlander and Michel L. Lapidus
Announcement issue of *Notices*: August 2003
Program first available on AMS website: August 21, 2003
Program issue of electronic *Notices*: October 2003
Issue of *Abstracts*: Volume 24, Issue 4

Deadlines

For organizers: March 3, 2003
For consideration of contributed papers in Special Sessions: June 6, 2003
For abstracts: August 12, 2003

Invited Addresses

J. Brian Conrey, American Institute of Mathematics, *Title to be announced.*

Giovanni Forni, Northwestern University, *Title to be announced.*

Juha M. Heinonen, University of Michigan, *Title to be announced.*

Joseph D. Lakey, New Mexico State University, *Title to be announced.*

Albert Schwarz, University of California Davis, *Title to be announced.*

Brooke E. Shipley, Purdue University, *Title to be announced.*

Avi Wigderson, Institute for Advanced Study, *Title to be announced* (Erdős Memorial Lecture).

Special Sessions

Algebras, Lattices and Varieties (Code: AMS SS A1), **Keith A. Kearnes**, University of Colorado, Boulder, **Agnes Szendrei**, Bolyai Institute, and **Walter Taylor**, University of Colorado, Boulder.

Binghamton, New York

SUNY-Binghamton

October 11–12, 2003

Meeting #990

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 2003
Program first available on AMS website: August 28, 2003
Program issue of electronic *Notices*: October 2003
Issue of *Abstracts*: Volume 24, Issue 4

Deadlines

For organizers: March 10, 2003
For consideration of contributed papers in Special Sessions: June 24, 2003
For abstracts: August 19, 2003

Invited Addresses

Peter Kuchment, Texas A&M University, *Title to be announced.*

Zlil Sela, Einstein Institute of Mathematics, *Title to be announced.*

Zoltan Szabo, University of Michigan, Ann Arbor, *Title to be announced.*

Jeb F. Willenbring, Yale University, *Title to be announced.*

Special Sessions

Biomolecular Mathematics (Code: AMS SS A1), **Thomas J. Head** and **Dennis G. Pixton**, SUNY at Binghamton, **Mitsunori Ogihara**, University of Rochester, and **Carlos Martin-Vide**, Universitat Rovira i Virgili.

Chapel Hill, North Carolina

University of North Carolina at Chapel Hill

October 24–25, 2003

Meeting #991

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: August 2003
Program first available on AMS website: September 11, 2003
Program issue of electronic *Notices*: October 2003
Issue of *Abstracts*: Volume 24, Issue 4

Deadlines

For organizers: March 24, 2003
For consideration of contributed papers in Special Sessions: July 19, 2003
For abstracts: September 3, 2003

Bangalore, India

India Institute of Science

December 17–20, 2003

Meeting #992

First Joint AMS-India Mathematics Meeting
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

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

Invited Addresses

George Papanicolaou, Stanford University, *Title to be announced.*

Peter Sarnak, Princeton University, *Title to be announced.*

Vladimir Voevodsky, Institute for Advanced Study, Princeton, *Title to be announced.*

Special Sessions

Algebraic and Geometric Methods in Multivariable Operator Theory, **Ronald G. Douglas**, Texas A&M University, and **Gadadhar Misra**, Indian Statistical Institute.

Phoenix, Arizona

Phoenix Civic Plaza

January 7–10, 2004

Meeting #993

Joint Mathematics Meetings, including the 110th Annual Meeting of the AMS, 87th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 2003
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2004
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 2, 2003
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Tallahassee, Florida

Florida State University

March 12–13, 2004

Meeting #994

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 13, 2003
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Athens, Ohio

Ohio University

March 26–27, 2004

Meeting #995

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 26, 2003
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Los Angeles, California

University of Southern California

April 3–4, 2004

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

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

Lawrenceville, New Jersey

Rider University

April 17–18, 2004

Meeting #997

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 17, 2003
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Houston, Texas

University of Houston

May 13–15, 2004

Sixth International Joint Meeting of the AMS and the Sociedad Matemática Mexicana (SMM).
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Pittsburgh, Pennsylvania

University of Pittsburgh

November 6–7, 2004

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 7, 2004
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Atlanta, Georgia

Atlanta Marriott Marquis and Hyatt Regency Atlanta

January 5–8, 2005

Joint Mathematics Meetings, including the 111th Annual Meeting of the AMS, 88th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association of Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic (ASL).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: October 2004
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2005
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 5, 2004
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Mainz, Germany

June 16–19, 2005

Second Joint AMS-Deutsche Mathematiker-Vereinigung (DMV) Meeting
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

San Antonio, Texas

Henry B. Gonzalez Convention Center

January 12-15, 2006

Joint Mathematics Meetings, including the 112th Annual Meeting of the AMS, 89th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).
Associate secretary: John L. Bryant
Announcement issue of *Notices*: October 2005
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2006
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 12, 2005
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

New Orleans, Louisiana

New Orleans Marriott and Sheraton New Orleans Hotel

January 4-7, 2007

Joint Mathematics Meetings, including the 113th Annual meeting of the AMS, 90th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 2006
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: January 2007
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 4, 2006
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

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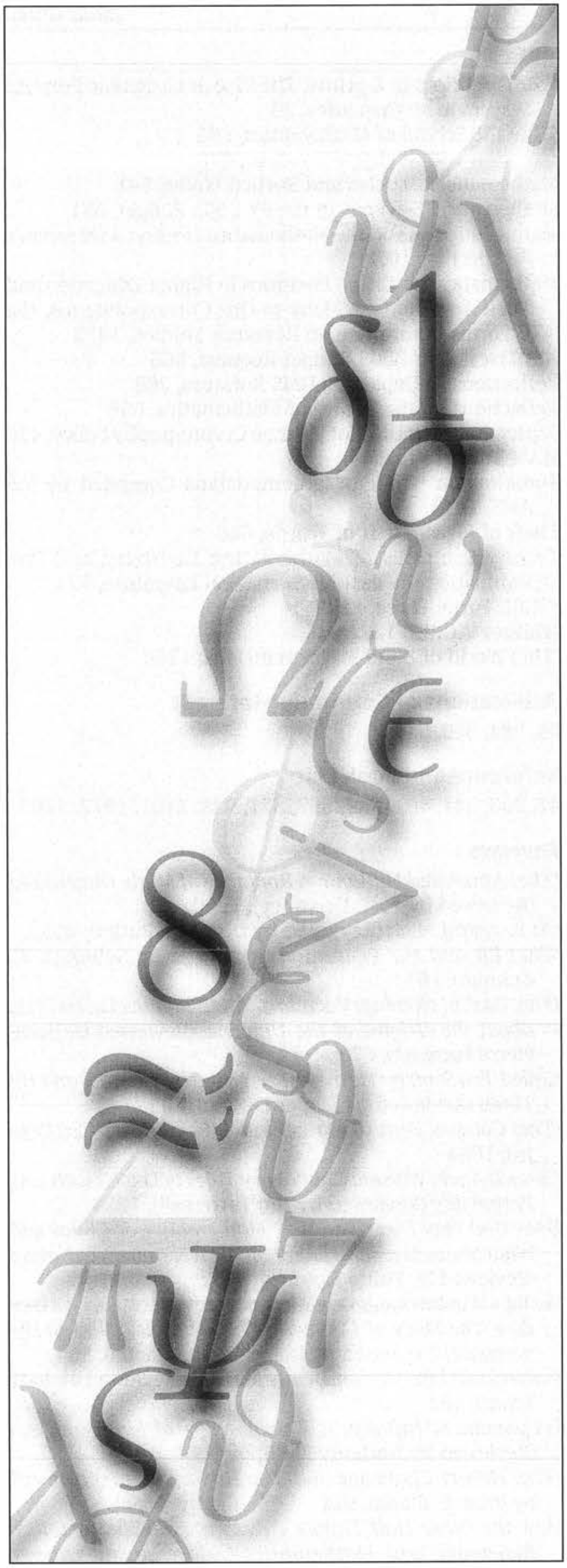

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WHAT IS...

Meetings and Conferences of the AMS

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The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information** at `www.ams.org/meetings/`.

Meetings:

Important Information regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 175 in the January 2002 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays must be typeset in LaTeX. To see descriptions of the forms available, visit `http://www.ams.org/abstracts/instructions.html`, or send mail to `abs-submit@ams.org`, typing `help` as the subject line; descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to `abs-submit@ams.org`, typing `submission` as the subject line. Questions about abstracts may be sent to `abs-info@ams.org`.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. There is a $20 processing fee for each paper abstract. There is no charge for electronic abstracts. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See `http://www.ams.org/meetings/` for the most up-to-date information on these conferences.)

February 13-18, 2003: AAAS Annual Meeting, Denver, Colorado.

June 8 - July 24, 2003: Joint Summer Research Conferences in the Mathematical Sciences, Snowbird, Utah.

Baltimore Joint Meetings Advance Registration/Housing Form

Name ______________________________________
(please write name as you would like it to appear on your badge)

Mailing Address ______________________________________

____

Telephone ____________________ Fax ____________________

Email Address ______________________________________

(Acknowledgment of this registration will be sent to the email address given here, unless you check this box: *Send by U.S. Mail* ☐)

Badge Information: Affiliation for badge ______________________________

Nonmathematician guest badge name ______________________
(please note charge below)

Membership
✓ all that apply

- AMS ☐
- ASA ☐
- ASL ☐
- AWM ☐
- CMS ☐
- MAA ☐
- NAM ☐
- SIAM ☐
- YMN ☐

☐ **I DO NOT want my program and badge to be mailed to me on 12/13/02.**

Registration Fees

Joint Meetings	**by Dec 19**	**at mtg**	**Subtotal**
☐ Member AMS, ASL, CMS, MAA, SIAM	$190	$247	
☐ Nonmember	$295	$383	
☐ Graduate Student	$ 35	$ 45	
☐ Undergraduate Student	$ 20	$ 26	
☐ High School Student	$ 2	$ 5	
☐ Unemployed	$ 35	$ 45	
☐ Temporarily Employed	$150	$172	
☐ Developing Countries Special Rate	$ 35	$ 45	
☐ Emeritus Member of AMS or MAA	$ 35	$ 45	
☐ High School Teacher	$ 35	$ 45	
☐ Librarian	$ 35	$ 45	
☐ Nonmathematician Guest	$ 5	$ 5	
			$ ______
AMS Short Course: *Public Key Cryptography (1/13–1/14)*			
☐ Member of AMS or MAA	$ 80	$100	
☐ Nonmember	$110	$130	
☐ Student, Unemployed, Emeritus	$ 35	$ 50	
			$ ______
MAA Short Course: *Mathematics in the Ancient World (1/13–1/14)*			
☐ Member of MAA or AMS	$125	$140	
☐ Nonmember	$175	$190	
☐ Student, Unemployed, Emeritus	$ 50	$ 60	
			$ ______

MAA Minicourses (see listing in text)

I would like to attend: ☐ One Minicourse ☐ Two Minicourses
Please enroll me in MAA Minicourse(s) #_____ and/or #_____
In order of preference, my alternatives are: #_____ and/or #_____

Prices: $90 for Minicourses #1–6 and $60 for Minicourses #7–16

$ ______

Employment Center

Applicant résumé forms and employer job listing forms will be on the AMS website and in *Notices* in September and October.

	by Dec 19	at mtg	Subtotal
Employer—First Table (☐ Regular ☐ Self-scheduled)	$220	$300	
Employer— Each Additional Table (☐ Regular ☐ Self-scheduled)	$ 65	$100	
☐ Employer—Posting Only	$ 50	N/A	
☐ Applicant (all services)	$ 40	$ 75	
☐ Applicant (Winter List & Message Ctr only)	$ 20	$ 20	
			$ ______

Events with Tickets

MER Banquet (1/16) $42 #___Regular #___Veg
NAM Banquet (1/17) $45 #___Regular #___Veg
AMS Banquet (1/18) $45 #___Regular #___Veg

$ ______

Other Events (no charge)
☐ Graduate Student Reception (1/15)

Total for Registrations and Events $ ______

Payment

Registration & Event Total (total from column on left) $ ______
Hotel Deposit (only if paying by check) $ ______

Total Amount To Be Paid **$** ______

(Note: A $5 processing fee will be charged for each returned check or invalid credit card. Debit cards are not accepted.)

Method of Payment

☐ Check. Make checks payable to the AMS. Checks drawn on foreign banks must be in equivalent foreign currency at current exchange rates.
☐ Credit Card. VISA, MasterCard, AMEX, Discover (no others accepted)

Card number: ______________________

Exp. date: ________ zipcode of credit card billing address: ____________

Signature: ______________________

Name on card: ______________________

☐ Purchase order #____________________ (please enclose copy)

Registration for the Joint Meetings is not required for the Short Courses, but it is required for the Minicourses and the Employment Center.

Other Information

Mathematical Reviews field of interest # ________

How did you hear about this meeting? Check one:
☐ Colleague(s) ☐ *Notices* ☐ *Focus* ☐ Internet

☐ I am a mathematics department chair.
☐ **Please do not include my name on any promotional mailing list.**
☐ Please ✓ this box if you have a disability requiring special services.

Mail to:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887
Fax: 401-455-4004
Questions/changes call: 401-455-4143 or 1-800-321-4267 x4143; mmsb@ams.org

Deadlines

For résumés/job descriptions printed in the *Winter Lists*, return this form by:	**Oct. 25, 2002**
To be eligible for the room lottery:	**Nov. 1, 2002**
For housing reservations, badges/programs mailed:	**Nov. 15, 2002**
For housing changes/cancellations through MMSB:	**Dec. 13, 2002**
For advance registration for the Joint Meetings, Employment Center, Short Courses, MAA Minicourses, & Tickets:	**Dec. 19, 2002**
For 50% refund on banquets, cancel by:	**Dec. 30, 2002***
For 50% refund on advance registration, Minicourses & Short Courses, cancel by:	**Jan. 10, 2003***

***no refunds after this date**

Baltimore Joint Meetings Hotel Reservations

To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc., in the column on the left and by circling the requested room type and rate. If the rate or the hotel requested is no longer available, you will be assigned a room at a ranked or unranked hotel at a comparable rate. Participants are urged to call the hotels directly for details on suite configurations, sizes, and availability; however, suite reservations can be made only through the MMSB to receive the convention rates listed. Reservations at the following hotels must be made through the MMSB to receive the convention rates listed. Reservations made directly with the hotels may be changed to a higher rate. All rates are subject to a 12.5% sales tax. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee.**

☐ Deposit enclosed ☐ Hold with my credit card Card Number ______ Exp. Date ______ Signature ______

Date and Time of Arrival ______ **Date and Time of Departure** ______

Name of Other Room Occupant ______ **Arrival Date** ______ **Departure Date** ______ **Child (give age(s)** ______

Order of choice	Hotel	Single	Double 1 bed	Double 2 beds	Triple 2 beds	Triple 2 beds w/cot	Quad 2 beds	Quad 2 beds w/cot	Suites Starting rates
	Baltimore Marriott Waterfront	$135	$135	$135	$155	$155	$175	$175	$410
	Brookshire Suites (all suites-rates include breakfast)	$129	$129	$129	$144	$169	$159	$184	$129
	Hyatt Regency Baltimore on the Inner Harbor (hqtrs)	$124	$124	$124	$164	$164	$174	$174	$450
	Student	$114	$114	$114	$154	$154	$164	$164	N/A
	Renaissance Harborplace Hotel	$124	$124	$124	$147	$147	$147	$147	$328
	Student	$113	$113	$113	$136	$136	$136	$136	N/A
	Baltimore Marriott Inner Harbor	$124	$134	$134	$154	$154	$174	$174	$189
	Student	$99	$105	$105	$125	$125	$145	$145	N/A
	Sheraton Inner Harbor	$122	$122	$122	$142	$162	$162	$182	$450
	Student	$110	$110	$110	$130	$150	$150	$170	N/A
	Holiday Inn Inner Harbor	$115	$123	$123	$123	$138	$123	$138	N/A
	Student	$89	$89	$89	$89	$104	$89	$104	N/A
	Wyndham Baltimore Inner Harbor	$114	$124	$124	$144	$156	$164	$176	$214
	Student	$91	$101	$101	$121	$133	$141	$153	N/A
	Radisson Plaza Lord Baltimore	$113	$113	$113	$133	$153	$153	$173	$175
	Student	$90	$90	$90	$110	$130	$130	$150	N/A
	Days Inn Inner Harbor	$109	$119	$119	$119	$129	$119	$129	N/A
	Student	$87	$95	$95	$95	$105	$95	$105	N/A

Special Housing Requests:

☐ I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are: ______

☐ Other requests: ______

☐ I am a member of a hotel frequent-travel club and would like to receive appropriate credit. The hotel chain and card number are: ______

If you are not making a reservation, please check off one of the following:

☐ I plan to make a reservation at a later date.

☐ I will be making my own reservations at a hotel not listed. Name of hotel: ______

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

☐ I plan to share a room with ______, who is making the reservations.

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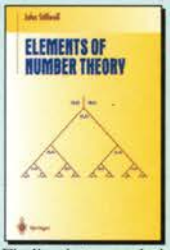

ELEMENTS OF NUMBER THEORY

J. STILLWELL, Monash University, Clayton, Australia

This book is a concise introduction to number theory and some related algebra, with an emphasis on solving equations in integers. Finding integer solutions led to two fundamental ideas of number theory in ancient times—the Euclidean algorithm and unique prime factorization; and in modern times to two fundamental ideas of algebra—rings and ideals. The development of these ideas, and the transition from ancient to modern, is the main theme of the book. The historical development has been followed where it helps to motivate the introduction of new concepts, but modern proofs have been used where they are simpler, more natural, or more interesting. It is clearly written, well illustrated, and supplied with carefully designed exercises, making it a pleasure to use as an undergraduate textbook or for independent study.

2002/254 PP., 35 ILLUS./HARDCOVER/$49.95
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A Diderot Mathematical Forum

G. ASSAYAG, ICRAM, Paris, France; **H.G. FEICHTINGER,** University of Vienna, Austria; and **J.F. RODRIGUES,** University of Lisbon, Portugal (Eds.)

Mathematical models can be found for almost all levels of musical activities from composition to sound production by traditional instruments or by digital means. Modern music theory has been incorporating more and more mathematical content during the last decades. This book offers a journey into recent work relating music and mathematics. It contains a large variety of articles covering the historical aspects, the influence of logic and mathematical thought in composition, perception and understanding of music, and the computational aspects of musical sound processing.

2002/288 PP./HARDCOVER/$79.95
ISBN 3-540-43727-4

NORMAL FORMS AND UNFOLDINGS FOR LOCAL DYNAMICAL SYSTEMS

J. MURDOCK, Iowa State University, Ames, IA

This book is about normal forms—the simplest form into which a dynamical system can be put for the purpose of studying its behavior in the neighborhood of a rest point—and about unfoldings, used to study the local bifurcations that the system can exhibit under perturbation. The book presents the advanced theory of normal forms, showing their interaction with representation theory, invariant theory, Groebner basis theory, and structure theory of rings and modules. In addition, this book includes algorithms suitable for use with computer algebra systems for computing normal forms. The interaction between the algebraic structure of normal forms and their geometrical consequences is emphasized.

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SPRINGER MONOGRAPHS IN MATHEMATICS

LEVEL SETS AND DYNAMIC IMPLICIT SURFACES

S.J. OSHER, University of California, Los Angeles, CA; and **R. FEDKIW,** Stanford University, Stanford, CA

This book is an introduction to level set methods and dynamic implicit surfaces. These are powerful techniques for analyzing and computing moving fronts in a variety of different settings. While it gives many examples of the utility of the methods to a diverse set of applications, it also gives complete numerical analysis and recipes, which will enable users to quickly apply the techniques to real problems. A student or researcher working in mathematics, computer graphics, science, or engineering interested in any dynamic moving front, which might change its topology or develop singularities, will find this book interesting and useful.

2002/296 PP., 71 ILLUS./HARDCOVER/$79.95
ISBN 0-387-95482-1
APPLIED MATHEMATICAL SCIENCES, VOL. 153

DYNAMICS IN INFINITE DIMENSIONS

SECOND EDITION

J.K. HALE, Georgia Institute of Technology, Atlanta, GA; **L.T. MAGALHÃES** and **W.M. OLIVIA,** both, Instituto Superior Tecnico, Lisbon, Portugal

This book presents an introduction to the geometric theory of infinite dimensional dynamical systems. Many of the fundamental results are presented for asymptotically smooth dynamical systems that have applications to functional differential equations as well as classes of dissipative partial differential equations. However, as in the earlier edition, the major emphasis is on retarded functional differential equations. This updated version also contains much material on neutral functional differential equations. The results in the earlier edition on Morse-Smale systems for maps are extended to a class of semiflows which include retarded functional differential equations and parabolic partial differential equations. In addition to being useful for researchers in the field, the book is appropriate for a graduate course in dynamical systems.

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APPLIED MATHEMATICAL SCIENCES, VOLUME 47

ASYMPTOTIC CONES AND FUNCTIONS IN OPTIMIZATION AND VARIATIONAL INEQUALITIES

A. AUSLENDER, Université Lyon 1, Villurbanne, France; and **M. TEBOULLE,** University of Tel Aviv, Israel

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RECENT ADVANCES IN ALGORITHMS AND COMBINATORICS

B. REED, Université Paris 6, Cedex, France; and **C.L. SALES,** Universidade Federale do Ceara, Foratela, Brazil (Eds.)

Many practical problems can be modeled and then efficiently solved using combinatorial theory. This real world motivation for studying algorithmic combinatorics has led not only to the development of many software packages but also to some beautiful mathematics which have no direct application to applied problems. This book highlights a few of the exciting recent developments in algorithmic combinatorics, including the search for patterns in DNA and protein sequences; the theory of semi-definite programming and its role in combinatorial optimization.

2002/368 PP., 51 ILLUS/HARDCOVER/$89.95
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CMS BOOKS IN MATHEMATICS, VOLUME 11

COLLECTED PAPERS

G. SHIMURA, Princeton University, Princeton, NJ

In 1996, the AMS awarded Goro Shimura the Steele Prize for Lifetime Achievement for his "important and extensive work on arithmetical geometry and automorphic forms." His seminal work has resulted in the "many notations in number theory that carry his name and that have long been familiar to workers in the field." These four volumes contain 103 of his most important papers, beginning in 1954 and continuing up through the present.

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