# QUARTERLY

OF

# APPLIED MATHEMATICS



**VOLUME LIX** **JUNE • 2001** **NUMBER 2**

## Quarterly of Applied Mathematics

The *Quarterly of Applied Mathematics* prints original papers in applied mathematics which have an intimate connection with applications. It is expected that each paper will be of a high scientific standard; that the presentation will be of such character that the paper can be easily read by those to whom it would be of interest; and that the mathematical argument, judged by the standard of the field of application, will be of an advanced character.

In accordance with their general policy, the Editors welcome particularly contributions which will be of interest both to mathematicians and to scientists or engineers. Authors will receive galley proof only. The author's institution will be requested to pay a publication charge of $30 per page which, if honored, entitles the author to 100 free reprints. Detailed instructions will be sent with galley proofs.

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This journal is indexed in *Mathematical Reviews, Zentralblatt MATH, Science Citation Index*®, *Science Citation Index*™*-Expanded, ISI Alerting Services*℠, *CompuMath Citation Index*®, *Current Contents*®*/Engineering, Computing & Technology.* It is also indexed by *Applied Science & Technology Index* and abstracted by *Applied Science & Technology Abstracts.*
Periodicals postage paid at Providence, Rhode Island.
Publication number 808680 (ISSN 0033-569X)

# SUGGESTIONS CONCERNING THE PREPARATION OF MANUSCRIPTS FOR THE QUARTERLY OF APPLIED MATHEMATICS

The editors will appreciate the authors' cooperation in taking note of the following directions for the preparation of manuscripts. These directions have been drawn up with a view toward eliminating unnecessary correspondence, avoiding the return of papers for changes, and reducing the charges made for "author's corrections."

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**Manuscripts:** Manuscripts should be typewritten double-spaced on one side only. Marginal instructions to the typesetter should be written in pencil to distinguish them clearly from the body of the text. The author should keep a complete copy.

The papers should be submitted in final form. Only typographical errors should be corrected in proof; composition charges for any major deviations from the manuscript will be passed on to the author.

**Titles:** The title should be brief but express adequately the subject of the paper. The name and initials of the author should be written as he/she prefers; all titles and degrees or honors will be omitted. The name of the organization with which the author is associated should be given in a separate line following his/her name.

**Mathematical Work:** As far as possible, formulas should be typewritten; Greek letters and other symbols not available on the average typewriter should be inserted using either instant lettering or by careful insertion in ink. Manuscripts containing pencilled material other than marginal instructions to the typesetter will not be accepted.

The difference between capital and lower-case letters should be clearly shown; care should be taken to avoid confusion between zero (0) and the letter $O$, between the numeral one (1), the letter $l$ and the prime ($'$), between alpha and $a$, kappa and $k$, mu and $u$, nu and $v$, eta and $n$.

The level of subscripts, exponents, subscripts to subscripts, and exponents to exponents should be clearly indicated.

Single embellishments over individual letters are allowed; the only embellishment allowed above groups of letters is the overbar.

Double embellishments are not allowed. These may be replaced by superscripts following the symbols.

Complicated exponents and subscripts should be avoided. Any complicated expression that recurs frequently should be represented by a special symbol.

For exponentials with lengthy or complicated exponents the symbol exp should be used, particularly if such exponentials appear in the body of the text. Thus,

$$\exp[(a^2 + b^2)^{1/2}] \text{ is preferable to } e^{[a^2+b^2]^{1/2}}.$$

Fractions in the body of the text and fractions occurring in the numerators or denominators of fractions should be written with the solidus. Thus,

$$\frac{\cos(x/2b)}{\cos(a/2b)} \text{ is preferable to } \frac{\cos \frac{x}{2b}}{\cos \frac{a}{2b}}.$$

In many instances the use of negative exponents permits saving of space. Thus,

$$\int u^{-1} \sin u \, du \text{ is preferable to } \int \frac{\sin u}{u} \, du.$$

Whereas the intended grouping of symbols in handwritten formulas can be made clear by slight variations in spacing, this procedure is not acceptable in typeset formulas. To avoid misunderstanding, the order of symbols should therefore be carefully considered. Thus,

$$(a + bx)\cos t \text{ is preferable to } \cos t(a + bx).$$

**Figures:** Figures should be drawn in black ink with clean, unbroken lines; do not use ball point pen. The paper should be of a nonabsorbant quality so that the ink does not spread and produce fuzzy lines. If the figures are intended for reduction, they should be drawn with heavy enough lines so that they do not become flimsy at the desired reduction. The notation should be of professional quality and in proportion for the expected reduction size. Figures that are unsuitable for reproduction will be returned to the author for redrawing. Legends accompanying figures should be written on a separate sheet.

**Bibliography:** References should be grouped together in a Bibliography at the end of the manuscript. References in text to the Bibliography should be made by numerals between square brackets.

The following examples show the desired arrangements: (*for books*—S. Timoshenko, *Strength of Materials*, vol. 2, Macmillan and Co., London, 1931, p. 237; *for periodicals*—Lord Rayleigh, *On the flow of viscous liquids, especially in three dimensions*, Phil. Mag. (5) 36, 354-372 (1893)). Note that the number of the series is not separated by commas from the name of the periodical or the number of the volume.

Authors' initials should precede their names rather than follow them.

In quoted titles of books or papers, capital letters should be used only where the language requires this. Thus, *On the flow of viscous fluids* is preferable to *On the Flow of Viscous Fluids*, but the corresponding German title would have to be rendered as *Über die Stromung zaher Flüssigkeiten.*

Titles of books or papers should be quoted in the original language (with an English translation added in parentheses, if this seems desirable), but only English abbreviations should be used for bibliographical details such as ed., vol., no., chap., p.

**Footnotes:** As far as possible, footnotes should be avoided. Footnotes containing mathematical formulas are not acceptable.

**Abbreviations:** Much space can be saved by the use of standard abbreviations such as Eq., Eqs., Fig., Sec., Art., etc. These should be used, however, only if they are followed by a reference number. Thus, "Eq. (25)" is acceptable but not "the preceding Eq." Moreover, if any one of these terms occurs as the first word of a sentence, it should be spelled out.

Special abbreviations should be avoided. Thus "boundary conditions" should always be spelled out and not be abbreviated as "b.c." even if this special abbreviation is defined somewhere in the text.

## CONTENTS

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*Mathematical Modeling in Continuum Mechanics.* By Roger Temam and Alain Miranville, Cambridge University Press, 2000, xiii+288 pp., $54.95

One of the aims of this book is to reduce the gap between mathematics and continuum mechanics. It is written in a style suitable for mathematicians, but the authors have attempted to remain very close to physics and to mathematics at the same time by making a clear separation between what is assumed and what is proven. The core of the book contains the fundamental parts of continuum mechanics: description of the motion of a continuous body, the fundamental law of mechanics, the Cauchy stress tensor, the constitutive laws, internal energy and the first principle of thermodynamics, shocks and the Rankine-Hugoniot relations, an introduction to fluid mechanics for inviscid and viscous Newtonian fluids, and an introduction to linear elasticity and the variational principles in linear elasticity. Besides the core of continuum mechanics, the book also contains introductions to several important related fields: magnetohydrodynamics, combustion, geophysical fluid dynamics, vibrations, linear acoustics, and nonlinear waves and solitons in the context of the Korteweg-de Vries and the nonlinear Schrödinger equations.

*Fourier Analysis and Applications—Filtering, Numerical Computation, Wavelets.* By C. Gasquet and P. Witomski, translated by R. Ryan, Springer-Verlag, 1998, xviii+442 pp., $49.95

This is volume 30 in the series Texts in Applied Mathematics. The range of the book is apparent from its table of contents. It is divided into 11 chapters: 1. Signals and systems; 2. Periodic signals; 3. The discrete Fourier transform and numerical computations; 4. The Lebesgue integral; 5. Spaces; 6. Convolution and the Fourier transform of functions; 7. Analog filters; 8. Distributions; 9. Convolution and the Fourier transform of distributions; 10. Filters and distributions; 11. Sampling and discrete filters. Each chapter is divided into several "lessons"—each "lesson" is designed to be assimilated relatively easily. The authors claim that mathematics students who have worked through the material will be well prepared to pursue work in many directions and to explore the proofs of results that have been assumed, such as the development of measure theory and the representation theorems of distributions, and physics and engineering students, who perhaps have a different outlook and motivation, will be well equipped to manipulate Fourier transforms and distributions correctly and to apply correctly results such as the Poisson summation formula.

*Aspects of Statistical Inference.* By A. H. Welsh, Wiley, 1996, xviii+451 pp., $59.95

This is a volume in the Wiley Series in Probability and Statistics. It provides an introduction to the central ideas and methods of statistical inference by integrating abstract conceptual development with the analysis of data. Data is used throughout the book to motivate the inference problem, explain the importance of context and of the choice of models, illustrate the nature of inference in practice, make concrete the effect of model choice and emphasize the need to discuss robustness. The data sets are intentionally simple so that their analysis does not overwhelm the concepts they are used to develop. The text has grown from the author's experience in teaching a one-semester course in statistical inference, to graduate students at the University of Chicago and to advanced undergraduates and graduate students at The Australian National University in Canberra. Chapter headings: 1. Statistical methods; 2. Bayesian, fiducial and likelihood inference; 3. Frequentist inference; 4. Large sample theory; 5. Robust inference; 6. Randomization and resampling; 7. Principles of inference.

*Graph Theory.* By Russell Merris, Wiley, 2001, xi+237 pp.

This is a volume in the Wiley-Interscience Series in Discrete Mathematics and Optimization. This is a mathematically rigorous introduction and designed as a versatile instructional tool for an undergraduate course, with the selection of topics dictated by "how well a topic lends itself to being pictured, calculated, manipulated, or counted". Chapter headings: 1. Invariants; 2. Chromatic numbers; 3. Connectivity; 4. Planar graphs. 5. Hamiltonian cycles; 6. Matchings; 7. Graphic sequences; 8. Chordal graphs; 9. Oriented graphs; 10. Edge colorings.

*Quantum Field Theory for Mathematicians.* By R. Ticciati, Cambridge University Press, 1999, xii+699 pp., $110.00

This is volume 72 of the Encyclopedia of Mathematics and its Applications. According to the author, "the text aims to provide the usual practical knowledge of Quantum Field Theory in comfortable stages naturally structured by the systematic introduction of fundamental principles, pleasantly enriched with overviews, summaries, and delightful mathematical details". He pays tribute to the notes he took from Sidney Coleman's course on the subject at Harvard. The scope of the book is apparent from the table of contents: 1. Relativistic quantum mechanics; 2. Fock space, the scalar field, and canonical quantization; 3. Symmetries and conservation laws; 4. From Dyson's formula to Feynman rules; 5. Differential transition probabilities and predictions; 6. Representations of the Lorentz group. 8. Four-component spinor fields; 9. Vector fields and gauge invariance; 10. Reformulating scattering theory; 11. Functional integral quantization; 13. Anomalies and vacua in gauge theories; 14. $SU(3)$ Representation theory; 15. The structure of the standard model; 16. Hadrons, flavor symmetry, and nucleon-pion interactions; 18. Regularization and renormalization; 19. Renormalization of quantum electrodynamics: three primitive divergences; 20. Renormalization and preservation of symmetries; 21. The renormalization group equations.

*Annual Review of Fluid Mechanics.* Edited by John L. Lumley, Milton Van Dyke, and Helen L. Reed, Annual Reviews, vol. 32, 2000, viii+873 pp., $127.00

In the preface, the editors pay tribute to Sir James Lighthill who died of heart failure in July of 1998 during his annual nine-hour swim around the Isle of Sark. A more complete appreciation will be published in volume 33 of the Reviews. The present volume contains authoritative articles on the following subjects: turbulence models for large-eddy simulation, hydrodynamics of fishlike swimming, mixing and segregation of granular materials, fluid mechanics in the driven cavity, active control of sound, orographic effects in rotating and stratified flows, passive scalars in turbulent flows, capillary effects on surface waves, liquid jet instability in a coaxial gas stream, shockwave-turbulence interactions, flows in stenotic vessels, homogeneous dynamos in planetary cores, magnetohydrodynamics in rapidly rotating spherical systems, sonoluminescence (how bubbles turn sound into light), the dynamics of lava flows, turbulence in plant canopies, vapor explosions, fluid motions in the presence of strong stable stratification, the motion of high-Reynolds-number bubbles in inhomogeneous flows, Rayleigh-Bénard convection, flows induced by temperature fields in a rarefied gas and their ghost effect on the behavior of a gas in the continuum limit.

*A First Course in Multivariate Analysis.* By Bernard Flury, Springer-Verlag, 1997, xiii+713 pp.

This is a volume in the series Springer Texts in Statistics. It is designed to be a unified treatment of both theoretical and practical aspects of the field, appealing to advanced undergraduates and graduate students in statistics, as well as graduate students in biology, anthropology, life sciences, and other areas, and postgraduate students. The style of the book reflects the author's belief that the distinction between multivariate statistical theory and multivariate methods is artificial and should be abandoned. The text covers mostly parametric models, but gives brief introductions to computer-intensive methods such as the bootstrap and randomization tests as well. S-Plus and Gauss tutorials for selected examples are available from a given ftp-site. Table of Contents: 1. Why multivariate statistics; 2. Joint distribution of several random variables; 3. The multivariate normal distribution; 4. Parameter estimation; 5. Discrimination and classification, round 1; 6. Statistical inference for means; 7. Discrimination and classification, round 2; 8. Linear principal component analysis; 9. Normal mixtures. There is also a section on software and data files, and nine appendices cover selected results from matrix analysis.

*Nonlinear Science—Emergence and Dynamics of Coherent Structures.* By Alwyn Scott, Oxford University Press, 1999, xvii+474 pp., $69.00

This is volume 1 in the series Oxford Applied and Engineering Mathematics. Originally prepared as notes for a course in nonlinear science for advanced undergraduates at the Technical University of Denmark, the book is designed as an introduction to the study of nonlinear partial and difference-differential equations with special emphasis on emergent phenomena. Contents: 1. The birth of a paradigm (a historical introduction to the emergent paradigm); 2. Linear wave theory (a brief review of some key ideas); 3. The classical soliton equations; 4. Nonlinear diffusion in excitable media (the aim is here to elucidate the scientific importance of nonlinear difussion in excitable media, and to see how it is related to soliton studies); 5. Nonlinear lattices; 6. Inverse scattering methods; 7. Perturbation theory; 8. Quantum lattice solitons (a survey of lattice solitons and solitary waves from the perspective of quantum theory); 9. Looking ahead (a speculative essay on the future directions of research in applied science).

*Theory of Financial Risk—From Statistical Physics to Risk Management.* By Jean-Philippe Bouchaud and Marc Potters, Cambridge University Press, 2000, xiii+218 pp., $49.95

This book summarizes recent theoretical developments inspired by statistical physics in the description of the potential moves in financial markets, and its application to derivative pricing and risk control. It aims to discuss the subject from the physicists' way of approaching scientific problems, in particular, a systematic comparison between "theory" and "experiments" (i.e., empirical results), the art of approximations and the use of intuition. The models discussed are devised to account for real markets' statistics where the construction of riskless hedges is in general impossible. The mathematical framework required to deal with these cases has the advantage of making the problem of risk more transparent. Chapter headings: 1. Probability theory: basic notions; 2. Statistics of real prices; 3. Extreme risks and optimal portfolios; 4. Futures and options: fundamental concepts; 5. Options: some more specific problems.

*Complex Systems: Chaos and Beyond: A Constructive Approach with Applications in Life Sciences.* By Kunihiko Kaneko and Ichiro Tsuda, Springer-Verlag, 2000, xiii+273 pp.

This is the English, updated, translation of the Japanese version published in 1996. The authors take the standpoint that chaos is essential to a practical and philosophical study of complex systems and examine what concepts in chaos are relevant to this study. Chapter headings: 1. Necessity for a science of complex systems; 2. Observation problems; 3. Coupled map lattices; constructive approach to spatiotemporal chaos; 4. Networks of chaotic elements; 5. Significance of coupled chaotic systems to biological networks; 6. Chaotic information processing in the brain; 7. Conversations with authors.

*Special Functions.* By George E. Andrews, Richard Askey, and Ranjan Roy, Cambridge University Press, 1999, xvi+664 pp., $85.00

This is volume 71 of the Encyclopedia of Mathematics and its Applications. Since the amount of knowledge about special functions is so great that only a small fraction of it can be included in one book, the authors decided to focus primarily on the best understood class of functions, hypergeometric functions and the associated hypergeometric series. The authors present many applications of two very significant properties of hypergeometric functions; they satisfy certain identities for special values of the functions and they have transformation formulas. The gamma functions and beta integrals dealt with in the first chapter are essential to understanding hypergeometric functions. Table of contents: 1. The gamma and beta functions; 2. The hypergeometric functions; 3. Hypergeometric transformations and identities; 4. Bessel functions and confluent hypergeometric functions; 5. Orthogonal polynomials; 6. Special orthogonal polynomials; 7. Topics in orthogonal polynomials; 8. The Selberg integral and its applications; 9. Spherical harmonics; 10. Introduction to $q$ series; 11. Partitions; 12. Bailey chains. There are appendices on: infinite products, summability and fractional integration; asymptotic expansions; Euler-Maclaurin summation formula; Lagrange inversion formula; series solutions of differential equations.

*Infinite Dimensional Optimization and Control Theory.* By H. O. Fattorini, Cambridge University Press, 1999, xi+798 pp., $110.00

This is volume 62 of the Encyclopedia of Mathematics and its Applications. The work is on Pontryagin's maximum principle for equations of the form $y'(t) = f(t, y(t))$ in a suitable function space, on its applications to diverse control systems described by partial differential equations, including control and state constraints and target conditions, and on other related questions such as existence and relaxation of controls. It is designed to be understood by nonspecialists and, to that end, contains sections of auxiliary material. The fourteen chapters are divided into three parts: finite dimensional control problems (chapters 1–4), infinite dimensional control problems (chapters 5–11), and relaxed controls (chapters 12–14). Chapter headings: 1. Calculus of variations and control theory; 2. Optimal control problems without target conditions; 3. Abstract minimization problems: the minimum principle for the time optimal problem; 4. The minimum principle for general optimal control problems; 5. Differential equations in Banach spaces and semigroup theory; 6. Abstract minimization problems in Hilbert spaces; 7. Abstract minimization problems in Banach spaces; 8. Interpolation and domains of fractional powers; 9. Linear control systems; 10. Optimal control problems with state constraints; 11. Optimal control problems with state constraints: the abstract parabolic case. Convergence of suboptimal controls; 12. Spaces of relaxed controls. Topology and measure theory; 13. Relaxed controls in finite dimensional systems; 14. Relaxed controls in infinite dimensional systems.

*Cosmological Inflation and Large-Scale Structure.* By Andrew R. Liddle and David H. Lyth, Cambridge University Press, 2000, xiii+400 pp., $34.95 (paper), $80.00 (cloth)

This book is designed to provide graduate students and others with a thorough and up-to-date introduction to all aspects of inflationary cosmology—from the origin of density perturbations during the inflationary period of the very early universe, through the evolution of the perturbations, up to the present for a range of possible cosmologies. It compares predictions with the latest observations, including those of the cosmic microwave background, the clustering and velocities of galaxies, and the epoch of structure formation. Chapter headings: 1. Introduction; 2. The hot big bang cosmology; 3. Inflation; 4. Simplest model for the origin of structure I; 5. Simplest model for the origin of structure II; 6. Extensions to the simplest model; 7. Scalar fields and the vacuum fluctuation; 8. Building and testing models of inflation; 9. The cosmic microwave background; 10. Galaxy motions and clustering; 11. The quasi-linear regime; 12. Putting observations together; 13. Outlook for the future; 14. Advanced topic: cosmological perturbation theory; 15. Advanced topic: diffusion and freestreaming.

*Nonlinear Water Waves.* By Lokenath Debnath, Academic Press, 1994, xi+544 pp.

This book is aimed at the reader interested in the wider theory of nonlinear wave phenomena, their applications, and other nonlinear aspects of fluid flow. As background, the first chapter deals with the fundamental equations governing the motion of inviscid and viscous fluids with boundary conditions, and chapters 2 and 3 are concerned with the linearized theory of surface waves on water. Chapter headings: 1. Basic equations of motion of inviscid and viscous fluids. 2. The theory of surface waves on water; 3. Transient wave motions in an inviscid fluid; 4. Nonlinear shallow water waves and solitons; 5. Ship waves and wave resistance; 6. Nonlinear diffraction of water waves; 7. The theory of nonlinear dispersive waves; 8. Nonlinear instability of dispersive waves with applications to water waves. There is a bibliography of close to 1000 items.

*Geometry of Cuts and Metrics.* By Michel Marie Deza and Monique Laurent, Springer-Verlag, 1998, xii+587 pp., $129.00

This is volume 15 in the series Algorithms and Combinatorics. Cuts and metrics are well-known central objects in graph theory, combinatorial optimization and, more generally, discrete mathematics. They also occur in areas such as distance geometry, the geometry of numbers, combinatorial matrix theory, the theory of designs, quantum mechanics, statistical physics, analysis, and probability theory. Because of the wealth of results, this book focuses on polyhedral and other geometric aspects of cuts and metrics and presents the material in a unified framework. After an outline of the book and basic definitions, the 31 chapters are divided into five parts: 1. Measure aspects; $l_1$ embeddability and probability; 2. Hypermetric spaces: an approach via geometry of numbers; 3. Isometric embeddings of graphs; 4. Hypercube embeddings and designs; 5. Facets of the cut cone and polytope. There is a bibliography of about 300 items.