# Mathematics of Computation 



EDITED BY
James H. Bramble
Bille C. Carlson
Walter Gautschi, Managing Editor
Donald Goldfarb
Eugene Isaacson
Heinz-Otto Kreiss
James N. Lyness
Morris Newman
Frank W. J. Olver
John E. Osborn
Stanley Osher
Beresford Parlett
Philip Rabinowitz
Ridgway Scott
Daniel Shanks
Frank Stenger
Hans J. Stetter
G. W. Stewart

Vidar C. Thomée
Lars B. Wahlbin
Hugh C. Williams
John W. Wrench, Jr.

July 1984
Volume 43, Number 167, Pages 1-348
Published by the American Mathematical Society
Providence, Rhode Island USA
ISSN 0025-5718

## Editorial Committee

WALTER GAUTSCHI, Chairman. Dept. of Computer Sciences, Purdue Univ., West Lafayette, IN 47907
JOHN E. OSBORN, Dept, of Mathematics, Univ. of Maryland, College Park, MD 20742
DANIEL SHANKS, Dept. of Mathematics, Univ. of Maryland, College Park, MD 20742
HUGH C. WILLIAMS. Dept. of Computer Science, Univ, of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

## Technical Editor

MIRIAM E. PORILE, Dept. of Computer Sciences, Purdue Univ.. West Lafayette, IN 47907

## Board of Associate Editors

JAMES H. BRAMBLE, Dept. of Mathematics, Cornell Univ., Ithaca. NY 14853
BILLE C. CARLSON, Dept. of Mathematics, Iowa State Univ.. Ames, IA 50011
DONALD GOLDFARB, Dept. of Industrial Engineering and Operations Research, Seely W. Mudd Building. Columbia Univ. in the City of New York, New York, NY 10027
EUGENE ISAACSON, Courant Institute of Mathematical Sciences, New York Univ., 251 Mercer Street. New York. NY 10012
HEINZ-OTTO KREISS, Dept. of Applied Mathematics, California Institute of Technology. Pasadena, CA 91125
JAMES N. LYNESS, Argonne National Laboratory, 9700 South Cass Avenue. Argonne, IL 60439
MORRIS NEWMAN. Dept. of Mathematics. Univ. of California, Santa Barbara, CA 93106
FRANK W, J. OLVER, Inst. for Physical Science and Technology, Univ. of Maryland, College Park. MD 20742
STANLEY OSHER, Dept. of Mathematics, Univ. of California, Los Angeles. CA 90024
BERESFORD PARLETT, Dept, of Mathematics, Univ. of California, Berkeley, CA 94720
PHILIP RABINOWITZ, Dept. of Applied Mathematics, The Weizmann Institute of Science. Rehovot, Israel
RIDGWAY SCOTT, Dept. of Mathematics, Univ. of Michigan, Ann Arbor, MI 48109
FRANK STENGER, Dept. of Mathematics, Univ. of Utah, Salt Lake City, UT 84112
HANS J. STETTER. Institut für Numerische Mathematik, Technische Universität Wien, Karlsplatz 13, A-1040. Wien, Austria
G. W. STEWART. Dept. of Computer Science, Univ. of Maryland, College Park, MD 20742

VIDAR C. THOMÉE, Mathematics Dept., Chalmers Univ, of Technology, Göteborg, Sweden
LARS B. WAHLBIN, Dept. of Mathematics, Cornell Univ., Ithaca. NY 14853
JOHN W. WRENCH, JR., 6310 Jefferson Blvd., Frederick, MD 21701
SUBSCRIPTION INFORMATION: MATHEMATICS OF COMPUTATION is published quarterly, with issues numbered serially since Volume 1. Number 1. Subscription prices for Volumes 42 and 43 (1984) are $\$ 100.00$ list; $\$ 75.00$ institutional member; $\$ 50.00$ member of CBMS organizations; $\$ 40.00$ individual AMS member. A late charge of $10 \%$ of the subscription price will be imposed upon orders received from nonmembers after January 1 of the subscription year. Subscribers outside the United States and India must pay a postage surcharge of $\$ 5,00$; subscribers in India must pay a postage surcharge of $\$ 8.00$. Combination paper and mircofiche subscription prices are $\$ 133.00$ list; $\$ 100.00$ institutional member; $\$ 67.00$ member of CBMS organizations; $\$ 53.00$ individual AMS member. Microfiche of each issue will be mailed the fastest way before the issue is mailed by the printer.

BACK NUMBER INFORMATION: Back number prices per volume are for Volumes 1-21, $\$ 80.00$ list, $\$ 60.00$ member; for Volumes 22-33, \$120.00 list, $\$ 90.00$ member; for Volumes 34-41, $\$ 80.00$ list, $\$ 60,00$ member. Back volumes may be purchased on microfilm or microfiche from University Microfilms International, 300 North Zeeb Road, Ann Arbor, MI 48106.

UNPUBLISHED MATHEMATICAL TABLES: The editorial office of the journal maintains a repository of Unpublished Mathematical Tables (UMT). When a table is deposited in the UMT repository a brief summary of its contents is published in the section Reviews and Descriptions of Tables and Books. Upon request, the chairman of the editorial committee will supply copies of any table for a nominal cost per page. All tables and correspondence concerning the UMT should be sent to Walter Gautschi, Chairman, Editorial Committee. Mathematics of Computation, Department of Computer Sciences, Purdue University, West Lafayette. IN 47907.

Orders for subscriptions and publications of the American Mathematical Society should be addressed to the AMS, P.O. Box 1571, Annex Station, Providence, RI 02901. All orders must be accompanied by payment. Other correspondence should be addressed to P.O. Box 6248, Providence, RI 02940.

[^0]
# Mathematics of Computation 

## EDITED BY

James H. Bramble
Bille C. Carlson
Walter Gautschi, Managing Editor
Donald Goldfarb
Eugene Isaacson
Heinz-Otto Kreiss
James N. Lyness
Morris Newman
Frank W. J. Olver
John E. Osborn
Stanley Osher
Beresford Parlett
Philip Rabinowitz
Ridgway Scott
Daniel Shanks
Frank Stenger
Hans J. Stetter
G. W. Stewart

Vidar C. Thomée
Lars B. Wahlbin
Hugh C. Williams
John W. Wrench, Jr.

## Information for Contributors

Manuscripts should be typewritten double-spaced in the format used by the journal. For journal abbreviations, see the latest Mathematical Reviews volume index. An author should submit the original and two copies of the manuscript and retain one copy. The author may suggest an appropriate editor for his paper. It is recommended that the author acquaint himself with the pertinent material contained in " $A$ Manual for Authors of Mathematical Papers," which is available from the American Mathematical Society. All contributions intended for publication and all books for review should be addressed to Walter Gautschi, Chairman, Editorial Committee, Mathematics of Computation, Department of Computer Sciences, Purdue University, West Lafayette, Indiana 47907. The date received, which is published with the final version of an accepted paper, is the date received in the office of the Chairman of the Editorial Committee, and it is the responsibility of the author to submit manuscripts directly to this office. Institutions sponsoring research reported in the journal are assessed page and microfiche charges.

Each article submitted for publication must be accompanied by a brief and reasonably self-contained abstract, and by 1980 Mathematics Subject Classification numbers. If a list of key words and phrases is included, it will be printed as a footnote on the first page. A list of the classification numbers may be found in the 1978 Subject Index to Mathematical Reviews.

The research journals of the American Mathematical Society carry a page charge of $\$ 50.00$ per page to help defray the cost of publication. This amount is charged to the institution or to a contract supporting the research reported in the published paper. The publication charge policy of the United States Federal Council for Science and Technology (FCST) is reported on page 112 of the February, 1975 issue of the NOTICES of the American Mathematical Society. In no case is the author personally responsible for paying the page charge, nor is acceptance of the author's paper for publication dependent upon payment of the page charge.

## Copying and Reprinting

Individual readers of this publication, and nonprofit libraries acting for them, are permitted to make fair use of the material, such as to copy an article for use in teaching or research. Permission is granted to quote brief passages from this publication in reviews provided the customary acknowledgement of the source is given.

Republication, systematic copying, or multiple reproduction of any material in this publication (including abstracts) is permitted only under license from the American Mathematical Society. Requests for such permission should be addressed to the Executive Director, American Mathematical Society, P. O. Box 6248, Providence, Rhode Island 02940.

The appearance of the code on the first page of an article in this journal indicates the copyright owner's consent for copying beyond that permitted by Sections 107 or 108 of the U. S. Copyright Law, provided that the fee of $\$ 1.00$ plus $\$ .25$ per page for each copy be paid directly to Copyright Clearance Center, Inc., 21 Congress Street, Salem, Massachusetts 01970. This consent does not extend to other kinds of copying, such as copying for general distribution, for advertising or promotion purposes, for creating new collective works, or for resale.

# MATHEMATICS OF COMPUTATION <br> TABLE OF CONTENTS 

July 1984
M. G. Crandall and P. L. Lions, Two Approximations of Solutions of Hamilton- Jacobi Equations ..... 1
J. M. Sanz-Serna, Methods for the Numerical Solution of the Nonlinear Schroedinger Equation ..... 21
A. Bendali, Numerical Analysis of the Exterior Boundary Value Problem for the Time-Harmonic Maxwell Equations by a Boundary Finite Element Method. Part 1: The Continuous Problem ..... 29
A. Bendali, Numerical Analysis of the Exterior Boundary Value Problem for the Time-Harmonic Maxwell Equations by a Boundary Finite Element Method. Part 2. The Discrete Problem ..... 47
D. Goldfarb and Ph. L. Toint, Optimal Estimation of Jacobian and Hessian Matrices That Arise in Finite Difference Calculations ..... 69
Steve Schaffer, Higher Order Multi-Grid Methods ..... 89
Ciprian Foias and Roger Temam, Determination of the Solutions of the Navier- Stokes Equations By a Set of Nodal Values ..... 117
Eric Schechter, Sharp Convergence Rates for Nonlinear Product Formulas .. ..... 135
U. Ascher and R. Weiss, Collocation for Singular Perturbation Problems II: Linear First Order Systems Without Turning Points ..... 157
P. Onumanyi and E. L. Ortiz, Numerical Solution of Stiff and Singularly Perturbed Boundary Value Problems With a Segmented-Adaptive Formu- lation of the Tau Method ..... 189
Wilhelm Werner, Polynomial Interpolation: Lagrange versus Newton ..... 205
D. S. Lubinsky and P. Rabinowitz, Rates of Convergence of Gaussian Quadra- ture for Singular Integrands ..... 219
Norbert H. J. Lacroix, On Common Zeros of Legendre's Associated Functions ..... 243
Ayşe Kiper, Fourier Series Coefficients for Powers of the Jacobian Elliptic Functions. ..... 247
J. Wróblewski, A Nonaveraging Set of Integers With a Large Sum of Recip- rocals ..... 261
Graeme L. Cohen, Primitive $\alpha$-Abundant Numbers ..... 263
A. Rotkiewicz, On the Congruence $2^{n-2} \equiv 1(\bmod n)$ ..... 271
Fred H. Hao and Charles J. Parry, Generalized Bernoulli Numbers and m- Regular Primes ..... 273
C. P. Schnorr and H. W. Lenstra, Jr., A Monte Carlo Factoring Algorithm With Linear Storage ..... 289
Duncan A. Buell, The Expectation of Success Using a Monte Carlo Factoring Method-Some Statistics on Quadratic Class Numbers. ..... 313
William W. Adams, Splitting of Quartic Polynomials ..... 329
Reviews and Descriptions of Tables and Books ..... 345
Werner, Wuytack, Ng and Bünger, Editors 7
Table Errata ..... 346
Magnus and Oberhettinger 603, Salzer and Levine 604
Corrigenda ..... 347
Lax and Agrawal, Keast, Fairweather and Diaz
Supplement to "Higher Order Multi-Grid Methods" by Steve Schaffer ..... S1

## (Continued from back cover)

Reviews and Descriptions of Tables and Books ..... 345Werner, Wuytack, Ng and Bünger, Editors 7
Table Errata ..... 346Magnus and Oberhettinger 603, Salzer and Levine 604Corrigenda347
Lax and Agrawal, Keast, Fairweather and Diaz
Supplement to "Higher Order Multi-Grid Methods" by Steve Schaffer ..... S1

# MATHEMATICS OF COMPUTATION <br> TABLE OF CONTENTS 

July 1984
M. G. Crandall and P. L. Lions, Two Approximations of Solutions of HamiltonJacobi Equations
J. M. Sanz-Serna, Methods for the Numerical Solution of the Nonlinear Schroedinger Equation ..... 21
A. Bendali, Numerical Analysis of the Exterior Boundary Value Problem for the Time-Harmonic Maxwell Equations by a Boundary Finite Element Method. Part 1: The Continuous Problem ..... 29
A. Bendali, Numerical Analysis of the Exterior Boundary Value Problem for the Time-Harmonic Maxwell Equations by a Boundary Finite Element Method, Part 2. The Discrete Problem ..... 47
D. Goldfarb and Ph. L. Toint, Optimal Estimation of Jacobian and Hessian Matrices That Arise in Finite Difference Calculations ..... 69
Steve Schaffer, Higher Order Multi-Grid Methods ..... 89
Ciprian Foias and Roger Temam, Determination of the Solutions of the Navier- Stokes Equations By a Set of Nodal Values ..... 117
Eric Schechter, Sharp Convergence Rates for Nonlinear Product Formulas. ..... 135
U. Ascher and R. Weiss, Collocation for Singular Perturbation Problems II: Linear First Order Systems Without Turning Points ..... 157
P. Onumanyi and E. L. Ortiz, Numerical Solution of Stiff and Singularly Perturbed Boundary Value Problems With a Segmented-Adaptive Formu- lation of the Tau Method ..... 189
Wilhelm Werner, Polynomial Interpolation: Lagrange versus Newton ..... 205
D. S. Lubinsky and P. Rabinowitz, Rates of Convergence of Gaussian Quadra- ture for Singular Integrands ..... 219
Norbert H. J. Lacroix, On Common Zeros of Legendre's Associated Functions ..... 243
Ayse Kiper, Fourier Series Coefficients for Powers of the Jacobian Elliptic Functions. ..... 247
J. Wróblewski, A Nonaveraging Set of Integers With a Large Sum of Recip- rocals. ..... 261
Graeme L. Cohen, Primitive $\alpha$-Abundant Numbers ..... 263
A. Rotkiewicz, On the Congruence $2^{n-2} \equiv 1(\bmod n)$. ..... 271
Fred H. Hao and Charles J. Parry, Generalized Bernoulli Numbers and $m$ - Regular Primes ..... 273
C. P. Schnorr and H. W. Lenstra, Jr., A Monte Carlo Factoring Algorithm With Linear Storage ..... 289
Duncan A. Buell, The Expectation of Success Using a Monte Carlo Factoring Method-Some Statistics on Quadratic Class Numbers. ..... 313
William W. Adams, Splitting of Quartic Polynomials ..... 329


[^0]:    MATHEMATICS OF COMPUTATION is published quarterly by the American Mathematical Society, 201 Charles Street. Providence, RI 02904, Second-class postage is paid at Providence. Rhode Island, and additional mailing offices. Postmaster: Send address changes to Mathematics of Computation. American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

