Lecture Notes in Mathematics

For information about Vols. 1–1145 please contact your bookseller or Springer-Verlag.

Vol. 1146: Séminaire d'Algèbre Paul Dubreil et Marie-Paule Malliavin. Proceedings, 1983–1984. Edité par M.-P. Malliavin. IV, 420 pages. 1985.

Vol. 1147: M. Wschebor, Surfaces Aléatoires. VII, 111 pages. 1985.

Vol. 1148: Mark A. Kon, Probability Distributions in Quantum Statistical Mechanics. V, 121 pages. 1985.

Vol. 1149: Universal Algebra and Lattice Theory. Proceedings, 1984. Edited by S. D. Comer. VI, 282 pages. 1985.

Vol. 1150: B. Kawohl, Rearrangements and Convexity of Level Sets in PDE. V, 136 pages. 1985.

Vol 1151: Ordinary and Partial Differential Equations. Proceedings, 1984. Edited by B.D. Sleeman and R.J. Jarvis. XIV, 357 pages. 1985.

Vol. 1152: H. Widom, Asymptotic Expansions for Pseudodifferential Operators on Bounded Domains. V, 150 pages. 1985.

Vol. 1153: Probability in Banach Spaces V. Proceedings, 1984. Edited by A. Beck, R. Dudley, M. Hahn, J. Kuelbs and M. Marcus. VI, 457 pages. 1985.

Vol. 1154: D.S. Naidu, A.K. Rao, Singular Pertubation Analysis of Discrete Control Systems. IX, 195 pages. 1985.

Vol. 1155: Stability Problems for Stochastic Models. Proceedings, 1984. Edited by V.V. Kalashnikov and V.M. Zolotarev. VI, 447 pages. 1985.

Vol. 1156: Global Differential Geometry and Global Analysis 1984. Proceedings, 1984. Edited by D. Ferus, R.B. Gardner, S. Helgason and U. Simon. V, 339 pages. 1985.

Vol. 1157: H. Levine, Classifying Immersions into $\mathbb{R}^4$ over Stable Maps of 3-Manifolds into $\mathbb{R}^2$. V, 163 pages. 1985.

Vol. 1158: Stochastic Processes – Mathematics and Physics. Proceedings, 1984. Edited by S. Albeverio, Ph. Blanchard and L. Streit. VI, 230 pages. 1986.

Vol. 1159: Schrödinger Operators, Como 1984. Seminar. Edited by S. Graffi. VIII, 272 pages. 1986.

Vol. 1160: J.-C. van der Meer, The Hamiltonian Hopf Bifurcation. VI, 115 pages. 1985.

Vol. 1161: Harmonic Mappings and Minimal Immersions, Montecatini 1984. Seminar. Edited by E. Giusti. VII, 285 pages. 1985.

Vol. 1162: S.J.L. van Eijndhoven, J. de Graaf, Trajectory Spaces, Generalized Functions and Unbounded Operators. IV, 272 pages. 1985.

Vol. 1163: Iteration Theory and its Functional Equations. Proceedings, 1984. Edited by R. Liedl, L. Reich and Gy. Targonski. VIII, 231 pages. 1985.

Vol. 1164: M. Meschiari, J.H. Rawnsley, S. Salamon, Geometry Seminar "Luigi Bianchi" II – 1984. Edited by E. Vesentini. VI, 224 pages. 1985.

Vol. 1165: Seminar on Deformations. Proceedings, 1982/84. Edited by J. Ławrynowicz. IX, 331 pages. 1985.

Vol. 1166: Banach Spaces. Proceedings, 1984. Edited by N. Kalton and E. Saab. VI, 199 pages. 1985.

Vol. 1167: Geometry and Topology. Proceedings, 1983–84. Edited by J. Alexander and J. Harer. VI, 292 pages. 1985.

Vol. 1168: S.S. Agaian, Hadamard Matrices and their Applications. III, 227 pages. 1985.

Vol. 1169: W.A. Light, E.W. Cheney, Approximation Theory in Tensor Product Spaces. VII, 157 pages. 1985.

Vol. 1170: B.S. Thomson, Real Functions. VII, 229 pages. 1985.

Vol. 1171: Polynômes Orthogonaux et Applications. Proceedings, 1984. Edité par C. Brezinski, A. Draux, A.P. Magnus, P. Maroni et A. Ronveaux. XXXVII, 584 pages. 1985.

Vol. 1172: Algebraic Topology, Göttingen 1984. Proceedings. Edited by L. Smith. VI, 209 pages. 1985.

Vol. 1173: H. Delfs, M. Knebusch, Locally Semialgebraic Spaces. XVI, 329 pages. 1985.

Vol. 1174: Categories in Continuum Physics, Buffalo 1982. Seminar. Edited by F.W. Lawvere and S.H. Schanuel. V, 126 pages. 1986.

Vol. 1175: K. Mathiak, Valuations of Skew Fields and Projective Hjelmslev Spaces. VII, 116 pages. 1986.

Vol. 1176: R.R. Bruner, J.P. May, J.E. McClure, M. Steinberger, H_∞ Ring Spectra and their Applications. VII, 388 pages. 1986.

Vol. 1177: Representation Theory I. Finite Dimensional Algebras. Proceedings, 1984. Edited by V. Dlab, P. Gabriel and G. Michler. XV, 340 pages. 1986.

Vol. 1178: Representation Theory II. Groups and Orders. Proceedings, 1984. Edited by V. Dlab, P. Gabriel and G. Michler. XV, 370 pages. 1986.

Vol. 1179: Shi J.-Y. The Kazhdan-Lusztig Cells in Certain Affine Weyl Groups. X, 307 pages. 1986.

Vol. 1180: R. Carmona, H. Kesten, J.B. Walsh, École d'Été de Probabilités de Saint-Flour XIV – 1984. Édité par P.L. Hennequin. X, 438 pages. 1986.

Vol. 1181: Buildings and the Geometry of Diagrams, Como 1984. Seminar. Edited by L. Rosati. VII, 277 pages. 1986.

Vol. 1182: S. Shelah, Around Classification Theory of Models. VII, 279 pages. 1986.

Vol. 1183: Algebra, Algebraic Topology and their Interactions. Proceedings, 1983. Edited by J.-E. Roos. XI, 396 pages. 1986.

Vol. 1184: W. Arendt, A. Grabosch, G. Greiner, U. Groh, H.P. Lotz, U. Moustakas, R. Nagel, F. Neubrander, U. Schlotterbeck, One-parameter Semigroups of Positive Operators. Edited by R. Nagel. X, 460 pages. 1986.

Vol. 1185: Group Theory, Beijing 1984. Proceedings. Edited by Tuan H.F. V, 403 pages. 1986.

Vol. 1186: Lyapunov Exponents. Proceedings, 1984. Edited by L. Arnold and V. Wihstutz. VI, 374 pages. 1986.

Vol. 1187: Y. Diers, Categories of Boolean Sheaves of Simple Algebras. VI, 168 pages. 1986.

Vol. 1188: Fonctions de Plusieurs Variables Complexes V. Séminaire, 1979–85. Edité par François Norguet. VI, 306 pages. 1986.

Vol. 1189: J. Lukeš, J. Malý, L. Zajíček, Fine Topology Methods in Real Analysis and Potential Theory. X, 472 pages. 1986.

Vol. 1190: Optimization and Related Fields. Proceedings, 1984. Edited by R. Conti, E. De Giorgi and F. Giannessi. VIII, 419 pages. 1986.

Vol. 1191: A.R. Its, V.Yu. Novokshenov, The Isomonodromic Deformation Method in the Theory of Painlevé Equations. IV, 313 pages. 1986.

Vol. 1192: Equadiff 6. Proceedings, 1985. Edited by J. Vosmansky and M. Zlámal. XXIII, 404 pages. 1986.

Vol. 1193: Geometrical and Statistical Aspects of Probability in Banach Spaces. Proceedings, 1985. Edited by X. Fernique, B. Heinkel, M.B. Marcus and P.A. Meyer. IV, 128 pages. 1986.

Vol. 1194: Complex Analysis and Algebraic Geometry. Proceedings, 1985. Edited by H. Grauert. VI, 235 pages. 1986.

Vol. 1195: J.M. Barbosa, A.G. Colares, Minimal Surfaces in $\mathbb{R}^3$. X, 124 pages. 1986.

Vol. 1196: E. Casas-Alvero, S. Xambó-Descamps, The Enumerative Theory of Conics after Halphen. IX, 130 pages. 1986.

Vol. 1197: Ring Theory. Proceedings, 1985. Edited by F.M.J. van Oystaeyen. V, 231 pages. 1986.

Vol. 1198: Séminaire d'Analyse, P. Lelong – P. Dolbeault – H. Skoda. Seminar 1983/84. X, 260 pages. 1986.

Vol. 1199: Analytic Theory of Continued Fractions II. Proceedings, 1985. Edited by W.J. Thron. VI, 299 pages. 1986.

Vol. 1200: V.D. Milman, G. Schechtman, Asymptotic Theory of Finite Dimensional Normed Spaces. With an Appendix by M. Gromov. VIII, 156 pages. 1986.

continued on page 425

Lecture Notes in Mathematics

Edited by A. Dold and B. Eckmann

1357

S. Hildebrandt R. Leis (Eds.)

Partial Differential Equations and Calculus of Variations

Springer-Verlag
Berlin Heidelberg New York London Paris Tokyo

Editors

Stefan Hildebrandt
Mathematisches Institut, Universität Bonn
Wegelerstr. 10, 5300 Bonn, Federal Republic of Germany

Rolf Leis
Institut für Angewandte Mathematik, Universität Bonn
Wegelerstr. 10, 5300 Bonn, Federal Republic of Germany

Mathematics Subject Classification (1980): 35A15 & A30, 35B, 35G, 35J, 35K, 35L, 49F, 53C

ISBN 3-540-50508-3 Springer-Verlag Berlin Heidelberg New York
ISBN 0-387-50508-3 Springer-Verlag New York Berlin Heidelberg

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in other ways, and storage in data banks. Duplication of this publication or parts thereof is only permitted under the provisions of the German Copyright Law of September 9, 1965, in its version of June 24, 1985, and a copyright fee must always be paid. Violations fall under the prosecution act of the German Copyright Law.

© Springer-Verlag Berlin Heidelberg 1988
Printed in Germany

Printing and binding: Druckhaus Beltz, Hemsbach/Bergstr.
2146/3140-543210

PREFACE

This volume contains 18 papers by members and guests of the former Sonderforschungsbereich 72 (SFB 72) "*Approximation und Mathematische Optimierung in einer anwendungsbezogenen Mathematik*", who have, over the years, collaborated in the research group "*Lösung partieller Differentialgleichungen und Variationsrechnung*". It is an account of 15 years of research.

The SFB 72 was in existence from 1971 to 1986 as an institute at the University of Bonn. It was supported by the Deutsche Forschungsgemeinschaft, by the University, and by the State of Nordrhein-Westfalen. Members of the special research group were mathematicians holding chairs at Bonn University as well as younger scientists with temporary positions. They collaborated with colleagues from neighbouring universities and with numerous guests from abroad who visited the SFB 72.

In 1986 the SFB 72 reached its maximum life span of 15 years. On this occasion we invited our colleagues and our former guests to contribute a research paper or a survey of a part of our common field of interest, the theory of partial differential equations and the calculus of variations. We hope to have attained a good balance of surveys and of original contributions. The emphasis is on existence and regularity results for variational problems and for nonlinear differential equations, on special equations of mathematical physics, and on problems of scattering theory.

We would like to take this opportunity to thank all those who have over the years supported the work of the Sonderforschungsbereich 72. Our special gratitude goes to the Deutsche Forschungsgemeinschaft and its referees. We are also deeply indebted to the State of Nordrhein-Westfalen, to our University, to our former colleagues and coworkers, and to our secretaries. We particularly thank Mrs. Anke Vogt who, as always, has overcome all difficulties in preparing this volume.

Last but not least we thank the series editors and the publisher for including our celebration issue in the series *Lecture Notes in Mathematics* of Springer-Verlag.

Bonn, 15th April 1988

Stefan Hildebrandt
Rolf Leis

TABLE OF CONTENTS

Page

Alber, Hans Dieter:
On the existence in the large of solutions to the one-dimensional, isentropic hydrodynamic equations in a bounded domain 1

Alber, Hans Dieter & Leis, Rolf:
Initial boundary value and scattering problems in mathematical physics 23

Alt, Hans Wilhelm:
On shape optimization of a turbine blade 61

Bemelmans, Josef:
Free boundary problems for the Navier-Stokes equations 96

Dierkes, Ulrich:
A geometric maximum principle, Plateau's problem for surfaces of prescribed mean curvature, and the two dimensional analogue of the catenary 116

Dziuk, Gerhard:
Finite elements for the Beltrami operator on arbitrary surfaces 142

Finn, Robert:
Comparison principles in capillarity 156

Frehse, Jens:
Remarks on diagonal elliptic systems 198

Giaquinta, Mariano:
Quasiconvexity, growth conditions and partial regularity 211

Grüter, Michael:
The monotonicity formula in geometric measure theory, and an application to a partially free boundary problem 238

Gulliver, Robert:
Isoperimetric problems having continua of solutions 256

Jost, Jürgen:
Harmonic maps - analytic theory and geometric significance 264

Meier, Michael:
Asymptotic behavior of solutions of some quasilinear elliptic systems in exterior domains 297

Milani, Albert & Picard, Rainer:
Decomposition theorems and their application to non-linear electro- and magneto-static boundary value problems 317

Page

Racke, Reinhard:
Initial boundary value problems in thermoelasticity 341

Struwe, Michael:
Applications of variational methods to problems in the geometry of surfaces 359

Tromba, Anthony:
Open problems in the degree theory for disc minimal surfaces spanning a curve in $\mathbb{R}^3$ 379

Witsch, Karl-Josef:
On a modified version of the free geodetic boundary-value problem 402