

LONDON MATHEMATICAL SOCIETY LECTURE NOTE SERIES

Managing Editor: Professor J.W.S. Cassels, Department of Pure Mathematics and Mathematical Statistics, University of Cambridge, 16 Mill Lane, Cambridge CB2 1SB, England

The books in the series listed below are available from booksellers, or, in case of difficulty, from Cambridge University Press.

- Algebraic topology, J.F. ADAMS
- 5 Commutative algebra, J.T. KNIGHT
- Topics in finite groups, T.M. GAGEN 16
- 17 Differential germs and catastrophes, Th. BROCKER & L. LANDER
- 18 A geometric approach to homology theory, S. BUONCRISTIANO, C.P. ROURKE & **B.J. SANDERSON**
- 20 Sheaf theory, B.R. TENNISON
- 21 Automatic continuity of linear operators, A.M. SINCLAIR
- Parallelisms of complete designs, P.J. CAMERON 23
- 24 The topology of Stiefel manifolds, I.M. JAMES
- Lie groups and compact groups, J.F. PRICE 25
- Skew field constructions, P.M. COHN 27
- 29 Pontryagin duality and the structure of LCA groups, S.A. MORRIS
- 30 Interaction models, N.L. BIGGS
- Continuous crossed products and type III von Neumann algebras, A. VAN DAELE 31
- Representation theory of Lie groups, M.F. ATIYAH et al
- Homological group theory, C.T.C. WALL (ed) Surveys in combinatorics, B. BOLLOBAS (ed) 36
- 38
- 39 Affine sets and affine groups, D.G. NORTHCOTT
- 40 Introduction to H_D spaces, P.J. KOOSIS
- Theory and applications of Hopf bifurcation, B.D. HASSARD, 41 N.D. KAZARINOFF & Y-H. WAN
- 42 Topics in the theory of group presentations, D.L. JOHNSON
- 43 Graphs, codes and designs, P.J. CAMERON & J.H. VAN LINT
- 44 Z/2-homotopy theory, M.C. CRABB
- 45 Recursion theory: its generalisations and applications, F.R. DRAKE & S.S. WAINER (eds)
- 46 p-adic analysis: a short course on recent work, N. KOBLITZ
- Low-dimensional topology, R. BROWN & T.L. THICKSTUN (eds) 48
- 49 Finite geometries and designs, P. CAMERON, J.W.P. HIRSCHFELD & D.R. HUGHES (eds)
- 50 Commutator calculus and groups of homotopy classes, H.J. BAUES
- 51 Synthetic differential geometry, A. KOCK
- 52 Combinatorics, H.N.V. TEMPERLEY (ed)
- 54 Markov processes and related problems of analysis, E.B. DYNKIN
- 55 Ordered permutation groups, A.M.W. GLASS
- Journees arithmetiques, J.V. ARMITAGE (ed) 56
- 57 Techniques of geometric topology, R.A. FENN
- 58 Singularities of smooth functions and maps, J.A. MARTINET
- 59 Applicable differential geometry, M. CRAMPIN & F.A.E. PIRANI
- Integrable systems, S.P. NOVIKOV et al 60
- 61 The core model. A. DODD
- 62 Economics for mathematicians, J.W.S. CASSELS
- 63 Continuous semigroups in Banach algebras, A.M. SINCLAIR
- Basic concepts of enriched category theory, G.M. KELLY 64
- 65 Several complex variables and complex manifolds I, M.J. FIELD
- Several complex variables and complex manifolds II, M.J. FIELD 66
- Classification problems in ergodic theory, W. PARRY & S. TUNCEL 67
- Complex algebraic surfaces, A. BEAUVILLE 68
- 69 Representation theory, I.M. GELFAND et al



- 70 Stochastic differential equations on manifolds, K.D. ELWORTHY
- 71 Groups St Andrews 1981, C.M. CAMPBELL & E.F. ROBERTSON (eds)
- 72 Commutative algebra: Durham 1981, R.Y. SHARP (ed)
- 73 Riemann surfaces: a view towards several complex variables, A.T. HUCKLEBERRY
- 74 Symmetric designs: an algebraic approach, E.S. LANDER
- 75 New geometric splittings of classical knots, L. SIEBENMANN & F. BONAHON
- 76 Spectral theory of linear differential operators and comparison algebras, H.O. CORDES
- 77 Isolated singular points on complete intersections, E.J.N. LOOIJENGA
- 78 A primer on Riemann surfaces, A.F. BEARDON
- 79 Probability, statistics and analysis, J.F.C. KINGMAN & G.E.H. REUTER (eds)
- 80 Introduction to the representation theory of compact and locally compact groups, A. ROBERT
- 81 Skew fields, P.K. DRAXL
- 82 Surveys in combinatorics, E.K. LLOYD (ed)
- 83 Homogeneous structures on Riemannian manifolds, F. TRICERRI & L. VANHECKE
- 84 Finite group algebras and their modules, P. LANDROCK
- 85 Solitons, P.G. DRAZIN
- 86 Topological topics, I.M. JAMES (ed)
- 87 Surveys in set theory, A.R.D. MATHIAS (ed)
- 88 FPF ring theory, C. FAITH & S. PAGE
- 89 An F-space sampler, N.J. KALTON, N.T. PECK & J.W. ROBERTS
- 90 Polytopes and symmetry, S.A. ROBERTSON
- 91 Classgroups of group rings, M.J. TAYLOR
- 92 Representation of rings over skew fields, A.H. SCHOFIELD
- 93 Aspects of topology, I.M. JAMES & E.H. KRONHEIMER (eds)
- 94 Representations of general linear groups, G.D. JAMES
- 95 Low-dimensional topology 1982, R.A. FENN (ed)
- 96 Diophantine equations over function fields, R.C. MASON
- 97 Varieties of constructive mathematics, D.S BRIDGES & F. RICHMAN
- 98 Localization in Noetherian rings, A.V. JATEGAONKAR
- 99 Methods of differential geometry in algebraic topology, M. KAROUBI & C. LERUSTE
- 100 Stopping time techniques for analysts and probabilists, L. EGGHE
- 101 Groups and geometry, ROGER C. LYNDON
- 102 Topology of the automorphism group of a free group, S.M. GERSTEN
- 103 Surveys in combinatorics 1985, I. ANDERSON (ed)
- 104 Elliptic structures on 3-manifolds, C.B. THOMAS
- 105 A local spectral theory for closed operators, I. ERDELYI & WANG SHENGWANG
- 106 Syzygies, E.G. EVANS & P. GRIFFITH
- 107 Compactification of Siegel moduli schemes, C-L. CHAI
- 108 Some topics in graph theory, H.P. YAP
- 109 Diophantine Analysis, J. LOXTON & A. VAN DER POORTEN (eds)
- 110 An introduction to surreal numbers, H. GONSHOR
- 111 Analytical and geometric aspects of hyperbolic space, D.B.A.EPSTEIN (ed)
- 112 Low-dimensional topology and Kleinian groups, D.B.A. EPSTEIN (ed)
- 113 Lectures on the asymptotic theory of ideals, D. REES
- 114 Lectures on Bochner-Riesz means, K.M. DAVIS & Y-C. CHANG
- 115 An introduction to independence for analysts, H.G. DALES & W.H. WOODIN
- 116 Representations of algebras, P.J. WEBB (ed)
- 117 Homotopy theory, E. REES & J.D.S. JONES (eds)
- 118 Skew linear groups, M. SHIRVANI & B. WEHRFRITZ
- 119 Triangulated categories in the representation theory of finite-dimensional algebras, D. HAPPEL
- 120 Lectures on Fermat varieties, T. SHIODA
- 121 Proceedings of Groups St Andrews 1985, E. ROBERTSON & C. CAMPBELL (eds)
- 122 Non-classical continuum mechanics, R.J. KNOPS & A.A. LACEY (eds)
- 123 Surveys in combinatorics 1987, C. WHITEHEAD (ed)
- 124 Lie groupoids and Lie algebroids in differential geometry, K. MACKENZIE
- 125 Commutator theory for congruence modular varieties, R. FREESE & R. MCKENZIE

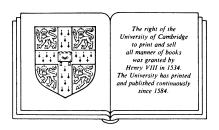


London Mathematical Society Lecture Note Series. 122

Non-Classical Continuum Mechanics

Proceedings of the London Mathematical Society Symposium, Durham, July 1986

Edited by R.J. KNOPS and A.A. LACEY Department of Mathematics, Heriot-Watt University



CAMBRIDGE UNIVERSITY PRESS

Cambridge

New York New Rochelle Melbourne Sydney



> CAMBRIDGE UNIVERSITY PRESS Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org Information on this title: www.cambridge.org/9780521349352

© Cambridge University Press 1987

This publication is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 1987 Re-issued in this digitally printed version 2007

A catalogue record for this publication is available from the British Library

ISBN 978-0-521-34935-2 paperback



FOREWORD

This volume contains most of the invited lectures delivered as part of the Symposium on "Non-classical Continuum Mechanics, Abstract Techniques and Applications" held in the University of Durham from 2 - 12th July, 1986. The meeting was under the auspices of the London Mathematical Society with financial support generously provided by the Science and Engineering Research Council of Great Britain. To these organisations and also to the University of Durham (including staff of the Department of Mathematics and of Grey College) grateful thanks are extended on behalf of all participants and members of the Organising Committee. Sincere thanks are also due to Mrs P. Hampton (Heriot-Watt University) and Mrs S. Cuttle (University of Durham) who admirably coped with the secretarial and administrative burdens.

One objective of the Symposium was to provide the opportunity for interaction between two broad trends now discernible in continuum mechanics which respectively emphasise applications and rigorous mathematical analysis. The mutual enrichment of these two developments requires frequent exchange of information and thanks to the right note struck in the formal addresses this certainly occurred at the Durham meeting. Indeed, all contributors are to be commended for ensuring that their presentations were readily accessible to both groups thus helping to further the aims of the organisers. This in turn has resulted in the present volume containing articles which besides being accounts of recent progress should also be of wide interest to the specialist and non-specialist alike.

Edinburgh March 1987 R.J. Knops

A.A. Lacey



LIST OF CONTENTS

PART 1 PRINCIPAL LECTURES	
R. BURRIDGE, G.C. PAPANICOLAOU, P. SHENG and B. WHITE Pulse Reflection by a Random Medium	3
I. MULLER Shape Memory Alloys-Phenomenology and Simulation	2.2
Relativistic Extended Thermodynamics	36
O.A. OLEINIK Spectra of Singularly Perturbed Operators	53
P.J. OLVER Conservation Laws in Continuum Mechanics	96
L.E. PAYNE On Geometric and Modeling Perturbations in Partial Differential Equations	108
L. TARTAR The Appearance of Oscillations in Optimization Problems	129
PART II SINGLE INVITED LECTURES C. ATKINSON, P.S. HAMMOND, M. SHEPPARD and I.J. SOBEY	
Some Mathematical Problems Arising From the Oil Service Industry	153
D.J. BERGMAN Randomly Diluted Inhomogeneous Elastic Networks near the Percolation Threshold	166
S.C. COWIN Adaptive Anisotropy: An Example in Living Bone	174
I. FONSECA Stability of Elastic Crystals	187
G.A. FRANCFORT and F. MURAT Optimal Bounds for Conduction in Two-Dimensional, Two-Phase, Anisotropic Media	197
J.T. JENKINS Rapid Flows of Granular Materials	213
R. KOHN and G. STRANG The Constrained Least Gradient Problem	226



List of contents	viii
E.H. LEE and A. AGAH-TEHRANI The Fusion of Physical and Continuum-Mechanical Concepts in the Formulation of Constitutive Relations for Elastic-Plastic Materials	244
D. LEGUILLON and E. SANCHEZ-PALENCIA Singularities in Elliptic Non-Smooth Problems. Applications to Elasticity	260
G.A. MAUGIN Solitons in Elastic Solids Exhibiting Phase Transitions	272
M. NIEZGODKA and J.SPREKELS On the Dynamics of Structural Phase Transitions in Shape Memory Alloy	284
J.R. RODRIGUES On the Homogenization of Some Free Boundary Problems	303
J. RUBINSTEIN The Point Interaction Approximation, Viscous Flow Through Porous Media, and Related Topics	316
M. SLEMROD The Vanishing Viscosity-Capillarity Approach to The Riemann Problem for a Van Der Waals Fluid	325



LMS SYMPOSIUM ON "NON-CLASSICAL CONTINUUM MECHANICS: ABSTRACT TECHNIQUES AND APPLICATIONS" 2 - 12 JULY, 1986, UNIVERSITY OF DURHAM

LIST OF PARTICIPANTS

ORGANISING COMMITTEE

- Professor R J KNOPS, (Chairman), Department of Mathematics, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS
- Dr A A LACEY, (Secretary), Department of Mathematics, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS
- Professor F M LESLIE, Department of Mathematics, University of Strathclyde, Livingstone Tower, 26 Richmond Street, Glasgow Gl 1XH
- Professor A J M SPENCER, Department of Theoretical Mechanics, University of Nottingham, University Park, Nottingham NG7 2RD
- Professor J R WILLIS, School of Mathematics, University of Bath, Claverton Down, Bath BA2 7AY

KEY SPEAKERS

- Professor I MULLER, Hermann Föttinger-Institut Für Thermo und Fluiddynamik, Technische Universität Berlin, Strasse des 17 June 135, 1000 Berlin 12, West Germany
- Professor O A OLEINIK, Department of Mathematics, University of Moscow, kozp "k" App 133, Moscow B-234, USSR
- Professor P J OLVER, University of Minnesota, 127 Vincent Hall, 206 Church Street SE, Minneapolis, Minnesota 55455, USA
- Professor G C PAPANICOLAOU, Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York NY 10012, USA
- Professor L E PAYNE, Department of Mathematics, White Hall, Cornell University, Ithaca NY 14853, USA
- Professor L TARTAR, Centre d'Etudes de Limeil-Valenton, Service MA, BP 27, 94190 Villeneuve-St-Georges, France

PARTICIPANTS

- Professor L ANAND, Department of Mechanical Engineering, Room 1.130, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge MA 02139, USA
- Dr C ATKINSON, Department of Mathematics, Imperial College, Queen's
 Gate, London SW7 2BZ



List of participants x

- Professor M M AVELLANEDA, Courant Institute, New York University, 251 Mercer Street, New York 10012, USA
- Professor J M BALL, Department of Mathematics, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS
- Professor D J BERGMAN, School of Physics and Astronomy, Tel-Aviv University, Tel-Aviv 69978, Israel.
- Dr J CARR, Department of Mathematics, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS
- Dr M G CLARK, GEC Research, East Lane, Wembley, Middlesex HA9 7PP
- Professor S C COWIN, Department of Biomedical Engineering, Tulane University, New Orleans LA 70018, USA
- Professor E N DANCER, Department of Mathematics, Statistics & Computer Science, University of New England, Armidale, NSW 2351, Australia
- Professor J N FLAVIN, Department of Mathematical Physics, University College, Galway, Ireland
- Professor I FONSECA, Centro de Matematica e Applicacoes Fundamentais, Ave Prof Gama Pinto 2, 1699 (Codex) Portugal
- Professor G A FRANCFORT, Laboratoire Central des Ponts et Chaussees, 58 Bld Lefebvre, 75732 Paris, Cedex 15, France
- Professor A E GREEN, 20 Lakeside, Oxford OX2 8JG
- Dr J M HILL, Department of Mathematics, University of Wollongong, Wollongong, New South Wales, Australia
- Dr S D HOWISON, Mathematical Institute, University of Oxford, 24-29 St Giles, Oxford OX1 3LB
- Professor R JAMES, Department of Aerospace Engineering & Mechanics, 107
 Akerman Hall, University of Minnesota, Minneapolis MN 55455, USA
- Professor J T JENKINS, Department of Theoretical and Applied Mechanics, Thurston Hall, Cornell University, Ithaca, New York 14853, USA
- Professor R V KOHN, Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York 10012, USA
- Professor E H LEE, Department of Mechanical Engineering, Aero Engineering and Mechanics, Rensselaer Polytechnic Institute, Troy, New York 12180, USA
- Professor J H MADDOCKS, Department of Mathematics, University of Maryland, College Park, Maryland 20742, USA



List of participants xi

- Professor G A MAUGIN, Universite Pierre et Marie Curie, Laboratoire de Mecanique Theorique, Tour 66, 4 Place Jussieu, 75230 Paris Cedex 05, France
- Dr G MILTON, Department of Physics, 405-47, California Institute of Technology, Pasadena, CA 91125, USA
- Mr S MULLER, Department of Mathematics, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS
- Professor F MURAT, Laboratoire d'Analyse Numerique, Tour 55-65, Universite Paris VI, 75230 Paris Cedex 05, France
- Professor A NOVICK-COHEN, Department of Mathematical Sciences, Rensselaer Polytechnic Institute, Troy, New York 12180, USA
- Dr J R OCKENDON, Mathematical Institute, University of Oxford, 24-29 St Giles, Oxford OX1 3LB
- Professor R W OGDEN, Department of Mathematics, University of Glasgow, Glasgow G1 8QW
- Professor E T ONAT, Department of Mechanical Engineering, Yale University, Becton Center, PO Box 2157, Yale Station, New Haven, Connecticut 06520, USA
- Dr D F PARKER, Department of Theoretical Mechanics, Nottingham University, Nottingham NG7 2RD
- Dr G P PARRY, School of Mathematics, University of Bath, Claverton Down, Bath BA2 7AY
- Dr R L PEGO, Department of Mathematics, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS
- Professor M RASCLE, Analyse Numerique, Universite de St Etienne, 42023 St Etienne Cedex, France
- Dr J F RODRIGUES, Centro de Matematica e Fundamentais Aplicacoes, Av Prof Gama Pinto 2, 1699 Lisboa Codex, Portugal
- Dr J RUBINSTEIN, Institute for Mathematics and its Applications, University of Minnesota, 514 Vincent Hall, Minneapolis MN 55455, USA
- Professor E SANCHEZ-PALENCIA, Department of Mechanics, Universite Pierre et Marie Curie, 4 Place Jussieu, 75230 Paris, France
- Dr C M SAYERS, School of Mathematics, University of Bath, Claverton Down, Bath BA2 7AY
- Dr M Shillor, Department of Mathematics, Imperial College, Queen's College, London SW7 2BZ



List of participants xii

- Dr J SIVALOGANATHAN, School of Mathematics, University of Bath, Claverton Down, Bath, BA2 7AY
- Professor M SLEMROD, Department of Mathematical Sciences, Rensselaer Polytechnic Institute, Troy, New York 12180-3590, USA
- Professor I N SNEDDON, Department of Mathematics, University of Glasgow, University Gardens, Glasgow G2 8QW
- Professor Dr J SPREKELS, Institute of Mathematics, Universität Augsburg, Memminger Strasse 6, D-8900 Augsburg, West Germany
- Professor G STRANG, Department of Mathematics, Massachusetts Institute of Technologoy, CAmbridge, Massachusetts 02119, USA
- Dr B STRAUGHAN, Department of Mathematics, University of Glasgow, University Gardens, Glasgow G12 8QW
- Dr D R S TALBOT, Department of Mathematics, Coventry (Lanchester),
 Polytechnic, Priory Street, Coventry CV1 5FB
- Dr TANG QI, Department of Mathematics, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS
- Dr A B TAYLER, Mathematical Institute, Oxford University, 24-29 St Giles, Oxford, OX1 3LB
- Professor J F TOLAND, School of Mathematics, University of Bath, Claverton Down, Bath BA2 7AY
- Dr K WALTON, School of Mathematics, University of Bath, Claverton Down, Bath BA2 tAY
- Dr J-R L WEBB, Department of Mathematics, University of Glasgow, Glasgow G12 8QW
- Dr H T WILLIAMS, Department of Mathematics, Heriot-Watt University, Edinburgh EH14 4AS