This book is based on expository lectures by six internationally known experts presented at the 2002 MSRI introductory workshop on commutative algebra. They focus on the interaction of commutative algebra with other areas of mathematics, including algebraic geometry, group cohomology and representation theory, and combinatorics, with all necessary background provided. Short complementary papers describing work at the research frontier are also included. The unusual scope and format make the book invaluable reading for graduate students and researchers interested in commutative algebra and its various uses.

Mathematical Sciences Research Institute Publications

51

Trends in Commutative Algebra

Mathematical Sciences Research Institute Publications

- $1 \quad {\rm Freed/Uhlenbeck:} \ Instantons \ and \ Four-Manifolds, \ {\rm second} \ {\rm edition}$
- 2 Chern (ed.): Seminar on Nonlinear Partial Differential Equations
- 3 Lepowsky/Mandelstam/Singer (eds.): Vertex Operators in Mathematics and Physics
- 4 Kac (ed.): Infinite Dimensional Groups with Applications
- 5 Blackadar: K-Theory for Operator Algebras, second edition
- 6 Moore (ed.): Group Representations, Ergodic Theory, Operator Algebras, and Mathematical Physics
- 7 Chorin/Majda (eds.): Wave Motion: Theory, Modelling, and Computation
- 8 Gersten (ed.): Essays in Group Theory
- 9 Moore/Schochet: Global Analysis on Foliated Spaces
- 10-11 Drasin/Earle/Gehring/Kra/Marden (eds.): Holomorphic Functions and Moduli
- 12-13 Ni/Peletier/Serrin (eds.): Nonlinear Diffusion Equations and Their Equilibrium States
 - 14 Goodman/de la Harpe/Jones: Coxeter Graphs and Towers of Algebras
 - 15 Hochster/Huneke/Sally (eds.): Commutative Algebra
 - 16 Ihara/Ribet/Serre (eds.): Galois Groups over $\mathbb Q$
 - 17 Concus/Finn/Hoffman (eds.): Geometric Analysis and Computer Graphics
 - 18 Bryant/Chern/Gardner/Goldschmidt/Griffiths: Exterior Differential Systems
 - 19 Alperin (ed.): Arboreal Group Theory
 - 20 Dazord/Weinstein (eds.): Symplectic Geometry, Groupoids, and Integrable Systems
 - 21 Moschovakis (ed.): Logic from Computer Science
 - $22 \quad {\rm Ratiu} \ ({\rm ed.}): \ The \ Geometry \ of \ Hamiltonian \ Systems$
 - 23 Baumslag/Miller (eds.): Algorithms and Classification in Combinatorial Group Theory
 - 24 Montgomery/Small (eds.): Noncommutative Rings
 - 25 Akbulut/King: Topology of Real Algebraic Sets
 - 26 Judah/Just/Woodin (eds.): Set Theory of the Continuum
 - 27 Carlsson/Cohen/Hsiang/Jones (eds.): Algebraic Topology and Its Applications
 - 28 Clemens/Kollár (eds.): Current Topics in Complex Algebraic Geometry
 - 29 Nowakowski (ed.): Games of No Chance
 - 30 Grove/Petersen (eds.): Comparison Geometry
 - 31 Levy (ed.): Flavors of Geometry
 - 32 Cecil/Chern (eds.): Tight and Taut Submanifolds
 - 33 Axler/McCarthy/Sarason (eds.): Holomorphic Spaces
 - 34 Ball/Milman (eds.): Convex Geometric Analysis
 - 35 Levy (ed.): The Eightfold Way
 - 36 Gavosto/Krantz/McCallum (eds.): Contemporary Issues in Mathematics Education
 - 37 Schneider/Siu (eds.): Several Complex Variables
 - 38 Billera/Björner/Green/Simion/Stanley (eds.): New Perspectives in Geometric Combinatorics
 - 39 Haskell/Pillay/Steinhorn (eds.): Model Theory, Algebra, and Geometry
 - 40 Bleher/Its (eds.): Random Matrix Models and Their Applications
 - 41 Schneps (ed.): Galois Groups and Fundamental Groups
 - 42 Nowakowski (ed.): More Games of No Chance
 - 43 Montgomery/Schneider (eds.): New Directions in Hopf Algebras
 - 44 Buhler/Stevenhagen (eds.): Algorithmic Number Theory
 - 45 Jensen/Ledet/Yui: Generic Polynomials: Constructive Aspects of the Inverse Galois Problem
 - 46 Rockmore/Healy (eds.): Modern Signal Processing
 - 47 Uhlmann (ed.): Inside Out: Inverse Problems and Applications
 - 48 Gross/Kotiuga: Electromagnetic Theory and Computation: A Topological Approach
 - 49 Darmon/Zhang (eds.): Heegner Points and Rankin L-Series
 - 50 Bao/Bryant/Chern/Shen (eds.): A Sampler of Riemann-Finsler Geometry
 - $51 \quad {\rm Avramov/Green/Huneke/Smith/Sturmfels \ (eds.):} \ Trends \ in \ Commutative \ Algebra$

Volumes 1-4 and 6-27 are published by Springer-Verlag

Trends in Commutative Algebra

 $Edited \ by$

Luchezar L. Avramov University of Nebraska

Mark Green University of California, Los Angeles

> Craig Huneke University of Kansas

Karen E. Smith University of Michigan

Bernd Sturmfels University of California, Berkeley



Luchezar L. Avramov University of Nebraska

Mark Green Univ. of California, Los Angeles

Craig Huneke University of Kansas

Karen E. Smith University of Michigan

Bernd Sturmfels Univ. of California, Berkeley Series Editor Silvio Levy Mathematical Sciences Research Institute 17 Gauss Way Berkeley, CA 94720 United States

MSRI Editorial Committee Hugo Rossi (chair) Alexandre Chorin Silvio Levy Jill Mesirov Robert Osserman Peter Sarnak

The Mathematical Sciences Research Institute wishes to acknowledge support by the National Science Foundation. This material is based upon work supported by NSF Grant 9810361.

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE The Pitt Building, Trumpington Street, Cambridge, United Kingdom

> CAMBRIDGE UNIVERSITY PRESS The Edinburgh Building, Cambridge CB2 2RU, UK 40 West 20th Street, New York, NY 10011-4211, USA 477 Williamstown Road, Port Melbourne, VIC 3207, Australia Ruiz de Alarcón 13, 28014 Madrid, Spain Dock House, The Waterfront, Cape Town 8001, South Africa

> > http://www.cambridge.org

© Mathematical Sciences Research Institute 2004

First published 2004

Printed in the United States of America

A catalogue record for this book is available from the British Library.

Library of Congress Cataloging in Publication data

Trends in commutative algebra / edited by Luchezar L. Avramov ... [et al.].

p. cm.

(Mathematical Sciences Research Institute publications ; 51) Includes bibliographical references and index. ISBN 0-521-83195-4 (hb)

1. Commutative algebra. I. Avramov, L. L. (Luchezar L.), 1948-

II. Title. III. Series.

QA251.3.T74 2005 512'.44-dc22 2004022712

ISBN 0521831954hardback