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# Online Library Algebraic Geometry A Problem Solving Approach Student Mathematical Library

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## ETD4GG - ANDREWS BRAEDON

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This ACM volume deals with tackling problems that can be represented by data structures which are essentially matrices with polynomial entries, mediated by the disciplines of commutative algebra and algebraic geometry. The discoveries stem from an interdisciplinary branch of research which has been growing steadily over the past decade. The author covers a wide range, from showing how to obtain deep heuristics in a computation of a ring, a module or a morphism, to developing means of solving nonlinear systems of equations - highlighting the use of advanced techniques to bring down the cost of computation. Although intended for advanced students and researchers with interests both in algebra and computation, many parts may be read by anyone with a basic abstract algebra course.

An introduction to abstract algebraic geometry, with the only prerequisites being results from commutative algebra, which are stated as needed, and some elementary topology. More than 400 exercises distributed throughout the book offer specific examples as well as more specialised topics not treated in the main text, while three appendices present brief accounts of some areas of current research. This book can thus be used as textbook for an introductory course in algebraic geometry following a basic graduate course in algebra. Robin Hartshorne studied algebraic geometry with Oscar Zariski and David Mumford at Harvard, and with J.-P. Serre and A. Grothendieck in Paris. He is the author of "Residues and Duality", "Foundations of Projective Geometry", "Ample Subvarieties of Algebraic Varieties", and numerous research titles.

Fill in any gaps in your knowledge with this overview of key topics

in undergraduate mathematics, now with four new chapters.

Algebraic Geometry has been at the center of much of mathematics for hundreds of years. It is not an easy field to break into, despite its humble beginnings in the study of circles, ellipses, hyperbolas, and parabolas. This text consists of a series of ex

This text covers topics in algebraic geometry and commutative algebra with a strong perspective toward practical and computational aspects. The first four chapters form the core of the book. A comprehensive chart in the Preface illustrates a variety of ways to proceed with the material once these chapters are covered. In addition to the fundamentals of algebraic geometry—the elimination theorem, the extension theorem, the closure theorem and the Nullstellensatz—this new edition incorporates several substantial changes, all of which are listed in the Preface. The largest revision incorporates a new Chapter (ten), which presents some of the essentials of progress made over the last decades in computing Gröbner bases. The book also includes current computer algebra material in Appendix C and updated independent projects (Appendix D). The book may serve as a first or second course in undergraduate abstract algebra and with some supplementation perhaps, for beginning graduate level courses in algebraic geometry or computational algebra. Prerequisites for the reader include linear algebra and a proof-oriented course. It is assumed that the reader has access to a computer algebra system. Appendix C describes features of Maple™, Mathematica® and Sage, as well as other systems that are most relevant to the text. Pseudocode is used in the text; Appendix B carefully describes the pseudocode used. From the reviews of previous editions: "...The book gives an

introduction to Buchberger's algorithm with applications to syzygies, Hilbert polynomials, primary decompositions. There is an introduction to classical algebraic geometry with applications to the ideal membership problem, solving polynomial equations and elimination theory. ...The book is well-written. ...The reviewer is sure that it will be an excellent guide to introduce further undergraduates in the algorithmic aspect of commutative algebra and algebraic geometry." —Peter Schenzel, zbMATH, 2007 "I consider the book to be wonderful. ... The exposition is very clear, there are many helpful pictures and there are a great many instructive exercises, some quite challenging ... offers the heart and soul of modern commutative and algebraic geometry." —The American Mathematical Monthly

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Challenge III Series (preparing for AIME, ZIML Varsity, or equivalent contests) Math Challenge IV Series (Math Olympiad level problem solving) These courses are designed and developed by educational experts and industry professionals to bring real world applications into the STEM education. These programs are ideal for students who wish to win in Math Competitions (AMC, AIME, USAMO, IMO, ARML, MathCounts, Math League, Math Olympiad, ZIML, etc.), Science Fairs (County Science Fairs, State Science Fairs, national programs like Intel Science and Engineering Fair, etc.) and Science Olympiad, or purely want to enrich their academic lives by taking more challenges and developing outstanding analytical, logical thinking and creative problem solving skills. Math Challenge I-C is a four-part course designed to bridge the middle school and high school math materials. For students who participate in the American Math Competitions (AMC), there is a big gap in both the fundamental math concepts and the problem-solving techniques involved between the AMC 8 and AMC 10 contests. This course is developed to help students transition smoothly from middle school to high school, and prepare them for high school math competitions including the AMC 10 & 12, ARML, and ZIML. The full course covers topics and introductory problem solving in algebra, geometry, and finite math. Algebraic topics include linear equations, systems of equations and inequalities, exponents and radicals, factoring polynomials, and solving quadratic equations. Geometric topics include angles in triangles, quadrilaterals, and polygons, congruent and similar polygons, calculating area, and algebraic geometry. Topics in finite math include logic, introductory number theory, and an introduction to probability and statistics. These topics serve as the fundamental knowledge needed for a more advanced problem solving course such as Math Challenge II-A. The course is divided into four terms: Summer, covering Algebra Fall, covering covering additional topics in Algebra Winter, covering Geometry Spring, covering Finite Math The book contains course materials for Math Challenge I-C: Additional topics in Algebra. We recommend that students take all four terms starting with the Summer, but students with the required background are welcome to join for later terms in the course, or select suitable terms for self-paced study. Students can sign up for the course at <https://classes.arteem.org> for the live online version or at <https://www.edurila.com> for the self-paced version.

This book is a unique collection of challenging geometry problems and detailed solutions that will build students' confidence in mathematics. By proposing several methods to approach each problem and emphasizing geometry's connections with different fields of mathematics, *Methods of Solving Complex Geometry Problems* serves as a bridge to more advanced problem solving. Written by an accomplished female mathematician who struggled with geometry as a child, it does not intimidate, but instead fosters the reader's ability to solve math problems through the direct application of theorems. Containing over 160 complex problems with hints and detailed solutions, *Methods of Solving Complex Geometry Problems* can be used as a self-study guide for mathematics competitions and for improving problem-solving skills in courses on plane geometry or the history of mathematics. It contains important and sometimes overlooked topics on triangles, quadrilaterals, and circles such as the Menelaus-Ceva theorem, Simon's line, Heron's formula, and the theorems of the three altitudes and medians. It can also be used by professors as a resource to stimulate the abstract thinking required to transcend the tedious and routine, bringing forth the original thought of which their students are capable. *Methods of Solving Complex Geometry Problems* will interest high school and college students needing to prepare for exams and competitions, as well as anyone who enjoys an intellectual challenge and has a special love of geometry. It will also appeal to instructors of geometry, history of mathematics, and math education courses.

This work has been selected by scholars as being culturally important and is part of the knowledge base of civilization as we know it. This work is in the public domain in the United States of America, and possibly other nations. Within the United States, you may freely copy and distribute this work, as no entity (individual or corporate) has a copyright on the body of the work. Scholars believe, and we concur, that this work is important enough to be preserved, reproduced, and made generally available to the public. To ensure a quality reading experience, this work has been proofread and republished using a format that seamlessly blends the original graphical elements with text in an easy-to-read typeface. We appreciate your support of the preservation process, and thank you for being an important part of keeping this knowledge alive and relevant.

Algorithmic and quantitative aspects in real algebraic geometry

are becoming increasingly important areas of research because of their roles in other areas of mathematics and computer science. The papers in this volume collectively span several different areas of current research. The articles are based on talks given at the DIMACS Workshop on "Algorithmic and Quantitative Aspects of Real Algebraic Geometry". Topics include deciding basic algebraic properties of real semi-algebraic sets, application of quantitative results in real algebraic geometry towards investigating the computational complexity of various problems, algorithmic and quantitative questions in real enumerative geometry, new approaches towards solving decision problems in semi-algebraic geometry, as well as computing algebraic certificates, and applications of real algebraic geometry to concrete problems arising in robotics and computer graphics. The book is intended for researchers interested in computational methods in algebra.

Algebraic geometry has benefited enormously from the powerful general machinery developed in the latter half of the twentieth century. The cost has been that much of the research of previous generations is in a language unintelligible to modern workers, in particular, the rich legacy of classical algebraic geometry, such as plane algebraic curves of low degree, special algebraic surfaces, theta functions, Cremona transformations, the theory of apolarity and the geometry of lines in projective spaces. The author's contemporary approach makes this legacy accessible to modern algebraic geometers and to others who are interested in applying classical results. The vast bibliography of over 600 references is complemented by an array of exercises that extend or exemplify results given in the book.

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This book presents algorithmic tools for algebraic geometry, with experimental applications. It also introduces Macaulay 2, a computer algebra system supporting research in algebraic geometry, commutative algebra, and their applications. The algorithmic tools presented here are designed to serve readers wishing to bring such tools to bear on their own problems. The first part of the book covers Macaulay 2 using concrete applications; the second emphasizes details of the mathematics.

Algorithms in algebraic geometry go hand in hand with software packages that implement them. Together they have established the modern field of computational algebraic geometry which has come to play a major role in both theoretical advances and applications. Over the past fifteen years, several excellent general purpose packages for computations in algebraic geometry have been developed, such as, CoCoA, Singular and Macaulay 2. While these packages evolve continuously, incorporating new mathematical advances, they both motivate and demand the creation of new mathematics and smarter algorithms. This volume reflects the workshop "Software for Algebraic Geometry" held in the week from 23 to 27 October 2006, as the second workshop in the thematic year on Applications of Algebraic Geometry at the IMA. The papers in this volume describe the software packages Bertini, PH-Clab, Gfan, DEMiCs, SYNAPS, TrIm, Gambit, ApaTools, and the application of Risa/Asir to a conjecture on multiple zeta values. They offer the reader a broad view of current trends in computational algebraic geometry through software development and applications.

In this first-ever graduate textbook on the algorithmic aspects of real algebraic geometry, the main ideas and techniques presented form a coherent and rich body of knowledge, linked to many areas of mathematics and computing. Mathematicians already aware of real algebraic geometry will find relevant information about the algorithmic aspects. Researchers in computer science and engineering will find the required mathematical background. This self-contained book is accessible to graduate and undergraduate students.

Excerpt from a review in the "Mathematics Teacher." A Mathematical Mosaic is a collection of wonderful topics from number theory through combinatorics to game theory, presented in a fashion that seventh- and eighth- grade students can handle yet high

school students will find challenging." John Cocharo, Saint Mark's School of Texas, Dallas, TX

This book is a guide to concepts and practice in numerical algebraic geometry ? the solution of systems of polynomial equations by numerical methods. Through numerous examples, the authors show how to apply the well-received and widely used open-source Bertini software package to compute solutions, including a detailed manual on syntax and usage options. The authors also maintain a complementary web page where readers can find supplementary materials and Bertini input files. Numerically Solving Polynomial Systems with Bertini approaches numerical algebraic geometry from a user's point of view with numerous examples of how Bertini is applicable to polynomial systems. It treats the fundamental task of solving a given polynomial system and describes the latest advances in the field, including algorithms for intersecting and projecting algebraic sets, methods for treating singular sets, the nascent field of real numerical algebraic geometry, and applications to large polynomial systems arising from differential equations. Those who wish to solve polynomial systems can start gently by finding isolated solutions to small systems, advance rapidly to using algorithms for finding positive-dimensional solution sets (curves, surfaces, etc.), and learn how to use parallel computers on large problems. These techniques are of interest to engineers and scientists in fields where polynomial equations arise, including robotics, control theory, economics, physics, numerical PDEs, and computational chemistry.

Based on lectures given at an advanced course on integrable systems at the Centre de Recerca Matemàtica in Barcelona, these lecture notes address three major aspects of integrable systems: obstructions to integrability from differential Galois theory; the description of singularities of integrable systems on the basis of their relation to bi-Hamiltonian systems; and the generalization of integrable systems to the non-Hamiltonian settings. All three sections were written by top experts in their respective fields. Native to actual problem-solving challenges in mechanics, the topic of integrable systems is currently at the crossroads of several disciplines in pure and applied mathematics, and also has important interactions with physics. The study of integrable systems also actively employs methods from differential geometry. Moreover, it is extremely important in symplectic geometry and Hamiltonian dynamics, and has strong correlations with mathematical physics,



Lie theory and algebraic geometry (including mirror symmetry). As such, the book will appeal to experts with a wide range of backgrounds.

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Polyhedral and Algebraic Methods in Computational Geometry provides a thorough introduction into algorithmic geometry and its applications. It presents its primary topics from the viewpoints of discrete, convex and elementary algebraic geometry. The first part of the book studies classical problems and techniques that refer to polyhedral structures. The authors include a study on algorithms for computing convex hulls as well as the construction of Voronoi diagrams and Delone triangulations. The second part of the book develops the primary concepts of (non-linear) computational algebraic geometry. Here, the book looks at Gröbner bases and solving systems of polynomial equations. The theory is illustrated by applications in computer graphics, curve reconstruction

and robotics. Throughout the book, interconnections between computational geometry and other disciplines (such as algebraic geometry, optimization and numerical mathematics) are established. Polyhedral and Algebraic Methods in Computational Geometry is directed towards advanced undergraduates in mathematics and computer science, as well as towards engineering students who are interested in the applications of computational geometry.

A classic problem in mathematics is solving systems of polynomial equations in several unknowns. Today, polynomial models are ubiquitous and widely used across the sciences. They arise in robotics, coding theory, optimization, mathematical biology, computer vision, game theory, statistics, and numerous other areas. This book furnishes a bridge across mathematical disciplines and exposes many facets of systems of polynomial equations. It covers a wide spectrum of mathematical techniques and algorithms, both symbolic and numerical. The set of solutions to a system of polynomial equations is an algebraic variety—the basic object of algebraic geometry. The algorithmic study of algebraic varieties is the central theme of computational algebraic geometry. Exciting recent developments in computer software for geometric calculations have revolutionized the field. Formerly inaccessible problems are now tractable, providing fertile ground for experimentation and conjecture. The first half of the book gives a snapshot of the state of the art of the topic. Familiar themes are covered in the first five chapters, including polynomials in one variable, Gröbner bases of zero-dimensional ideals, Newton polytopes and Bernstein's Theorem, multidimensional resultants, and primary decomposition. The second half of the book explores polynomial equations from a variety of novel and unexpected angles. It introduces interdisciplinary connections, discusses highlights of current research, and outlines possible future algorithms. Topics include computation of Nash equilibria in game theory, semidefinite programming and the real Nullstellensatz, the algebraic geometry of statistical models, the piecewise-linear geometry of valuations and amoebas, and the Ehrenpreis-Palamodov theorem on linear partial differential equations with constant coefficients. Throughout the text, there are many hands-on examples and exercises, including short but complete sessions in MapleR, MATLABR, Macaulay 2, Singular, PHCpack, CoCoA, and SOSTools. These examples will be particularly useful for readers with no back-

ground in algebraic geometry or commutative algebra. Within minutes, readers can learn how to type in polynomial equations and actually see some meaningful results on their computer screens. Prerequisites include basic abstract and computational algebra. The book is designed as a text for a graduate course in computational algebra. R Waterloo Maple, Inc., Ontario, Canada. R MATLAB, The MathWorks, Inc., Natick, MA. Singular is a free software distributed under the GNU license. cDepartment of Mathematics, and Centre for Computer Algebra, University of Kaiserslautern, Germany. Macaulay 2, c Daniel R. Grayson and Michael E. Stillman (1993-2001) and is distributed under the GNU license. PHCpack c1998, Katholieke Universiteit Leuven, Department of Computer Science, Heverlee, Belgium. CoCoA, A. Capani, G. Niesi, L. Robbiano, a system for doing Computations in Commutative Algebra, available via anonymous ftp from: <http://cocoa.dima.unige.it>. SOS-Tools is a MATLABR toolbox and freely available under the GNU license at <http://www.cds.caltech.edu/sostools> or <http://www.aut.ee.ethz.ch/> Maxwell's equations have led to many important mathematical discoveries. This text introduces mathematics students to some of their wonders.

Interest in the study of geometry is currently enjoying a resurgence—understandably so, as the study of curves was once the playground of some very great mathematicians. However, many of the subject's more exciting aspects require a somewhat advanced mathematics background. For the "fun stuff" to be accessible, we need to offer students an introduction with modest prerequisites, one that stimulates their interest and focuses on problem solving. Integrating parametric, algebraic, and projective curves into a single text, *Geometry of Curves* offers students a unique approach that provides a mathematical structure for solving problems, not just a catalog of theorems. The author begins with the basics, then takes students on a fascinating journey from conics, higher algebraic and transcendental curves, through the properties of parametric curves, the classification of limaçons, envelopes, and finally to projective curves, their relationship to algebraic curves, and their application to asymptotes and boundedness. The uniqueness of this treatment lies in its integration of the different types of curves, its use of analytic methods, and its generous number of examples, exercises, and illustrations. The result is a practical text, almost entirely self-contained, that not on-

ly imparts a deeper understanding of the theory, but inspires a heightened appreciation of geometry and interest in more advanced studies.

Written at a level appropriate to undergraduates, this book covers such topics as the Hilbert Basis Theorem, the Nullstellensatz, invariant theory, projective geometry, and dimension theory. Contains a new section on Axiom and an update about MAPLE, Mathematica and REDUCE.

Algebraic geometry, central to pure mathematics, has important applications in such fields as engineering, computer science, statistics and computational biology, which exploit the computational algorithms that the theory provides. Users get the full benefit, however, when they know something of the underlying theory, as well as basic procedures and facts. This book is a systematic introduction to the central concepts of algebraic geometry most useful for computation. Written for advanced undergraduate and graduate students in mathematics and researchers in application areas, it focuses on specific examples and restricts development of formalism to what is needed to address these examples. In particular, it introduces the notion of Gröbner bases early on and develops algorithms for almost everything covered. It is based on courses given over the past five years in a large interdisciplinary programme in computational algebraic geometry at Rice University, spanning mathematics, computer science, biomathematics and bioinformatics.

Sure to be influential, Watanabe's book lays the foundations for the use of algebraic geometry in statistical learning theory. Many models/machines are singular: mixture models, neural networks, HMMs, Bayesian networks, stochastic context-free grammars are major examples. The theory achieved here underpins accurate estimation techniques in the presence of singularities.

This textbook covers topics of undergraduate mathematics in abstract algebra, geometry, topology and analysis with the purpose of connecting the underpinning key ideas. It guides STEM students towards developing knowledge and skills to enrich their scientific education. In doing so it avoids the common mechanical approach to problem-solving based on the repetitive application of dry formulas. The presentation preserves the mathematical rigour throughout and still stays accessible to undergraduates. The didactical focus is threaded through the assortment of subjects and reflects in the book's structure. Part 1 introduces the mathemati-

cal language and its rules together with the basic building blocks. Part 2 discusses the number systems of common practice, while the backgrounds needed to solve equations and inequalities are developed in Part 3. Part 4 breaks down the traditional, outdated barriers between areas, exploring in particular the interplay between algebra and geometry. Two appendices form Part 5: the Greek etymology of frequent terms and a list of mathematicians mentioned in the book. Abundant examples and exercises are disseminated along the text to boost the learning process and allow for independent work. Students will find invaluable material to shepherd them through the first years of an undergraduate course, or to complement previously learnt subject matters. Teachers may pickmix the contents for planning lecture courses or supplementing their classes.

This book provides a quick access to computational tools for algebraic geometry, the mathematical discipline which handles solution sets of polynomial equations. Originating from a number of intense one week schools taught by the authors, the text is designed so as to provide a step by step introduction which enables the reader to get started with his own computational experiments right away. The authors present the basic concepts and ideas in a compact way.

This book is a true introduction to the basic concepts and techniques of algebraic geometry. The language is purposefully kept on an elementary level, avoiding sheaf theory and cohomology theory. The introduction of new algebraic concepts is always motivated by a discussion of the corresponding geometric ideas. The main point of the book is to illustrate the interplay between abstract theory and specific examples. The book contains numerous problems that illustrate the general theory. The text is suitable for advanced undergraduates and beginning graduate students. It contains sufficient material for a one-semester course. The reader should be familiar with the basic concepts of modern algebra. A course in one complex variable would be helpful, but is not necessary.

On Lack of Effectiveness in Semi-algebraic Geometry.- A simple constructive proof of Canonical Resolution of Singularities.- Local Membership Problems for Polynomial Ideals.- Un Algorithme pour le Calcul des Résultants.- On algorithms for real algebraic plane curves.- Duality methods for the membership problem.- Exemples d'ensembles de Points en Position Uniforme.- Efficient Algorithms

and Bounds for Wu-Ritt Characteristic Sets.- Noetherian Properties and Growth of some Associative Algebras.- Codes and Elliptic Curves.- Algorithmes - disons rapides - pour la décomposition d'une variété algébrique en composantes irréductibles et équidimensionnelles.- Complexity of Solving Systems of Linear Equations over the Rings of Differential Operators.- Membership problem, Representation problem and the Computation of the Radical for one-dimensional Ideals.- On the Complexity of Zero-dimensional Algebraic Systems.- A Single Exponential Bound on the Complexity of Computing Gröbner Bases of Zero Dimensional Ideals.- Algorithms for a Multiple Algebraic Extension.- Elementary constructive theory of ordered fields.- Effective real Nullstellensatz and variants.- Algorithms for the Solution of Systems of Linear Equations in Commutative Rings.- Une conjecture sur les anneaux de Chow  $A(G, ?)$  renforcée par un calcul formel.- Construction de courbes de genre 2 à partir de leurs modules.- Computing Syzygies à la Gau?-Jordan.- The non-scalar Model of Complexity in Computational Geometry.- Géométrie et Interpretations Génériques, un Algorithme.- Canonical Bases: Relations with Standard Bases, Finiteness Conditions and Application to Tame Automorphisms.- The tangent cone algorithm and some applications to local algebraic geometry.- Effective Methods for Systems of Algebraic Partial Differential Equations.- Finding roots of equations involving functions defined by first order algebraic differential equations.- Some Effective Methods in the Openness of Loci for Cohen-Macaulay and Gorenstein Properties.- Sign determination on zero dimensional sets.- A Classification of Finite-dimensional Monomial Algebras.- An algorithm related to compactifications of adjoint groups.- Deciding Consistency of Systems of Polynomial in Exponent Inequalities in Subexponential Time.

"Analytic and algebraic geometers often study the same geometric structures but bring different methods to bear on them. While this dual approach has been spectacularly successful at solving problems, the language differences between algebra and analysis also represent a difficulty for students and researchers in geometry, particularly complex geometry. The PCMI program was designed to partially address this language gulf, by presenting some of the active developments in algebraic and analytic geometry in a form suitable for students on the 'other side' of the analysis-algebra language divide. One focal point of the summer school was multiplier ideals, a subject of wide current interest in both sub-

jects. The present volume is based on a series of lectures at the PCMI summer school on analytic and algebraic geometry. The series is designed to give a high-level introduction to the advanced techniques behind some recent developments in algebraic and analytic geometry. The lectures contain many illustrative examples, detailed computations, and new perspectives on the topics presented, in order to enhance access of this material to non-specialists."--Publisher's description.

This book gathers twenty-two papers presented at the second NLAGA-BIRS Symposium, which was held at Cap Skirring and at the Assane Seck University in Ziguinchor, Senegal, on January 25-30, 2022. The five-day symposium brought together African experts on nonlinear analysis and geometry and their applications, as well as their international partners, to present and discuss mathematical results in various areas. The main goal of the NLAGA project is to advance and consolidate the development of these mathematical fields in West and Central Africa with a focus on solving real-world problems such as coastal erosion, pollution, and urban network and population dynamics problems. The book addresses a range of topics related to partial differential equations, geometric analysis, geometric structures, dynamics, optimization, inverse problems, complex analysis, algebra, algebraic geometry, control theory, stochastic approximations, and modelling.

This book develops the Weyr matrix canonical form, a largely unknown cousin of the Jordan form. It explores novel applications, including include matrix commutativity problems, approximate simultaneous diagonalization, and algebraic geometry. Module theory and algebraic geometry are employed but with self-contained accounts.

Through its engaging and unusual problems, this book demonstrates methods of reasoning necessary for learning number theory. Every technique is followed by problems (as well as detailed hints and solutions) that apply theorems immediately, so readers can solve a variety of abstract problems in a systematic, creative manner. New solutions often require the ingenious use of earlier mathematical concepts - not the memorization of formulas and facts. Questions also often permit experimental numeric validation or visual interpretation to encourage the combined use of deductive and intuitive thinking. The first chapter starts with simple topics like even and odd numbers, divisibility, and prime numbers and helps the reader to solve quite complex, Olympiad-type



problems right away. It also covers properties of the perfect, amicable, and figurate numbers and introduces congruence. The next chapter begins with the Euclidean algorithm, explores the representations of integer numbers in different bases, and examines continued fractions, quadratic irrationalities, and the Lagrange Theorem. The last section of Chapter Two is an exploration of different methods of proofs. The third chapter is dedicated to solving Diophantine linear and nonlinear equations and includes different methods of solving Fermat's (Pell's) equations. It also covers Fermat's factorization techniques and methods of solving challenging problems involving exponent and factorials. Chapter Four reviews the Pythagorean triple and quadruple and emphasizes their connection with geometry, trigonometry, algebraic geometry, and stereographic projection. A special case of Waring's problem as a representation of a number by the sum of the squares or cubes of other numbers is covered, as well as quadratic residuals, Legendre and Jacobi symbols, and interesting word problems related to the properties of numbers. Appendices provide a historic overview of number theory and its main developments from the ancient cultures in Greece, Babylon, and Egypt to the modern day. Drawing from cases collected by an accomplished female mathematician, *Methods in Solving Number Theory Problems* is designed as a self-study guide or supplementary

textbook for a one-semester course in introductory number theory. It can also be used to prepare for mathematical Olympiads. Elementary algebra, arithmetic and some calculus knowledge are the only prerequisites. Number theory gives precise proofs and theorems of an irreproachable rigor and sharpens analytical thinking, which makes this book perfect for anyone looking to build their mathematical confidence.

An illustration of the many uses of algebraic geometry, highlighting the more recent applications of Groebner bases and resultants. Along the way, the authors provide an introduction to some algebraic objects and techniques more advanced than typically encountered in a first course. The book is accessible to non-specialists and to readers with a diverse range of backgrounds, assuming readers know the material covered in standard undergraduate courses, including abstract algebra. But because the text is intended for beginning graduate students, it does not require graduate algebra, and in particular, does not assume that the reader is familiar with modules.

This book provides a general introduction to modern mathematical aspects in computing with multivariate polynomials and in solving algebraic systems. It presents the state of the art in several symbolic, numeric, and symbolic-numeric techniques, including effective and algorithmic methods in algebraic geometry and com-

putational algebra, complexity issues, and applications ranging from statistics and geometric modelling to robotics and vision. Graduate students, as well as researchers in related areas, will find an excellent introduction to currently interesting topics. These cover Groebner and border bases, multivariate resultants, residues, primary decomposition, multivariate polynomial factorization, homotopy continuation, complexity issues, and their applications.

John Vince explains a wide range of mathematical techniques and problem-solving strategies associated with computer games, computer animation, virtual reality, CAD, and other areas of computer graphics. Covering all the mathematical techniques required to resolve geometric problems and design computer programs for computer graphic applications, each chapter explores a specific mathematical topic prior to moving forward into the more advanced areas of matrix transforms, 3D curves and surface patches. Problem-solving techniques using vector analysis and geometric algebra are also discussed. All the key areas are covered including: Numbers, Algebra, Trigonometry, Coordinate geometry, Transforms, Vectors, Curves and surfaces, Barycentric coordinates, Analytic geometry. Plus – and unusually in a student textbook – a chapter on geometric algebra is included.