

Commutative Algebra Exercises Solutions

Originally published in 1985, this classic textbook is an English translation of *Einführung in die kommutative Algebra und algebraische Geometrie*. As part of the Modern Birkhäuser Classics series, the publisher is proud to make *Introduction to Commutative Algebra and Algebraic Geometry* available to a wider audience. Aimed at students who have taken a basic course in algebra, the goal of the text is to present important results concerning the representation of algebraic varieties as intersections of the least possible number of hypersurfaces and—a closely related problem—with the most economical generation of ideals in Noetherian rings. Along the way, one encounters many basic concepts of commutative algebra and algebraic geometry and proves many facts which can then serve as a basic stock for a deeper study of these subjects.

These lecture notes provide a self-contained introduction to a wide range of generalizations of Hopf algebras. Multiplication of their modules is described by replacing the category of vector spaces with more general monoidal categories, thereby extending the range of applications. Since Sweedler's work in the 1960s, Hopf algebras have earned a noble place in the garden of mathematical structures. Their use is well accepted in fundamental areas such as algebraic geometry, representation theory, algebraic topology, and combinatorics. Now, similar to having moved from groups to groupoids, it is becoming clear that generalizations of Hopf algebras must also be

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considered. This book offers a unified description of Hopf algebras and their generalizations from a category theoretical point of view. The author applies the theory of liftings to Eilenberg–Moore categories to translate the axioms of each considered variant of a bialgebra (or Hopf algebra) to a bimonad (or Hopf monad) structure on a suitable functor. Covered structures include bialgebroids over arbitrary algebras, in particular weak bialgebras, and bimonoids in duoidal categories, such as bialgebras over commutative rings, semi-Hopf group algebras, small categories, and categories enriched in coalgebras. Graduate students and researchers in algebra and category theory will find this book particularly useful. Including a wide range of illustrative examples, numerous exercises, and completely worked solutions, it is suitable for self-study.

Problem-solving is an art central to understanding and ability in mathematics. With this series of books, the authors have provided a selection of worked examples, problems with complete solutions and test papers designed to be used with or instead of standard textbooks on algebra. For the convenience of the reader, a key explaining how the present books may be used in conjunction with some of the major textbooks is included. Each volume is divided into sections that begin with some notes on notation and prerequisites. The majority of the material is aimed at the students of average ability but some sections contain more challenging problems. By working through the books, the student will gain a deeper understanding of the fundamental concepts

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involved, and practice in the formulation, and so solution, of other problems. Books later in the series cover material at a more advanced level than the earlier titles, although each is, within its own limits, self-contained.

Algebraic geometry is a fascinating branch of mathematics that combines methods from both, algebra and geometry. It transcends the limited scope of pure algebra by means of geometric construction principles. Moreover, Grothendieck's schemes invented in the late 1950s allowed the application of algebraic-geometric methods in fields that formerly seemed to be far away from geometry, like algebraic number theory. The new techniques paved the way to spectacular progress such as the proof of Fermat's Last Theorem by Wiles and Taylor. The scheme-theoretic approach to algebraic geometry is explained for non-experts. More advanced readers can use the book to broaden their view on the subject. A separate part deals with the necessary prerequisites from commutative algebra. On a whole, the book provides a very accessible and self-contained introduction to algebraic geometry, up to a quite advanced level. Every chapter of the book is preceded by a motivating introduction with an informal discussion of the contents. Typical examples and an abundance of exercises illustrate each section. This way the book is an excellent solution for learning by yourself or for complementing knowledge that is already present. It can equally be used as a convenient source for courses and seminars or as supplemental literature.

Modern theory of rational and nearly rational varieties. Many problems with solutions

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make it ideal for graduate courses.

Designed for an advanced undergraduate- or graduate-level course, *Abstract Algebra* provides an example-oriented, less heavily symbolic approach to abstract algebra. The text emphasizes specifics such as basic number theory, polynomials, finite fields, as well as linear and multilinear algebra. This classroom-tested, how-to manual takes a more narrative approach than the stiff formalism of many other textbooks, presenting coherent storylines to convey crucial ideas in a student-friendly, accessible manner. An unusual feature of the text is the systematic characterization of objects by universal mapping properties, rather than by constructions whose technical details are irrelevant.

Addresses Common Curricular Weaknesses In addition to standard introductory material on the subject, such as Lagrange's and Sylow's theorems in group theory, the text provides important specific illustrations of general theory, discussing in detail finite fields, cyclotomic polynomials, and cyclotomic fields. The book also focuses on broader background, including brief but representative discussions of naive set theory and equivalents of the axiom of choice, quadratic reciprocity, Dirichlet's theorem on primes in arithmetic progressions, and some basic complex analysis. Numerous worked examples and exercises throughout facilitate a thorough understanding of the material. This substantially enlarged second edition aims to lead a further stage in the computational revolution in commutative algebra. This is the first handbook/tutorial to extensively deal with SINGULAR. Among the book's most distinctive features is a new,

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completely unified treatment of the global and local theories. Another feature of the book is its breadth of coverage of theoretical topics in the portions of commutative algebra closest to algebraic geometry, with algorithmic treatments of almost every topic. This book can be understood as a model for teaching commutative algebra, and takes into account modern developments such as algorithmic and computational aspects. As soon as a new concept is introduced, the authors show how the concept can be worked on using a computer. The computations are exemplified with the computer algebra system Singular, developed by the authors. Singular is a special system for polynomial computation with many features for global as well as for local commutative algebra and algebraic geometry. The book includes a CD containing Singular as well as the examples and procedures explained in the book.

This book contains exercises and solutions that can be used for independent study or in creating a challenging and stimulating environment that encourages active engagement in the learning process. The coverage includes topics of special interest and relevance in statistics and related disciplines, as well as standard topics. The book can be of value to both teachers and students. The requisite background is some previous exposure to matrix algebra of the kind obtained in a first course.

Commutative algebra, combinatorics, and algebraic geometry are thriving areas

of mathematical research with a rich history of interaction. *Connections Between Algebra and Geometry* contains lecture notes, along with exercises and solutions, from the Workshop on Connections Between Algebra and Geometry held at the University of Regina from May 29-June 1, 2012. It also contains research and survey papers from academics invited to participate in the companion Special Session on Interactions Between Algebraic Geometry and Commutative Algebra, which was part of the CMS Summer Meeting at the University of Regina held June 2–3, 2012, and the meeting Further Connections Between Algebra and Geometry, which was held at the North Dakota State University February 23, 2013. This volume highlights three mini-courses in the areas of commutative algebra and algebraic geometry: differential graded commutative algebra, secant varieties, and fat points and symbolic powers. It will serve as a useful resource for graduate students and researchers who wish to expand their knowledge of commutative algebra, algebraic geometry, combinatorics, and the intricacies of their intersection.

The American Mathematical Monthly recommended this advanced undergraduate-level text for teacher education. It starts with groups, rings, fields, and polynomials and advances to Galois theory, radicals and roots of unity, and solution by radicals. Numerous examples, illustrations, commentaries, and

exercises enhance the text, along with 13 appendices. 1971 edition. This English translation of Daniel Coray's original French textbook *Notes de géométrie et d'arithmétique* introduces students to Diophantine geometry. It engages the reader with concrete and interesting problems using the language of classical geometry, setting aside all but the most essential ideas from algebraic geometry and commutative algebra. Readers are invited to discover rational points on varieties through an appealing 'hands on' approach that offers a pathway toward active research in arithmetic geometry. Along the way, the reader encounters the state of the art on solving certain classes of polynomial equations with beautiful geometric realizations, and travels a unique ascent towards variations on the Hasse Principle. Highlighting the importance of Diophantus of Alexandria as a precursor to the study of arithmetic over the rational numbers, this textbook introduces basic notions with an emphasis on Hilbert's Nullstellensatz over an arbitrary field. A digression on Euclidian rings is followed by a thorough study of the arithmetic theory of cubic surfaces. Subsequent chapters are devoted to p -adic fields, the Hasse principle, and the subtle notion of Diophantine dimension of fields. All chapters contain exercises, with hints or complete solutions. *Notes on Geometry and Arithmetic* will appeal to a wide readership, ranging from graduate students through to researchers.

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Assuming only a basic background in abstract algebra and number theory, the text uses Diophantine questions to motivate readers seeking an accessible pathway into arithmetic geometry.

This book is an expanded text for a graduate course in commutative algebra, focusing on the algebraic underpinnings of algebraic geometry and of number theory. Accordingly, the theory of affine algebras is featured, treated both directly and via the theory of Noetherian and Artinian modules, and the theory of graded algebras is included to provide the foundation for projective varieties. Major topics include the theory of modules over a principal ideal domain, and its applications to matrix theory (including the Jordan decomposition), the Galois theory of field extensions, transcendence degree, the prime spectrum of an algebra, localization, and the classical theory of Noetherian and Artinian rings. Later chapters include some algebraic theory of elliptic curves (featuring the Mordell-Weil theorem) and valuation theory, including local fields. One feature of the book is an extension of the text through a series of appendices. This permits the inclusion of more advanced material, such as transcendental field extensions, the discriminant and resultant, the theory of Dedekind domains, and basic theorems of rings of algebraic integers. An extended appendix on derivations includes the Jacobian conjecture and Makar-Limanov's theory of locally nilpotent

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derivations. Grobner bases can be found in another appendix. Exercises provide a further extension of the text. The book can be used both as a textbook and as a reference source.

This book intends to provide material for a graduate course on computational commutative algebra and algebraic geometry, highlighting potential applications in cryptography. Also, the topics in this book could form the basis of a graduate course that acts as a segue between an introductory algebra course and the more technical topics of commutative algebra and algebraic geometry. This book contains a total of 124 exercises with detailed solutions as well as an important number of examples that illustrate definitions, theorems, and methods. This is very important for students or researchers who are not familiar with the topics discussed. Experience has shown that beginners who want to take their first steps in algebraic geometry are usually discouraged by the difficulty of the proposed exercises and the absence of detailed answers. Therefore, exercises (and their solutions) as well as examples occupy a prominent place in this course. This book is not designed as a comprehensive reference work, but rather as a selective textbook. The many exercises with detailed answers make it suitable for use in both a math or computer science course.

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 MapleTM, 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. Readers who are teaching from *Ideals, Varieties, and Algorithms*, or are studying the book on their own, may obtain a copy of the

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solutions manual by sending an email to jlittle@holycross.edu. 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

This book, the first of two volumes, contains over 250 selected exercises in Algebra which have featured as exam questions for the Arithmetic course taught by the authors at the University of Pisa. Each exercise is presented together with one or more solutions, carefully written with consistent language and notation. A distinguishing feature of this book is the fact that each exercise is unique and requires some creative thinking in order to be solved. The themes covered in this volume are: mathematical induction, combinatorics, modular arithmetic, Abelian

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groups, commutative rings, polynomials, field extensions, finite fields. The book includes a detailed section recalling relevant theory which can be used as a reference for study and revision. A list of preliminary exercises introduces the main techniques to be applied in solving the proposed exam questions. This volume is aimed at first year students in Mathematics and Computer Science. As algebra becomes more widely used in a variety of applications and computers are developed to allow efficient calculations in the field, so there becomes a need for new techniques to further this area of research. Gröbner Bases is one topic which has recently become a very popular and important area of modern algebra. This book provides a concrete introduction to commutative algebra through Gröbner Bases. The inclusion of exercises, lists of further reading and related literature make this a practical approach to introducing Gröbner Bases. The author presents new concepts and results of recent research in the area allowing students and researchers in technology, computer science and mathematics to gain a basic understanding of the technique. A first course in algebra is the only prior knowledge required for this introduction. Chapter titles include: * Monomial Ideas * Gröbner Bases * Algebraic Sets * Solving Systems of Polynomial Equations * Applications of Gröbner Bases * Homogeneous Algebra * Hilbert Series * Variations of Gröbner Bases * Improvements to Buchberger's Algorithms

* Software

Prof. Gopalakrishnan Passed His B.Sc. (Hons) In Mathematics From Vivekananda College Madras In 1955 And His M.A. In The Same Subject From The University Of Madras In 1956. He Had His Early Research Training At The Tata Institute Of Fundamental Research, Bombay. He Did His Ph.D. In Homological Algebra In 1963 From The Poona University. He Has Been Teaching Algebra, Algebraic Topology, Homological Algebra And Commutative Algebra In The Poona University. He Is A Professor In The Department Of Mathematics And A Recognised Guide For Ph.D. In The University Of Poona. He Has Participated In Various National And International Symposia And Has Taught At Several Summer Institutes. He Has Published Research Papers In Scientific Journals, And Has Written A Textbook, ``Commutative Algebra``. Translated from the popular French edition, this book offers a detailed introduction to various basic concepts, methods, principles, and results of commutative algebra. It takes a constructive viewpoint in commutative algebra and studies algorithmic approaches alongside several abstract classical theories. Indeed, it revisits these traditional topics with a new and simplifying manner, making the subject both accessible and innovative. The algorithmic aspects of such naturally abstract topics as Galois theory, Dedekind rings, Prüfer rings,

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finitely generated projective modules, dimension theory of commutative rings, and others in the current treatise, are all analysed in the spirit of the great developers of constructive algebra in the nineteenth century. This updated and revised edition contains over 350 well-arranged exercises, together with their helpful hints for solution. A basic knowledge of linear algebra, group theory, elementary number theory as well as the fundamentals of ring and module theory is required. *Commutative Algebra: Constructive Methods* will be useful for graduate students, and also researchers, instructors and theoretical computer scientists.

- Contains many examples and problems (with hints) - Provides a good introduction for beginners in algebraic number theory and algebraic geometry
"The second volume of the authors' 'Computational commutative algebra'...covers on its 586 pages a wealth of interesting material with several unexpected applications. ... an encyclopedia on computational commutative algebra, a source for lectures on the subject as well as an inspiration for seminars. The text is recommended for all those who want to learn and enjoy an algebraic tool that becomes more and more relevant to different fields of applications." --ZENTRALBLATT MATH

The second text in this two-book series extends the classical material of Volume

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I, which focuses on field theory and the ideal theory of Noetherian rings and Dedekind domains. The connection of Volume II's material to algebraic geometry is stressed throughout the presentation, making this book a practical introduction to some basic concepts and the arithmetical foundations of algebraic geometry. The opening chapter deals with properties of places and is followed by a chapter that explores the classical properties of polynomial and power series rings and their applications to algebraic geometry. The final chapter examines the theory of local rings, which provides the algebraic basis for the local study of algebraic and analytical varieties. Several helpful Appendixes conclude the text.

This is a comprehensive review of commutative algebra, from localization and primary decomposition through dimension theory, homological methods, free resolutions and duality, emphasizing the origins of the ideas and their connections with other parts of mathematics. The book gives a concise treatment of Grobner basis theory and the constructive methods in commutative algebra and algebraic geometry that flow from it. Many exercises included.

Computational Commutative Algebra and Algebraic Geometry
course and exercises with detailed solutions
Computational Algebra: Course And Exercises
With Solutions
World Scientific

This introduction to polynomial rings, Gröbner bases and applications bridges the

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gap in the literature between theory and actual computation. It details numerous applications, covering fields as disparate as algebraic geometry and financial markets. To aid in a full understanding of these applications, more than 40 tutorials illustrate how the theory can be used. The book also includes many exercises, both theoretical and practical.

This book is a concise account of topics in commutative algebra. It combines elegant theory with applications to number theory, some problems of classical Greek geometry, and the theory of finite fields which has important uses in other branches of science. The material covered prepares the way for the study of more advanced abstract algebra, but could also form an entire course in itself. This textbook offers a thorough, modern introduction into commutative algebra. It is intended mainly to serve as a guide for a course of one or two semesters, or for self-study. The carefully selected subject matter concentrates on the concepts and results at the center of the field. The book maintains a constant view on the natural geometric context, enabling the reader to gain a deeper understanding of the material. Although it emphasizes theory, three chapters are devoted to computational aspects. Many illustrative examples and exercises enrich the text. Recent developments are covered Contains over 100 figures and 250 exercises Includes complete proofs

The main goal of this book is to find the constructive content hidden in abstract proofs of concrete theorems in Commutative Algebra, especially in well-known theorems concerning projective modules over polynomial rings (mainly the Quillen-Suslin theorem) and syzygies of multivariate polynomials with coefficients in a valuation ring. Simple and constructive proofs of some results in the theory of projective modules over polynomial rings are also given, and light is cast upon recent progress on the Hermite ring and Gröbner ring conjectures. New conjectures on unimodular completion arising from our constructive approach to the unimodular completion problem are presented. Constructive algebra can be understood as a first preprocessing step for computer algebra that leads to the discovery of general algorithms, even if they are sometimes not efficient. From a logical point of view, the dynamical evaluation gives a constructive substitute for two highly nonconstructive tools of abstract algebra: the Law of Excluded Middle and Zorn's Lemma. For instance, these tools are required in order to construct the complete prime factorization of an ideal in a Dedekind ring, whereas the dynamical method reveals the computational content of this construction. These lecture notes follow this dynamical philosophy.

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.

This contributed volume brings together the highest quality expository papers written by leaders and talented junior mathematicians in the field of Commutative Algebra. Contributions cover a very wide range of topics, including core areas in Commutative Algebra and also relations to Algebraic Geometry, Algebraic Combinatorics, Hyperplane Arrangements, Homological Algebra, and String Theory. The book aims to showcase the area, especially for the benefit of junior mathematicians and researchers who are new to the field; it will aid them in broadening their background and to gain a deeper understanding of the current research in this area. Exciting developments are surveyed and many open problems are discussed with the aspiration to inspire the readers and foster

further research.

This book is the first to be devoted entirely to fuzzy abstract algebra. It presents an up-to-date version of fuzzy commutative algebra, and focuses on the connection between L -subgroups of a group, and L -subfields of a field. In particular, an up-to-date treatment of nonlinear systems of fuzzy intersection equations is given.

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. The book bases its discussion of algorithms on a generalisation of the division algorithm for polynomials in one variable that was only discovered in the 1960's. Although the algorithmic roots of algebraic geometry are old, the computational aspects were neglected earlier in this century. This has changed in recent years, and new algorithms, coupled with the power of fast computers, have led to some interesting applications, for example in robotics and in geometric theorem proving. In preparing this new edition, the authors present an improved proof of the Buchberger Criterion as well as a proof of Bezout's Theorem.

This book gives a systematic presentation of real algebraic varieties. Real algebraic varieties are ubiquitous. They are the first objects encountered when learning of coordinates, then equations, but the systematic study of these objects, however elementary they may be, is formidable. This book is intended for two kinds of audiences: it accompanies the reader, familiar with algebra and geometry at the masters level, in learning the basics of this rich theory, as much as it brings to the most advanced reader many fundamental results often

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missing from the available literature, the “folklore”. In particular, the introduction of topological methods of the theory to non-specialists is one of the original features of the book. The first three chapters introduce the basis and classical methods of real and complex algebraic geometry. The last three chapters each focus on one more specific aspect of real algebraic varieties. A panorama of classical knowledge is presented, as well as major developments of the last twenty years in the topology and geometry of varieties of dimension two and three, without forgetting curves, the central subject of Hilbert's famous sixteenth problem. Various levels of exercises are given, and the solutions of many of them are provided at the end of each chapter.

An Introduction to Commutative Algebra and Number Theory is an elementary introduction to these subjects. Beginning with a concise review of groups, rings and fields, the author presents topics in algebra from a distinctly number-theoretic perspective and sprinkles number theory results throughout his presentation. The topics in algebra include polynomial rings, UFD, PID, and Euclidean domains; and field extensions, modules, and Dedekind domains. In the section on number theory, in addition to covering elementary congruence results, the laws of quadratic reciprocity and basics of algebraic number fields, this book gives glimpses into some deeper aspects of the subject. These include Warning's and Chevalley's theorems in the finite field sections, and many results of additive number theory, such as the derivation of LaGrange's four-square theorem from Minkowski's result in the geometry of numbers. With addition of remarks and comments and with references in the bibliography, the author stimulates readers to explore the subject beyond the scope of this book.

Approximate Commutative Algebra is an emerging field of research which endeavours to

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bridge the gap between traditional exact Computational Commutative Algebra and approximate numerical computation. The last 50 years have seen enormous progress in the realm of exact Computational Commutative Algebra, and given the importance of polynomials in scientific modelling, it is very natural to want to extend these ideas to handle approximate, empirical data deriving from physical measurements of phenomena in the real world. In this volume nine contributions from established researchers describe various approaches to tackling a variety of problems arising in Approximate Commutative Algebra.

This is the most current textbook in teaching the basic concepts of abstract algebra. The author finds that there are many students who just memorise a theorem without having the ability to apply it to a given problem. Therefore, this is a hands-on manual, where many typical algebraic problems are provided for students to be able to apply the theorems and to actually practice the methods they have learned. Each chapter begins with a statement of a major result in Group and Ring Theory, followed by problems and solutions. Contents: Tools and Major Results of Groups; Problems in Group Theory; Tools and Major Results of Ring Theory; Problems in Ring Theory; Index.

This volume offers a compendium of exercises of varying degree of difficulty in the theory of modules and rings. It is the companion volume to GTM 189. All exercises are solved in full detail. Each section begins with an introduction giving the general background and the theoretical basis for the problems that follow.

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