

# Graduate Texts in Mathematics

Joseph H. Silverman

## The Arithmetic of Elliptic Curves

2nd Edition



 Springer

# Arithmetic Of Elliptic Curves

**J. H. Silverman**



## **Arithmetic Of Elliptic Curves:**

*The Arithmetic of Elliptic Curves* Joseph H. Silverman, 2009-04-20 The theory of elliptic curves is distinguished by its long history and by the diversity of the methods that have been used in its study This book treats the arithmetic approach in its modern formulation through the use of basic algebraic number theory and algebraic geometry Following a brief discussion of the necessary algebro geometric results the book proceeds with an exposition of the geometry and the formal group of elliptic curves elliptic curves over finite fields the complex numbers local fields and global fields Final chapters deal with integral and rational points including Siegel's theorem and explicit computations for the curve  $Y^2 = X^3 + DX$  while three appendices conclude the whole Elliptic Curves in Characteristics 2 and 3 Group Cohomology and an overview of more advanced topics

**Arithmetic on Elliptic Curves with Complex Multiplication** B.H. Gross, 2006-11-14 *Advanced Topics in the Arithmetic of Elliptic Curves* Joseph H. Silverman, 1994-11-04 In the introduction to the first volume of *The Arithmetic of Elliptic Curves* Springer Verlag 1986 I observed that the theory of elliptic curves is rich varied and amazingly vast and as a consequence many important topics had to be omitted I included a brief introduction to ten additional topics as an appendix to the first volume with the tacit understanding that eventually there might be a second volume containing the details You are now holding that second volume it turned out that even those ten topics would not fit Unfortunately into a single book so I was forced to make some choices The following material is covered in this book I Elliptic and modular functions for the full modular group II Elliptic curves with complex multiplication III Elliptic surfaces and specialization theorems IV Neron models Kodaira Neron classification of special fibers Tate's algorithm and Ogg's conductor discriminant formula V Tate's theory of  $q$  curves over  $p$  adic fields VI Neron's theory of canonical local height functions

**The Arithmetic of Elliptic Curves** J. H. Silverman, 1996 *Arithmetic on Elliptic Curves with Complex Multiplication* B. H. Gross, 2014-09-01

**Arithmetic Theory of Elliptic Curves** J. Coates, R. Greenberg, K.A. Ribet, K. Rubin, 1999-10-19 This volume contains the expanded versions of the lectures given by the authors at the C I M E instructional conference held in Cetraro Italy from July 12 to 19 1997 The papers collected here are broad surveys of the current research in the arithmetic of elliptic curves and also contain several new results which cannot be found elsewhere in the literature Owing to clarity and elegance of exposition and to the background material explicitly included in the text or quoted in the references the volume is well suited to research students as well as to senior mathematicians

**Elliptic Curves** J. S. Milne, 2006 This book uses the beautiful theory of elliptic curves to introduce the reader to some of the deeper aspects of number theory It assumes only a knowledge of the basic algebra complex analysis and topology usually taught in advanced undergraduate or first year graduate courses Reviews Indeed the book is affordable in fact the most affordable of all references on the subject but also a high quality work and a complete introduction to the rich theory of the arithmetic of elliptic curves with numerous examples and exercises for the reader many interesting remarks and an updated bibliography Mathematical Reviews Ivano Lozano Robledo J S Milne's lecture notes on

elliptic curves are already well known The book under review is a rewritten version of just these famous lecture notes from 1996 which appear here as a compact and inexpensive paperback that is now available worldwide Zentralblatt MATH Werner Kleinert *Arithmetic Moduli of Elliptic Curves* Nicholas M. Katz, Barry Mazur, 1985-02-21 This work is a comprehensive treatment of recent developments in the study of elliptic curves and their moduli spaces The arithmetic study of the moduli spaces began with Jacobi's *Fundamenta Nova* in 1829 and the modern theory was erected by Eichler Shimura Igusa and Deligne Rapoport In the past decade mathematicians have made further substantial progress in the field This book gives a complete account of that progress including not only the work of the authors but also that of Deligne and Drinfeld

*Rational Points on Elliptic Curves* Joseph H. Silverman, John T. Tate, 2015-06-02 The theory of elliptic curves involves a pleasing blend of algebra geometry analysis and number theory This volume stresses this interplay as it develops the basic theory thereby providing an opportunity for advanced undergraduates to appreciate the unity of modern mathematics At the same time every effort has been made to use only methods and results commonly included in the undergraduate curriculum This accessibility the informal writing style and a wealth of exercises make *Rational Points on Elliptic Curves* an ideal introduction for students at all levels who are interested in learning about Diophantine equations and arithmetic geometry Most concretely an elliptic curve is the set of zeroes of a cubic polynomial in two variables If the polynomial has rational coefficients then one can ask for a description of those zeroes whose coordinates are either integers or rational numbers It is this number theoretic question that is the main subject of *Rational Points on Elliptic Curves* Topics covered include the geometry and group structure of elliptic curves the Nagell Lutz theorem describing points of finite order the Mordell Weil theorem on the finite generation of the group of rational points the Thue Siegel theorem on the finiteness of the set of integer points theorems on counting points with coordinates in finite fields Lenstra's elliptic curve factorization algorithm and a discussion of complex multiplication and the Galois representations associated to torsion points Additional topics new to the second edition include an introduction to elliptic curve cryptography and a brief discussion of the stunning proof of Fermat's Last Theorem by Wiles et al via the use of elliptic curves *Elliptic Curves* Henry McKean, Victor Moll, Victor H. Moll, 1999-08-13 The subject of elliptic curves is one of the jewels of nineteenth century mathematics originated by Abel Gauss Jacobi and Legendre This 1997 book presents an introductory account of the subject in the style of the original discoverers with references to and comments about more recent and modern developments It combines three of the fundamental themes of mathematics complex function theory geometry and arithmetic After an informal preparatory chapter the book follows an historical path beginning with the work of Abel and Gauss on elliptic integrals and elliptic functions This is followed by chapters on theta functions modular groups and modular functions the quintic the imaginary quadratic field and on elliptic curves Requiring only a first acquaintance with complex function theory this book is an ideal introduction to the subject for graduate students and researchers in mathematics and physics with many exercises with hints scattered

throughout the text

**Elliptic Curves** Anthony W. Knapp, 2018-06-05 An elliptic curve is a particular kind of cubic equation in two variables whose projective solutions form a group. Modular forms are analytic functions in the upper half plane with certain transformation laws and growth properties. The two subjects elliptic curves and modular forms come together in Eichler Shimura theory which constructs elliptic curves out of modular forms of a special kind. The converse that all rational elliptic curves arise this way is called the Taniyama Weil Conjecture and is known to imply Fermat's Last Theorem. Elliptic curves and the modular forms in the Eichler Shimura theory both have associated L functions and it is a consequence of the theory that the two kinds of L functions match. The theory covered by Anthony Knapp in this book is therefore a window into a broad expanse of mathematics including class field theory, arithmetic algebraic geometry and group representations in which the coincidence of L functions relates analysis and algebra in the most fundamental ways. Developing with many examples the elementary theory of elliptic curves, the book goes on to the subject of modular forms and the first connections with elliptic curves. The last two chapters concern Eichler Shimura theory which establishes a much deeper relationship between the two subjects. No other book in print treats the basic theory of elliptic curves with only undergraduate mathematics and no other explains Eichler Shimura theory in such an accessible manner.

**Elliptic Curves** R. V. Gurjar, 2006 These notes constitute a lucid introduction to Elliptic Curves, one of the central and vigorous areas of current mathematical research. The subject has been studied from diverse viewpoints: analytic, algebraic and arithmetical. These notes offer the reader glimpses of all three aspects and present some of the basic important theorems in all of them. The first part introduces a little of the theory of Riemann surfaces and goes on to the study of tori and their projective embeddings as cubics. This part ends with a discussion of the identification of the moduli space of complex tori with the quotient of the upper half plane by the modular groups. The second part handles the algebraic geometry of elliptic curves. It begins with a rapid introduction to some basic algebraic geometry and then focuses on elliptic curves. The Riemann-Roch theorem and the Riemann hypothesis for elliptic curves are proved and the structure of the endomorphism ring of an elliptic curve is described. The third and last part is on the arithmetic of elliptic curves over  $\mathbb{Q}$ . The Mordell-Weil theorem, Mazur's theorem on torsion in rational points of an elliptic curve over  $\mathbb{Q}$  and theorems of Thue and Siegel are among the results which are presented. There is a brief discussion of theta functions, Eisenstein series and cusp forms with an application to representation of natural numbers as sums of squares. The notes end with the formulation of the Birch and Swinnerton-Dyer conjectures. There is an additional brief chapter Appendix C written in July 2004 by Kirti Joshi describing some developments since the original notes were written up in the present form in 1992.

*Modern Cryptography and Elliptic Curves* Thomas R. Shemanske, 2017-07-31 This book offers the beginning undergraduate student some of the vista of modern mathematics by developing and presenting the tools needed to gain an understanding of the arithmetic of elliptic curves over finite fields and their applications to modern cryptography. This gradual introduction also makes a significant effort to teach students how to

produce or discover a proof by presenting mathematics as an exploration and at the same time it provides the necessary mathematical underpinnings to investigate the practical and implementation side of elliptic curve cryptography ECC Elements of abstract algebra number theory and affine and projective geometry are introduced and developed and their interplay is exploited Algebra and geometry combine to characterize congruent numbers via rational points on the unit circle and group law for the set of points on an elliptic curve arises from geometric intuition provided by B zout s theorem as well as the construction of projective space The structure of the unit group of the integers modulo a prime explains RSA encryption Pollard s method of factorization Diffie Hellman key exchange and ElGamal encryption while the group of points of an elliptic curve over a finite field motivates Lenstra s elliptic curve factorization method and ECC The only real prerequisite for this book is a course on one variable calculus other necessary mathematical topics are introduced on the fly Numerous exercises further guide the exploration

*Elliptic Functions and Elliptic Integrals* Viktor Vasil\_evich Prasolov,I Uri\_Pavlovich Solov\_ev,1997-09-16 This book is devoted to the geometry and arithmetic of elliptic curves and to elliptic functions with applications to algebra and number theory It includes modern interpretations of some famous classical algebraic theorems such as Abel s theorem on the lemniscate and Hermite s solution of the fifth degree equation by means of theta functions Suitable as a text the book is self contained and assumes as prerequisites only the standard one year courses of algebra and analysis

*Elliptic Curves, Modular Forms, and Their L-functions* Álvaro Lozano-Robledo,2011 Many problems in number theory have simple statements but their solutions require a deep understanding of algebra algebraic geometry complex analysis group representations or a combination of all four The original simply stated problem can be obscured in the depth of the theory developed to understand it This book is an introduction to some of these problems and an overview of the theories used nowadays to attack them presented so that the number theory is always at the forefront of the discussion Lozano Robledo gives an introductory survey of elliptic curves modular forms and L functions His main goal is to provide the reader with the big picture of the surprising connections among these three families of mathematical objects and their meaning for number theory As a case in point Lozano Robledo explains the modularity theorem and its famous consequence Fermat s Last Theorem He also discusses the Birch and Swinnerton Dyer Conjecture and other modern conjectures The book begins with some motivating problems and includes numerous concrete examples throughout the text often involving actual numbers such as  $\frac{3344161}{747348}$  and  $\frac{2244035177043369699245575130906674863160948472041}{8912332268928859588025535178967163570016480830}$  The theories of elliptic curves modular forms and L functions are too vast to be covered in a single volume and their proofs are outside the scope of the undergraduate curriculum However the primary objects of study the statements of the main theorems and their corollaries are within the grasp of advanced undergraduates This book concentrates on motivating the definitions explaining the statements of the theorems and conjectures making connections and providing lots of examples

rather than dwelling on the hard proofs The book succeeds if after reading the text students feel compelled to study elliptic curves and modular forms in all their glory

*Elliptic Curves and Arithmetic Invariants* Haruzo Hida, 2013-06-13 This book contains a detailed account of the result of the author's recent Annals paper and JAMS paper on arithmetic invariant including invariant L invariant and similar topics This book can be regarded as an introductory text to the author's previous book *p*-Adic Automorphic Forms on Shimura Varieties Written as a down to earth introduction to Shimura varieties this text includes many examples and applications of the theory that provide motivation for the reader Since it is limited to modular curves and the corresponding Shimura varieties this book is not only a great resource for experts in the field but it is also accessible to advanced graduate students studying number theory Key topics include non triviality of arithmetic invariants and special values of L functions elliptic curves over complex and *p*-adic fields Hecke algebras scheme theory elliptic and modular curves over rings and Shimura curves

**Elliptic Curves** Dale Husemöller, 2004 First Edition sold over 2500 copies in the Americas New Edition contains three new chapters and two new appendices

*Rational Points on Modular Elliptic Curves* Henri Darmon, 2004 The book surveys some recent developments in the arithmetic of modular elliptic curves It places a special emphasis on the construction of rational points on elliptic curves the Birch and Swinnerton Dyer conjecture and the crucial role played by modularity in shedding light on these two closely related issues The main theme of the book is the theory of complex multiplication Heegner points and some conjectural variants The first three chapters introduce the background and prerequisites elliptic curves modular forms and the Shimura Taniyama Weil conjecture complex multiplication and the Heegner point construction The next three chapters introduce variants of modular parametrizations in which modular curves are replaced by Shimura curves attached to certain indefinite quaternion algebras The main new contributions are found in Chapters 7-9 which survey the author's attempts to extend the theory of Heegner points and complex multiplication to situations where the base field is not a CM field Chapter 10 explains the proof of Kolyvagin's theorem which relates Heegner points to the arithmetic of elliptic curves and leads to the best evidence so far for the Birch and Swinnerton Dyer conjecture

*On Twisted Triple Products and the Arithmetic of Elliptic Curves* Michele Fornea, 2019 The unifying theme of the thesis is the arithmetic of elliptic curves more specifically the conjecture of Birch and Swinnerton Dyer and its generalizations This subject leverages different aspects of number theory arithmetic geometry and representation theory including automorphic representations Shimura varieties *p*-adic modular forms and *p*-adic L functions Simply put the BSD conjecture claims the equality of the analytic and the algebraic rank of an elliptic curve A tantalizing aspect of the conjecture is its offering very subtle information that goes beyond the Sato Tate conjecture on how the size of rational points influences and is influenced by the distribution of the number of *emph mod ell* points for all rational primes *ell*

In the past 50 years gifted mathematicians have done gorgeous work establishing the first cases of the BSD conjecture

parencite CoatesWiles parencite GZformula parencite Koly and the intertwining of *p*-adic methods with Euler systems has

become more and more widespread. Kato, LLZ, DR2 providing a deeper understanding of the objects involved. The work in this thesis is part of this growing thread of investigation. The idea of this project rests on the exploration of a twisted variant of the setting studied in DR, DR2 and DR3 with an emphasis on understanding the relation between twisted triple product L functions and Hirzebruch Zagier cycles. After a brief introduction Chapter 1, MicAnalytic investigates twisted triple product L functions with applications to arithmetic statistics. By solving a class of Galois embedding problems over totally real fields it demonstrates that the analytic rank of a modular elliptic curve of odd non square conductor grows over a positive proportion of quintic extensions. Chapter 2, Fornea, comprises the construction of twisted triple product  $p$ -adic L functions over totally real fields for nearly ordinary Hida families. When  $L = \mathbb{Q}(\sqrt{d})$  is a real quadratic field and  $p$  splits in  $L$ , a  $p$ -adic Gross Zagier formula expresses values of the  $p$ -adic L functions that are outside the range of interpolation in terms of the syntomic Abel Jacobi map of generalized Hirzebruch Zagier cycles. Novel ideas appear in the treatment of compactifications of Kuga Sato varieties using Wildeshaus work on the interior motive, Wildeshaus and in the choice of the Coleman primitive for the evaluation of the syntomic regulator. The final chapter of the dissertation features a preview of a work in progress joint with Zhaorong Jin, Princeton, bringing to fruition the preceding pieces. When  $p$  splits in the real quadratic field  $L$ , we expect to provide a geometric construction of twisted triple product  $p$ -adic L functions using big Hirzebruch Zagier classes. This geometric construction together with MicAnalytic should lead to new instances of the BSD conjecture in rank 0 for rational elliptic curves over certain quintic number fields whose normal closure has Galois group  $S_5$ .

Rational Points on Elliptic Curves  
 Joseph H. Silverman, John T. Tate, 1994-11-18. The theory of elliptic curves involves a blend of algebra, geometry, analysis and number theory. This book stresses this interplay as it develops the basic theory providing an opportunity for readers to appreciate the unity of modern mathematics. The book's accessibility, the informal writing style and a wealth of exercises make it an ideal introduction for those interested in learning about Diophantine equations and arithmetic geometry.

## **Arithmetic Of Elliptic Curves** Book Review: Unveiling the Magic of Language

In a digital era where connections and knowledge reign supreme, the enchanting power of language has become more apparent than ever. Its ability to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**Arithmetic Of Elliptic Curves**," published by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound affect our existence. Throughout this critique, we shall delve to the book is central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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