

# Graduate Texts in Mathematics

**Serge Lang**

**Cyclotomic Fields II**



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# Cyclotomic Fields

**Paulo Ribenboim**



## Cyclotomic Fields:

*Introduction to Cyclotomic Fields* Lawrence C. Washington, 1997 This text on a central area of number theory covers  $p$ -adic  $L$  functions class numbers cyclotomic units Fermat's Last Theorem and Iwasawa's theory of  $\mathbb{Z}_p$  extensions This edition contains a new chapter on the work of Thaine Kolyvagin and Rubin including a proof of the Main Conjecture as well as a chapter on other recent developments such as primality testing via Jacobi sums and Sinnott's proof of the vanishing of Iwasawa's  $f$ -invariant

**Introduction to Cyclotomic Fields** Lawrence C. Washington, 2012-12-06 Introduction to Cyclotomic Fields is a carefully written exposition of a central area of number theory that can be used as a second course in algebraic number theory Starting at an elementary level the volume covers  $p$ -adic  $L$  functions class numbers cyclotomic units Fermat's Last Theorem and Iwasawa's theory of  $\mathbb{Z}_p$  extensions leading the reader to an understanding of modern research literature Many exercises are included The second edition includes a new chapter on the work of Thaine Kolyvagin and Rubin including a proof of the Main Conjecture There is also a chapter giving other recent developments including primality testing via Jacobi sums and Sinnott's proof of the vanishing of Iwasawa's  $f$ -invariant

*Cyclotomic Fields* S. Lang, 2012-12-06 Kummer's work on cyclotomic fields paved the way for the development of algebraic number theory in general by Dedekind Weber Hensel Hilbert Takagi Artin and others However the success of this general theory has tended to obscure special facts proved by Kummer about cyclotomic fields which lie deeper than the general theory For a long period in the 20th century this aspect of Kummer's work seems to have been largely forgotten except for a few papers among which are those by Pollaczek Po Artin Hasse A H and Vandiver Va In the mid 1950's the theory of cyclotomic fields was taken up again by Iwasawa and Leopoldt Iwasawa viewed cyclotomic fields as being analogues for number fields of the constant field extensions of algebraic geometry and wrote a great sequence of papers investigating towers of cyclotomic fields and more generally Galois extensions of number fields whose Galois group is isomorphic to the additive group of  $p$ -adic integers Leopoldt concentrated on a fixed cyclotomic field and established various  $p$ -adic analogues of the classical complex analytic class number formulas In particular this led him to introduce with Kubota  $p$ -adic analogues of the complex  $L$  functions attached to cyclotomic extensions of the rationals Finally in the late 1960's Iwasawa Iw 1 I made the fundamental discovery that there was a close connection between his work on towers of cyclotomic fields and these  $p$ -adic  $L$  functions of Leopoldt Kubota

The Theory of Algebraic Number Fields David Hilbert, 2013-03-14 Constance Reid in Chapter VII of her book Hilbert tells the story of the writing of the *Zahlbericht* as his report entitled *Die Theorie der algebraischen Zahlkörper* has always been known At its annual meeting in 1893 the Deutsche Mathematiker Vereinigung the German Mathematical Society invited Hilbert and Minkowski to prepare a report on the current state of affairs in the theory of numbers to be completed in two years The two mathematicians agreed that Minkowski should write about rational number theory and Hilbert about algebraic number theory Although Hilbert had almost completed his share of the report by the beginning of 1896 Minkowski had made

much less progress and it was agreed that he should withdraw from his part of the project Shortly afterwards Hilbert finished writing his report on algebraic number fields and the manuscript carefully copied by his wife was sent to the printers The proofs were read by Minkowski aided in part by Hurwitz slowly and carefully with close attention to the mathematical exposition as well as to the type setting at Minkowski's insistence Hilbert included a note of thanks to his wife As Constance Reid writes The report on algebraic number fields exceeded in every way the expectation of the members of the Mathematical Society They had asked for a summary of the current state of affairs in the theory They received a masterpiece which simply and clearly fitted all the difficult developments of recent times into an elegantly integrated theory

Cyclotomic Fields I and II Serge Lang, 2012-12-06 Kummer's work on cyclotomic fields paved the way for the development of algebraic number theory in general by Dedekind Weber Hensel Hilbert Takagi Artin and others However the success of this general theory has tended to obscure special facts proved by Kummer about cyclotomic fields which lie deeper than the general theory For a long period in the 20th century this aspect of Kummer's work seems to have been largely forgotten except for a few papers among which are those by Pollaczek Po Artin Hasse A H and Vandiver Va In the mid 1950's the theory of cyclotomic fields was taken up again by Iwasawa and Leopoldt Iwasawa viewed cyclotomic fields as being analogues for number fields of the constant field extensions of algebraic geometry and wrote a great sequence of papers investigating towers of cyclotomic fields and more generally Galois extensions of number fields whose Galois group is isomorphic to the additive group of  $p$ -adic integers Leopoldt concentrated on a fixed cyclotomic field and established various  $p$ -adic analogues of the classical complex analytic class number formulas In particular this led him to introduce with Kubota  $p$ -adic analogues of the complex  $L$ -functions attached to cyclotomic extensions of the rationals Finally in the late 1960's Iwasawa Iw 11 made the fundamental discovery that there was a close connection between his work on towers of cyclotomic fields and these  $p$ -adic  $L$ -functions of Leopoldt Kubota

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s Iwasawa Iw 1 I made the fundamental discovery that there was a close connection between his work on towers of cyclotomic fields and these  $p$ -adic  $L$ -functions of Leopoldt Kubota      **Algebraic Number Fields**, 1973-08-15 Algebraic Number Fields      **Cyclotomic Fields I and II** Serge Lang, 2011-09-28 Kummer's work on cyclotomic fields paved the way for the development of algebraic number theory in general by Dedekind Weber Hensel Hilbert Takagi Artin and others However the success of this general theory has tended to obscure special facts proved by Kummer about cyclotomic fields which lie deeper than the general theory For a long period in the 20th century this aspect of Kummer's work seems to have been largely forgotten except for a few papers among which are those by Pollaczek Po Artin Hasse A H and Vandiver Va In the mid 1950 s the theory of cyclotomic fields was taken up again by Iwasawa and Leopoldt Iwasawa viewed cyclotomic fields as being analogues for number fields of the constant field extensions of algebraic geometry and wrote a great sequence of papers investigating towers of cyclotomic fields and more generally Galois extensions of number fields whose Galois group is isomorphic to the additive group of  $p$ -adic integers Leopoldt concentrated on a fixed cyclotomic field and established various  $p$ -adic analogues of the classical complex analytic class number formulas In particular this led him to introduce with Kubota  $p$ -adic analogues of the complex  $L$ -functions attached to cyclotomic extensions of the rationals Finally in the late 1960 s Iwasawa Iw 11 made the fundamental discovery that there was a close connection between his work on towers of cyclotomic fields and these  $p$ -adic  $L$ -functions of Leopoldt Kubota      *13 Lectures on Fermat's Last Theorem* Paulo

Ribenboim, 2012-12-06 Lecture I The Early History of Fermat's Last Theorem 1 The Problem 2 Early Attempts 3 Kummer's Monumental Theorem 4 Regular Primes 5 Kummer's Work on Irregular Prime Exponents 6 Other Relevant Results 7 The Golden Medal and the Wolfskehl Prize Lecture II Recent Results 1 Stating the Results 2 Explanations Lecture III B K Before Kummer 1 The Pythagorean Equation 2 The Biquadratic Equation 3 The Cubic Equation 4 The Quintic Equation 5 Fermat's Equation of Degree Seven Lecture IV The Naïve Approach 1 The Relations of Barlow and Abel 2 Sophie Germain 3 Co

*Cyclotomic Fields II* Serge Lang, 2012-03 This second volume incorporates a number of results which were discovered and or systematized since the first volume was being written Again I limit myself to the cyclotomic fields proper without introducing modular functions As in the first volume the main concern is with class number formulas Gauss sums and the like We begin with the Ferrero Washington theorems proving Iwasawa's conjecture that the  $p$ -primary part of the ideal class group in the cyclotomic  $\mathbb{Z}_p$ -extension of a cyclotomic field grows linearly rather than exponentially This is first done for the minus part the minus referring as usual to the eigenspace for complex conjugation and then it follows for the plus part because of results bounding the plus part in terms of the minus part Kummer had already proved such results e g if  $p \nmid h$  then  $p \mid h$  These are now formulated in ways applicable to the Iwasawa invariants following Iwasawa himself After that we do what amounts to Dwork theory to derive the Gross Koblitz formula expressing Gauss sums in terms of the  $p$ -adic gamma function This lifts Stickelberger's theorem  $p$ -adically Half of the proof relies on a course of Katz who had first obtained Gauss sums as

limits of certain factorials and thought of using Washnitzer Monsky cohomology to prove the Gross Koblitz formula

**Characters and Cyclotomic Fields in Finite Geometry** Bernhard Schmidt, 2004-10-13 This monograph contributes to the existence theory of difference sets cyclic irreducible codes and similar objects The new method of field descent for cyclotomic integers of prescribed absolute value is developed Applications include the first substantial progress towards the Circulant Hadamard Matrix Conjecture and Ryser's conjecture since decades It is shown that there is no Barker sequence of length  $l$  with  $13$

**Algebraic Number Fields** Janusz, 1995-12-05 The book is directed toward students with a minimal background who want to learn class field theory for number fields The only prerequisite for reading it is some elementary Galois theory The first three chapters lay out the necessary background in number fields such as the arithmetic of fields Dedekind domains and valuations The next two chapters discuss class field theory for number fields The concluding chapter serves as an illustration of the concepts introduced in previous chapters In particular some interesting calculations with quadratic fields show the use of the norm residue symbol For the second edition the author added some new material expanded many proofs and corrected errors found in the first edition The main objective however remains the same as it was for the first edition to give an exposition of the introductory material and the main theorems about class fields of algebraic number fields that would require as little background preparation as possible Janusz's book can be an excellent textbook for a year long course in algebraic number theory the first three chapters would be suitable for a one semester course It is also very suitable for independent study

**A Classical Introduction to Modern Number Theory** Kenneth Ireland, Michael Ira Rosen, 1990-09-07 This well developed accessible text details the historical development of the subject throughout It also provides wide ranging coverage of significant results with comparatively elementary proofs some of them new This second edition contains two new chapters that provide a complete proof of the Mordel Weil theorem for elliptic curves over the rational numbers and an overview of recent progress on the arithmetic of elliptic curves

**Algebraic Number Theory** Serge Lang, 2013-06-29 The present book gives an exposition of the classical basic algebraic and analytic number theory and supersedes my Algebraic Numbers including much more material e g the class field theory on which I make further comments at the appropriate place later For different points of view the reader is encouraged to read the collection of papers from the Brighton Symposium edited by Cassels Frohlich the Artin Tate notes on class field theory Weil's book on Basic Number Theory Borevich Shafarevich's Number Theory and also older books like those of Weber Hasse Hecke and Hilbert's Zahlbericht It seems that over the years everything that has been done has proved useful theoretically or as examples for the further development of the theory Old and seemingly isolated special cases have continuously acquired renewed significance often after half a century or more The point of view taken here is principally global and we deal with local fields only incidentally For a more complete treatment of these cf Serre's book Corps Locaux There is much to be said for a direct global approach to number fields Stylistically I have intermingled the ideal and idelic approaches without

prejudice for either 1 also include two proofs of the functional equation for the zeta function to acquaint the reader with different techniques in some sense equivalent but in another sense suggestive of very different moods      **Number Fields**

Daniel A. Marcus, 2018-07-05 Requiring no more than a basic knowledge of abstract algebra this text presents the mathematics of number fields in a straightforward pedestrian manner It therefore avoids local methods and presents proofs in a way that highlights the important parts of the arguments Readers are assumed to be able to fill in the details which in many places are left as exercises      **Classical Theory of Algebraic Numbers** Paulo Ribenboim, 2013-11-11 Gauss created the theory of binary quadratic forms in *Disquisitiones Arithmeticae* and Kummer invented ideals and the theory of cyclotomic fields in his attempt to prove Fermat's Last Theorem These were the starting points for the theory of algebraic numbers developed in the classical papers of Dedekind Dirichlet Eisenstein Hermite and many others This theory enriched with more recent contributions is of basic importance in the study of diophantine equations and arithmetic algebraic geometry including methods in cryptography This book has a clear and thorough exposition of the classical theory of algebraic numbers and contains a large number of exercises as well as worked out numerical examples The Introduction is a recapitulation of results about principal ideal domains unique factorization domains and commutative fields Part One is devoted to residue classes and quadratic residues In Part Two one finds the study of algebraic integers ideals units class numbers the theory of decomposition inertia and ramification of ideals Part Three is devoted to Kummer's theory of cyclotomic fields and includes Bernoulli numbers and the proof of Fermat's Last Theorem for regular prime exponents Finally in Part Four the emphasis is on analytical methods and it includes Dirichlet's Theorem on primes in arithmetic progressions the theorem of Chebotarev and class number formulas A careful study of this book will provide a solid background to the learning of more recent topics

**Finite Fields and Applications** Dieter Jungnickel, H. Niederreiter, 2012-12-06 This volume represents the refereed proceedings of the Fifth International Conference on Finite Fields and Applications Fq5 held at the University of Augsburg Germany from August 2-6 1999 and hosted by the Department of Mathematics The conference continued a series of biennial international conferences on finite fields following earlier conferences at the University of Nevada at Las Vegas USA in August 1991 and August 1993 the University of Glasgow Scotland in July 1995 and the University of Waterloo Canada in August 1997 The Organizing Committee of Fq5 comprised Thomas Beth

**Advances in Cryptology - ASIACRYPT 2024** Kai-Min Chung, Yu Sasaki, 2024-12-13 The 9 volume set LNCS 15484-15492 constitutes the refereed proceedings of the 30th International Conference on the Theory and Application of Cryptology and Information Security ASIACRYPT 2024 which took place in Kolkata India during December 9-13 2024 The 127 full papers included in the proceedings were carefully reviewed and selected from 433 submissions They were organized in topical sections as follows Advances Primitives homomorphic encryption digital signatures public key cryptography pairing based cryptography threshold cryptography isogeny based cryptography post quantum cryptography secure data structures lattice based cryptography lattice assumptions key

exchange protocols succinct arguments verifiable computation zero knowledge protocols secure multiparty computation blockchain protocols information theoretic cryptography secret sharing security against physical attacks cryptanalysis on symmetric key schemes cryptanalysis on public key schemes fault attacks and side channel analysis cryptanalysis on various problems quantum cryptanalysis quantum cryptography symmetric key cryptography      **Topics in the Theory of**

**Algebraic Function Fields** Gabriel Daniel Villa Salvador, 2007-10-10 The fields of algebraic functions of one variable appear in several areas of mathematics complex analysis algebraic geometry and number theory This text adopts the latter perspective by applying an arithmetic algebraic viewpoint to the study of function fields as part of the algebraic theory of numbers The examination explains both the similarities and fundamental differences between function fields and number fields including many exercises and examples to enhance understanding and motivate further study The only prerequisites are a basic knowledge of field theory complex analysis and some commutative algebra The book can serve as a text for a graduate course in number theory or an advanced graduate topics course Alternatively chapters 1-4 can serve as the base of an introductory undergraduate course for mathematics majors while chapters 5-9 can support a second course for advanced undergraduates Researchers interested in number theory field theory and their interactions will also find the work an excellent reference

**Algebraic Number Theory** Richard A. Mollin, 1999-03-16 From its history as an elegant but abstract area of mathematics algebraic number theory now takes its place as a useful and accessible study with important real world practicality Unique among algebraic number theory texts this important work offers a wealth of applications to cryptography including factoring primality testing and public key cryptosystems A follow up to Dr Mollin's popular Fundamental Number Theory with Applications Algebraic Number Theory provides a global approach to the subject that selectively avoids local theory Instead it carefully leads the student through each topic from the level of the algebraic integer to the arithmetic of number fields to ideal theory and closes with reciprocity laws In each chapter the author includes a section on a cryptographic application of the ideas presented effectively demonstrating the pragmatic side of theory In this way Algebraic Number Theory provides a comprehensible yet thorough treatment of the material Written for upper level undergraduate and graduate courses in algebraic number theory this one of a kind text brings the subject matter to life with historical background and real world practicality It easily serves as the basis for a range of courses from bare bones algebraic number theory to a course rich with cryptography applications to a course using the basic theory to prove Fermat's Last Theorem for regular primes Its offering of over 430 exercises with odd numbered solutions provided in the back of the book and even numbered solutions available a separate manual makes this the ideal text for both students and instructors



## Reviewing **Cyclotomic Fields**: Unlocking the Spellbinding Force of Linguistics

In a fast-paced world fueled by information and interconnectivity, the spellbinding force of linguistics has acquired newfound prominence. Its capacity to evoke emotions, stimulate contemplation, and stimulate metamorphosis is really astonishing. Within the pages of "**Cyclotomic Fields**," an enthralling opus penned by a highly acclaimed wordsmith, readers embark on an immersive expedition to unravel the intricate significance of language and its indelible imprint on our lives. Throughout this assessment, we shall delve in to the book is central motifs, appraise its distinctive narrative style, and gauge its overarching influence on the minds of its readers.

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