University of Western Australia
DEPARTMENT OF MATHEMATICS

UWA ACADEMY
FOR YOUNG MATHEMATICIANS

Number Theory II: Problems with Solutions

Greg Gamble

1. Show $7 \mid 2222^{5555} + 5555^{2222}$.

Solution. By Fermat's Little Theorem, for any natural number n

$$n^7 \equiv n \pmod 7.$$

So for natural numbers q and r,

$$n^{7q+r} \equiv (n^7)^q . n^r \pmod 7$$
$$\equiv n^q . n^r \pmod 7$$
$$\equiv n^{q+r} \pmod 7.$$

Below we will use this result repeatedly. First though, observe that

$$2222 \equiv 3 \pmod 7 \quad \text{and} \quad 5555 \equiv 4 \equiv -3 \pmod 7.$$

Thus

$$2222^{5555} + 5555^{2222} \equiv 3^{5555} + (-3)^{2222} \pmod 7$$
$$\equiv 3^{793+4} + (-3)^{317+3} \pmod 7$$
$$\equiv 3^{113+6} + (-3)^{45+5} \pmod 7$$
$$\equiv 3^{17+0} + (-3)^{7+1} \pmod 7$$
$$\equiv 3^{2+3} + (-3)^{1+1} \pmod 7$$
$$\equiv 3^2(3^3 + 1) \pmod 7$$
$$\equiv 3^2 . 28 \pmod 7$$
$$\equiv 0 \pmod 7.$$

Hence $7 \mid 2222^{5555} + 5555^{2222}$.

Solution. *(Alternative)* The above solution is not a particularly clever way of using Fermat's Little Theorem. Since $n^7 - n$ factorises as $n(n^6 - 1)$, it follows from Fermat's Little Theorem that:

If n is a natural number and $n \not\equiv 0 \pmod 7$ then $n^6 \equiv 1 \pmod 7$.

So for natural numbers n, q and r, if $n \not\equiv 0 \pmod 7$ then

$$n^{6q+r} \equiv (n^6)^q . n^r \pmod 7$$
$$\equiv 1^q . n^r \pmod 7$$
$$\equiv n^r \pmod 7.$$

Number Theory Problems Solutions

Ramin Takloo-Bighash

Number Theory Problems Solutions:

Number Theory Titu Andreescu,Dorin Andrica,2009-06-12 This introductory textbook takes a problem solving approach to number theory situating each concept within the framework of an example or a problem for solving Starting with the essentials the text covers divisibility unique factorization modular arithmetic and the Chinese Remainder Theorem Diophantine equations binomial coefficients Fermat and Mersenne primes and other special numbers and special sequences Included are sections on mathematical induction and the pigeonhole principle as well as a discussion of other number systems By emphasizing examples and applications the authors motivate and engage readers **1001 Problems in Classical Number Theory** Armel Mercier, This translation of a French text offers an incomparable collection of problems in number theory with appeal to everyone from the novice to the experienced mathematician The problems are presented in a way that compels the reader to attack the next one eagerly The problems reinforce a passion for both the beauty and lingering mystery of number theory **Unsolved Problems in Number Theory** Richard Guy,2013-03-09 Mathematics is kept alive by the appearance of new unsolved problems problems posed from within mathematics itself and also from the increasing number of disciplines where mathematics is applied This book provides a steady supply of easily understood if not easily solved problems which can be considered in varying depths by mathematicians at all levels of mathematical maturity For this new edition the author has included new problems on symmetric and asymmetric primes sums of higher powers Diophantine m tuples and Conway s RATS and palindromes The author has also included a useful new feature at the end of several of the sections lists of references to OEIS Neil Sloane s Online Encyclopedia of Integer Sequences About the first Edition many talented young mathematicians will write their first papers starting out from problems found in this book Andr s S rk zi MathSciNet **Methods of Solving Number Theory Problems** Ellina Grigorieva,2018-07-06 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 therepresentations 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   111 Problems in Algebra and Number Theory Adrian Andreescu,Vinjai Vale,2016 Algebra plays a fundamental role not only in mathematics but also in various other scientific fields Without algebra there would be no uniform language to express concepts such as numbers properties Thus one must be well versed in this domain in order to improve in other mathematical disciplines We cover algebra as its own branch of mathematics and discuss important techniques that are also applicable in many Olympiad problems Number theory too relies heavily on algebraic machinery Often times the solutions to number theory problems involve several steps Such a solution typically consists of solving smaller problems originating from a hypothesis and ending with a concrete statement that is directly equivalent to or implies the desired condition In this book we introduce a solid foundation in elementary number theory focusing mainly on the strategies which come up frequently in junior level Olympiad problems   **Number Theory** George A. Duckett,2015-12-30 If you have a question about Number Theory this is the book with the answers Number Theory Questions and Answers takes some of the best questions and answers asked on the math stackexchange com website You can use this book to look up commonly asked questions browse questions on a particular topic compare answers to common topics check out the original source and much more This book has been designed to be very easy to use with many internal references set up that makes browsing in many different ways possible Topics covered include prime numbers diophantine equations algebraic number theory sequences and series analytic number theory and many more   **104 Number Theory Problems** Titu Andreescu,Dorin Andrica,Zuming Feng,2007-04-05 This challenging problem book by renowned US Olympiad coaches mathematics teachers and researchers develops a multitude of problem solving skills needed to excel in mathematical contests and in mathematical research in number theory Offering inspiration and intellectual delight the problems throughout the book encourage students to express their ideas in writing to explain how they conceive problems what conjectures they make and what conclusions they reach Applying specific techniques and strategies readers will acquire a

solid understanding of the fundamental concepts and ideas of number theory **Problem-Solving and Selected Topics in Number Theory** Michael Th. Rassias,2010-12-02 The book provides a self contained introduction to classical Number Theory All the proofs of the individual theorems and the solutions of the exercises are being presented step by step Some historical remarks are also presented The book will be directed to advanced undergraduate beginning graduate students as well as to students who prepare for mathematical competitions ex Mathematical Olympiads and Putnam Mathematical competition **A Pythagorean Introduction to Number Theory** Ramin Takloo-Bighash,2018-11-26 Right triangles are at the heart of this textbook s vibrant new approach to elementary number theory Inspired by the familiar Pythagorean theorem the author invites the reader to ask natural arithmetic questions about right triangles then proceeds to develop the theory needed to respond Throughout students are encouraged to engage with the material by posing questions working through exercises using technology and learning about the broader context in which ideas developed Progressing from the fundamentals of number theory through to Gauss sums and quadratic reciprocity the first part of this text presents an innovative first course in elementary number theory The advanced topics that follow such as counting lattice points and the four squares theorem offer a variety of options for extension or a higher level course the breadth and modularity of the later material is ideal for creating a senior capstone course Numerous exercises are included throughout many of which are designed for SageMath By involving students in the active process of inquiry and investigation this textbook imbues the foundations of number theory with insights into the lively mathematical process that continues to advance the field today Experience writing proofs is the only formal prerequisite for the book while a background in basic real analysis will enrich the reader s appreciation of the final chapters *Problems in Number Theory* Adam J Wick,2024-02-11 Welcome to the fascinating world of elementary number theory a branch of mathematics that deals with the properties and relationships of numbers especially the integers This book is designed to introduce readers to the beauty and utility of number theory through a collection of problems and their solutions Whether you are a student educator or enthusiast this book aims to enhance your understanding of number theory in an engaging and accessible manner Number theory is often considered the queen of mathematics due to its ancient origins and pure nature It is a field that has captivated mathematicians for centuries from the early discoveries of Euclid and Diophantus to the groundbreaking work of Fermat Euler Gauss and beyond The allure of number theory lies not only in its rich history but also in its applicability to modern day cryptography computer science and problem solving This book is structured to cater to a wide audience from beginners to those with some background in number theory The problems presented range from simple exercises that reinforce basic concepts to more challenging questions that stimulate deeper thinking and exploration Each problem is carefully selected and crafted to illustrate a particular aspect of number theory with solutions provided to guide the reader through the thought process and techniques involved The journey through this book begins with the fundamentals of divisibility primes and the Euclidean

algorithm gradually progressing to more complex topics such as congruences and Diophantine equations Along the way readers will encounter famous theorems and conjectures that have shaped the field including the Fundamental Theorem of Arithmetic Fermat s Little Theorem and Wilson s theorem Our goal is not only to solve problems but also to cultivate a deeper appreciation for the elegance of mathematical concepts We encourage readers to actively engage with the material to explore beyond the solutions provided and to discover the joy of uncovering truths for themselves In preparing this book we have drawn upon a wealth of sources including classic texts and contemporary research to ensure a comprehensive and enriching experience We are grateful to the many mathematicians whose work has inspired and informed these pages and we hope to pass on a fraction of their passion for number theory to our readers Whether you are embarking on this journey out of curiosity academic interest or the pursuit of mathematical beauty we welcome you May this book serve as a valuable resource and companion as you explore the intriguing world of elementary number theory   The Math Problems Notebook Valentin Boju,Louis Funar,2007-08-15 This volume offers a collection of non trivial unconventional problems that require deep insight and imagination to solve They cover many topics including number theory algebra combinatorics geometry and analysis The problems start as simple exercises and become more difficult as the reader progresses through the book to become challenging enough even for the experienced problem solver The introductory problems focus on the basic methods and tools while the advanced problems aim to develop problem solving techniques and intuition as well as promote further research in the area Solutions are included for each problem   Problems And Solutions In Real Analysis (Second Edition) Masayoshi Hata,2016-12-12 This second edition introduces an additional set of new mathematical problems with their detailed solutions in real analysis It also provides numerous improved solutions to the existing problems from the previous edition and includes very useful tips and skills for the readers to master successfully There are three more chapters that expand further on the topics of Bernoulli numbers differential equations and metric spaces Each chapter has a summary of basic points in which some fundamental definitions and results are prepared This also contains many brief historical comments for some significant mathematical results in real analysis together with many references Problems and Solutions in Real Analysis can be treated as a collection of advanced exercises by undergraduate students during or after their courses of calculus and linear algebra It is also instructive for graduate students who are interested in analytic number theory Readers will also be able to completely grasp a simple and elementary proof of the Prime Number Theorem through several exercises This volume is also suitable for non experts who wish to understand mathematical analysis   **Advanced Algebra** Anthony W. Knapp,2007-10-11 Basic Algebra and Advanced Algebra systematically develop concepts and tools in algebra that are vital to every mathematician whether pure or applied aspiring or established Advanced Algebra includes chapters on modern algebra which treat various topics in commutative and noncommutative algebra and provide introductions to the theory of associative algebras homological algebras algebraic number theory and algebraic geometry Together the two books

give the reader a global view of algebra its role in mathematics as a whole and are suitable as texts in a two semester advanced undergraduate or first year graduate sequence in algebra **Elementary Number Theory** George A. Duckett,2016-05-17 If you have a question about Elementary Number Theory this is the book with the answers Elementary Number Theory Questions and Answers takes some of the best questions and answers asked on the math stackexchange com website You can use this book to look up commonly asked questions browse questions on a particular topic compare answers to common topics check out the original source and much more This book has been designed to be very easy to use with many internal references set up that makes browsing in many different ways possible Topics covered include Prime Numbers Number Theory Divisibility Diophantine Equations Contest Math Modular Arithmetic Algebra Precalculus Factorial Recreational Mathematics Combinatorics Sequences And Series Abstract Algebra Arithmetic Discrete Mathematics Induction Fibonacci Numbers Summation Proof Verification Reference Request Totient Function and many more **Number Theory** David Chudnovsky,Gregory Chudnovsky,Harvey Cohn,Melvyn Bernard Nathanson,1984 *Introduction to Number Theory Solutions Manual* Mathew Crawford,2008 The American Mathematical Monthly ,1929 Includes section Recent publications *Mathematical Creativity and Mathematical Giftedness* Florence Mihaela Singer,2018-03-07 This book discusses the relationships between mathematical creativity and mathematical giftedness It gathers the results of a literature review comprising all papers addressing mathematical creativity and giftedness presented at the International Congress on Mathematical Education ICME conferences since 2000 How can mathematical creativity contribute to children s balanced development What are the characteristics of mathematical giftedness in early ages What about these characteristics at university level What teaching strategies can enhance creative learning How can young children s mathematical promise be preserved and cultivated preparing them for a variety of professions These are some of the questions addressed by this book The book offers among others analyses of substantial learning environments that promote creativity in mathematics lessons discussions of a variety of strategies for posing and solving problems investigations of students progress throughout their schooling and examinations of technological tools and virtual resources meant to enhance learning with understanding Multiple perspectives in the interdisciplinary fields of mathematical creativity and giftedness are developed to offer a springboard for further research The theoretical and empirical studies included in the book offer a valuable resource for researchers as well as for teachers of gifted students in specialized or inclusive settings at various levels of education
Number Theory - Structures, Examples and Problems Nik Pachis,2016-04-01 Number theory branch of mathematics concerned with properties of the positive integers Sometimes called higher arithmetic it is among the oldest and most natural of mathematical pursuits Number theory has always fascinated amateurs as well as professional mathematicians In contrast to other branches of mathematics many of the problems and theorems of number theory can be understood by laypersons although solutions to the problems and proofs of the theorems often require a sophisticated mathematical

background Number theory is a vast and fascinating field of mathematics sometimes called higher arithmetic consisting of the study of the properties of whole numbers Primes and prime factorisation are especially important in number theory as are a number of functions such as the divisor function Riemann zeta function and totient function Number theory is an ongoing rich area of mathematical exploration with connections and applications to other fields from representation theory to physics cryptography and more While the forefront of number theory is replete with sophisticated and famous open problems at its foundation are basic elementary ideas that can stimulate and challenge beginning students This book Number Theory Structures Examples and Problems focuses on a problem solving approach to the subject *Mathematical Pamphlets* Louis Charles Karpinski,1915

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