Chapter 1 : American River Software - Elementary Number Theory, by David M. Burton

Elementary Number Theory, by David M. Burton The downloadable files below, in PDF format, contain answers to the exercises from chapters 1 - 9 of the 5th edition. To download any exercise to your computer, click on the appropriate file.

The work is well suited for prospective secondary school teachers for whom a little familiarity with number theory may be particularly helpful. The theory of numbers has always occupied a unique position in the world of mathematics. This is due to the unquestioned historical importance of the subject: Nearly every century since classical antiquity has witnessed new and fascinating discoveries relating to the properties of numbers; and, at some point in their careers, most of the great masters of the mathematical sciences have contributed to this body of knowledge. Why has number theory held such an irresistible appeal for the leading mathematicians and for thousands of amateurs? One answer lies in the basic nature of its problems. Although many questions in the field are extremely hard to decide, they can be formulated in terms simple enough to arouse the interest and curiosity of those with little mathematical training. Some of the simplest sounding questions have withstood intellectual assaults for ages and remain among the most elusive unsolved problems in the whole of mathematics. It therefore comes as something of a surprise to find that many students look upon number theory with good-humored indulgence, regarding it as a frippery on the edge of mathematics. This no doubt stems from the widely held view that it is the purest branch of pure mathematics and from the attendant suspicion that it can have few substantive applications to real-world problems. Hardy, the best known figure of 20th century British mathematics, once wrote, "Both Gauss and lesser mathematicians may be justified in rejoicing that there is one science at any rate, and that their own, whose very remoteness from ordinary human activities should keep it clean and gentle. Leaving practical applications aside, the importance of number theory derives from its central position in mathematics; its concepts and problems have been instrumental in the creation oflarge parts of mathematics. Few branches of the discipline have absolutely no connection with the theory of numbers. The past few years have seen a dramatic shift in focus in the undergraduate curriculum away from the more abstract areas of mathematics and toward applied and computational mathematics. With the increasing latitude in course choices, one commonly encounters the mathematics major who knows little or no number theory. This is especially unfortunate, because the elementary theory of numbers should be one of the very best subjects for early mathematical instruction. It requires no long preliminary training, the content is tangible and familiar, and-more than in any other part of mathematics-the methods of inquiry adhere to the scientific approach. The student working in the field must rely to a large extent upon trial and error, in combination with his own curiosity, intuition, and ingenuity; nowhere else in the mathematical disciplines is rigorous proof so often preceded by patient, plodding experiment. If the going occasionally becomes slow and difficult, one can take comfort in that nearly every noted mathematician of the past has traveled the same arduous road. There is a dictum that anyone who desires to get at the root of a subject should first study its history. Endorsing this, we have taken pains to fit the material into the larger historical frame. In addition to enlivening the theoretical side of the text, the historical remarks woven into the presentation bring out the point that number theory is not a dead art, but a living one fed by the efforts of many practitioners. They reveal that the discipline developed bit by bit, with the work of each individual contributor built upon the research of many others; often centuries of endeavor were required before significant steps were made. A student who is aware of how people of genius stumbled and groped their way through the creative process to arrive piecemeal at their results is less likely to be discouraged by his or her own fumblings with the homework problems. A word about the problems. Most sections close with a substantial number of them ranging in difficulty from the purely mechanical to challenging theoretical questions. The computational exercises develop basic techniques and test understanding of concepts, whereas those of a theoretical nature give practice in constructing proofs. Besides conveying additional information about the material covered earlier, the problems introduce a variety of ideas not treated in the body of the text. We have on the whole resisted the temptation to use the problems to introduce results that will be needed thereafter. Problems whose solutions do not appear straightforward are frequently accompanied by hints. The text was written with the mathematics major in mind; it is equally valuable for education or computer science majors minoring in mathematics. Very little is demanded in the way of specific prerequisites. A significant portion of the book can be profitably read by anyone who has taken the equivalent of a first-year college course in mathematics. Those who have had additional courses will generally be better prepared, if only because of their enhanced mathematical maturity. In particular, a knowledge of the concepts of abstract algebra is not assumed. When the book is used by students who have had an exposure to such matter, much of the first four chapters can be omitted. Our treatment is structured for use in a wide range of number theory courses, of varying length and content. Even a cursory glance at the table of contents makes plain that there is more material than can be conveniently presented in an introductory one-semester course, perhaps even enough for a full-year course. This provides flexibility with regard to the audience, and allows topics to be selected in accordance with personal taste. Experience has taught us that a semester-length course having the Quadratic Reciprocity Law as a goal can be built up from Chapters 1 through 9. It is unlikely that every section in these chapters need be covered; some or all of Sections 5. The text is also suited to serve a quarter-term course or a six-week summer session. For such shorter courses, segments of further chapters can be chosen after completing Chapter 4 to construct a rewarding account of number theory. Chapters 10 through 16 are almost entirely independent of one another and so may be taken up or omitted as the instructor wishes. Probably most users will want to continue with parts of Chapter 10, while Chapter 14 on Fibonacci numbers seems to be a frequent choice. These latter chapters furnish the opportunity for additional reading in the subject, as well as being available for student presentations, seminars, or extra-credit projects. Number theory is by nature a discipline that demands a high standard of rigor. Thus our presentation necessarily has its formal aspect, with care taken to present clear and detailed arguments. An understanding of the statement of a theorem, not the proof, is the important issue. Regrettably, it is all too easy for some students to become discouraged by what may be their first intensive experience in reading and constructing proofs. An instructor might ease the way by approaching the beginnings of the book at a more leisurely pace, as well as restraining the urge to attempt all the interesting problems. Nevertheless, the preparation of this sixth edition has Xii PREFACE provided the opportunity for making a number of small improvements, and several more significant ones. The advent and general accessibility of fast computers has had a profound effect on almost all aspects of number theory. This influence has been particularly felt in the areas of primality testing, integers factorization, and cryptographic applications. Consequently, the exposition on cryptosystems has been considerably expanded and now appears as Chapters 10, Introduction to Cryptography. Another addition with an applied flavor is the inclusion of the continued fraction factoring algorithm in Section An understanding of the procedure does not require a detailed reading of Chapter The expanded Section An instructor who wishes to include computational number theory should find these optional topics particularly appealing. There are others less-pronounced, but equally noteworthy, changes in the text. The resolution of certain challenging conjectures-especially the confirmation of the Catalan Conjecture and that of the composite nature of the monstrous Fermat number F31 -likewise receives our attention. These striking achievements affirm once again the vitality of number theory as an area of research mathematics. Beyond these specific modifications are a number of relatively minor enhancements: An attempt has been made to correct any minor errors that crept into the previous edition. The advice of the following reviewers was particularly helpful: A special debt of gratitude must go to my wife, Martha, whose generous assistance with the book at all stages of development was indispensable. The author must, of course, accept the responsibility for any errors or shortcomings that remain. The origin of this misnomer harks back to the early Greeks for whom the word number meant positive integer, and nothing else. The natural numbers have been known to us for so long that the mathematician Leopold Kronecker once remarked, "God created the natural numbers, and all the rest is the work of man. We shall make no attempt to construct the integers axiomatically, assuming instead that they are already given and that any reader of this book is familiar with many elementary facts about them. Among these is the Well-Ordering Principle, stated here to refresh the memory. Every nonempty set S of nonnegative integers contains a least element; that is, there is some integer a inS such that a:: If a and b are any positive integers, then there exists a positive integer n such that na ; By the Well-Ordering Principle, S will possess a least element, say, b- ma. This contradiction arose out of our original assumption that the Archimedean property did not hold; hence, this property is proven true. With the Well-Ordering Principle available, it is an easy matter to derive the First Principle of Finite Induction, which provides a basis for a method of proof called mathematical induction. Loosely speaking, the First Principle of Finite Induction asserts that if a set of positive integers has two specific properties, then it is the set of all positive integers. To be less cryptic, we state this principle in Theorem 1. Let S be a set of positive integers with the following properties: Then S is the set of all positive integers. Let T be the set of all positive integers not in S, and assume that T is nonempty. The Well-Ordering Principle tells us that T possesses a least element, which we denote by a. The choice of a as the smallest positive integer in T implies that a - 1 is not a member of T, or equivalently that a- 1 belongs to S. We conclude that the set T is empty and in consequence that S contains all the positive integers. Here is a typical formula that can be established by mathematical induction: In anticipation of using Theorem 1. Although mathematical induction provides a standard technique for attempting to prove a statement about the positive integers, one disadvantage is that it gives no aid in formulating such statements. Of course, if we can make an "educated guess" at a property that we believe might hold in general, then its validity can often be tested by the induction principle. The pattern emerging from these few cases suggests a formula for obtaining the value of the 4.

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Elementary Number Theory, Seventh Edition, is written for the one-semester undergraduate number theory course taken by math majors, secondary education majors, and computer science students. This contemporary text provides a simple account of classical number theory, set against a historical background that shows the subject's evolution from.