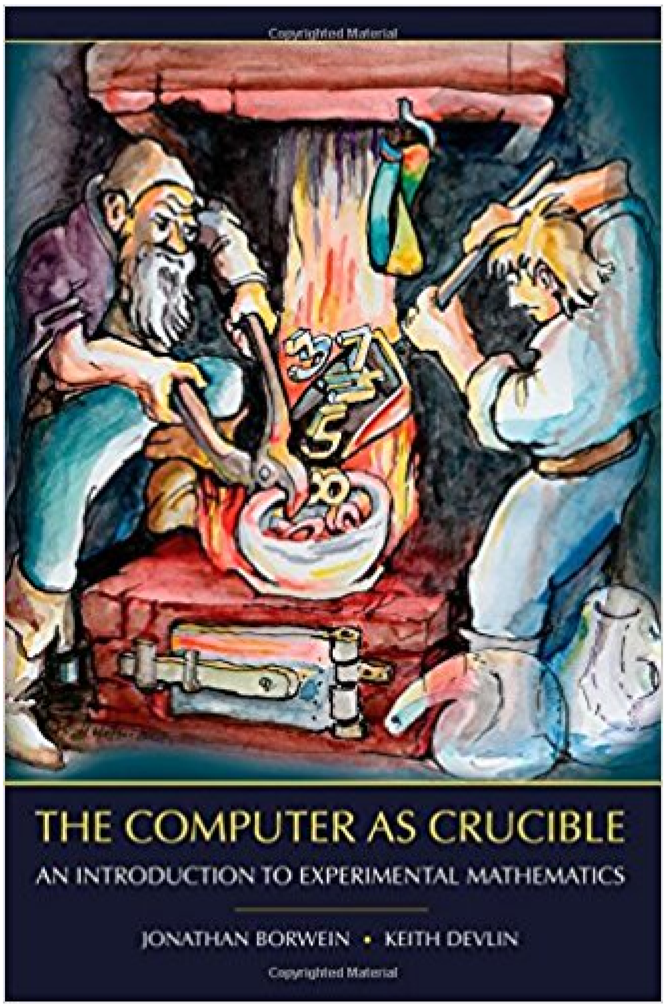
The Computer As Crucible: An Introduction To Experimental Mathematics



Synopsis

Keith Devlin and Jonathan Borwein, two well-known mathematicians with expertise in different mathematical specialties but with a common interest in experimentation in mathematics, have joined forces to create this introduction to experimental mathematics. They cover a variety of topics and examples to give the reader a good sense of the current state of play in the rapidly growing new field of experimental mathematics. The writing is clear and the explanations are enhanced by relevant historical facts and stories of mathematicians and their encounters with the field over time.

Book Information

Paperback: 170 pages

Publisher: A K Peters/CRC Press (October 30, 2008)

Language: English

ISBN-10: 1568813430

ISBN-13: 978-1568813431

Product Dimensions: 5.9 x 0.4 x 8.9 inches

Shipping Weight: 8.8 ounces (View shipping rates and policies)

Average Customer Review: 4.4 out of 5 stars 2 customer reviews

Best Sellers Rank: #1,926,325 in Books (See Top 100 in Books) #88 inÃ Â Books > Science & Math > Mathematics > Research #296 inÃ Â Books > Science & Math > Mathematics > Number Systems #572 inÃ Â Books > Humor & Entertainment > Puzzles & Games > Math Games

Customer Reviews

The long experience of both authors can be clearly seen in the way they describe a number of problems Ã¢â ¬Â¦ they succeeded in exactly the right balance between mathematical depth and accessibility for a wide audience. The result is an easily digestible book full of humor for anyone with an affinity for mathematics Ã¢â ¬Â¦Ã¢â ¬â ¢Dan Roozemond, Nieuw Archief voor Wiskunde The sleuth-like style and lucid writing certainly make this book an enjoyable read. Many explanations are framed by relevant historical context and tales of mathematicians whose use of experimental mathematics helped them gain insights into difficult problems. . . . I thoroughly enjoyed reading this short introduction to experimental mathematics. It will no doubt appeal to a broad mathematical audience, both professional and amateur alike.Ã¢â ¬â ¢Mitch Wheat, Gazette of the Australian Mathematical Society, July 2009 It is a pleasant and readable book for any working mathematician who wants to know something more about the use of computers for generating hypotheses on relations among known and less known special numbers.Ã¢â ¬â ¢Newsletter of the European

Mathematical Society, June 2009 ... allows [the reader] to take a look at some interesting problems and solve [them] using [a] computer. The authors are showing how a mathematician can use a computer as a tool. ... The book covers a variety of topics and examples in order to give the reader a good sense of the current state of play in the rapidly growing new field of experimental mathematics. ... The writing is clear and the explanations are enhanced by relevant historical facts and stories of mathematicians and their encounters with the field over time. The book will be of interest to any reader who would like to taste the solving of mathematical problems with a computer. No matter if readers may not have much mathematical knowledge: they can catch the essentials with the book, and have fun exploring some questions.Ã¢â ¬â ¢Valentina Dagiene, Zentralblatt MATH, September 2009 ...Ã Â a pleasant and readable book for any working mathematician who wants to know something more about the use of computers for generating hypotheses on relations among known and less known special numbers.Ã¢â ¬â ¢EMS Newsletter, June 2009 ...Ã Â a lovely little book which builds a strong case for experimental mathematics. Any practicing mathematician or serious amateur should consider checking out this introduction to a topic that will no doubt transform mathematics.Ã¢â ¬â ¢Antonio Cangiano, Math-Blog.com, July 2010

Jonathan Borwein received his PhD from Oxford University as a Rhodes Scholar and is a professor of mathematics and computer science at Dalhousie University in Canada. He is the author of seminal works in the growing field of experimental mathematics, including Mathematics by Experimentand Experimental Mathematics in Action . Keith Devlin is Executive Director and Senior Researcher at the Center for the Study of Language and Information at Stanford University. He is the author of many books and articles that popularize mathematics and is the Math Guy for National Public Radio. He is the author of The Unfinished Game and The Math Instinct, among many others.

A good and interesting first view of the field of experimental mathematics.

Jonathan Borwein and Keith Devlin are well-known mathematicians who have a strong appreciation of, and expertise in, experimental mathematics. In this book they provide us with a concise, inviting introduction to the field.The first chapter tries to succinctly explain what experimental mathematics is and why it’s a fundamental tool for the modern mathematician. The following is their definition:"Experimental mathematics is the use of a computer to run computations--sometimes no more than trial-and-error tests--to look for patterns, to identify particular numbers and sequences, to gather evidence in support of specific mathematical assertions that may themselves arise by computational means, including search. Like contemporary chemists--and before them the alchemists of old--who mix various substances together in a crucible and heat them to a high temperature to see what happens, today's experimental mathematician puts a hopefully potent mix of numbers, formulas, and algorithms into a computer in the hope that something of interest emerges."They immediately address some of the possible objections and illustrate how an approach that doesn't focus on formal proof, but rather on exploration and experimentation, ultimately leads to hypotheses which can then be, in many cases, proved analytically. The authors argue that in this sense, thanks to the aid of advanced computers, mathematics is becoming more and more similar to other natural sciences.They also make a case for how great mathematicians like Euler, Gauss, and Reimann were doing experimental mathematics well before calculators where available. Their calculations on paper were far more limited than what computers afford us these days, yet they served them well when it came to sharpening and verifying their intuitions.The rest of the book is a continuous series of examples that show the advantages of this approach in practice. The examples are highly interesting (some of them stunning) and tend to focus on calculus, analysis and analytical number theory. Each chapter is accompanied by a section called "Explorations". I found this section to be particularly valuable. Within it you'll find exercises, and further examples and considerations. The answers/solutions to the actual problems are provided in the second to last chapter, just before the brief epilogue.Chapter 2 discusses how to calculate an arbitrary digit for irrational numbers like pi, in certain bases. They illustrate how the so called BBP Formula (Bailey-Borwein-Plouffe formula, co-discovered by Jonathan Borwein's brother) came to be. The use of a program which implements the PSQL integer relation algorithm in high-precision, floating-point arithmetic was key to its discovery. The BBP Formula in turn allowed the calculation of the quadrillionth binary digit of pi back in 2000.Chapter 3 focuses on identifying numbers, digits patterns, and sequences once you obtain a numeric result through your calculations and experimentation. They introduce the subject with relatively obvious values like the approximations of e - 2 or pi + e/2, but the chapter quickly escalates to an example where a closed form for a seemingly random sequence needs to be found.Chapter 4 analyzes the Reimann Zeta function from the eyes of an experimental mathematician, and shows us what kind of insight we can gain from this unique perspective.In chapter 5 we learn how by numerically evaluating definite integrals, it is sometimes possible to identify the resulting value which will help us to analytically resolve those particular integrals. The examples presented in this chapter originate for the most part from physics and are very challenging if attempted without the aid of experimental methods. The explorations section provides a few more interesting integrals, including some for which a closed form is not known. The authors even include an integral that intentionally stumps Mathematica 6 and Maple 11.Chapter 6 is dedicated to serendipitous discoveries ("proof by serendipity") with a few interesting examples of how "luck" met preparation, ultimately enriching the body of mathematical knowledge almost by chance.In chapter 7 the authors go back to talk about pi, this time in base 10, to calculate its digits with efficient, fast converging formulas and methods. The chapter wraps up with a discussion about the normality of pi, which hasn't been proven of course, but appears to be empirically supported by the statistical analysis of the first trillion digits. In the explorations section there is a nice discussion about the implementation of fast arithmetic through the Karatsuba multiplication, and the subject of Montecarlo simulations (a very inefficient method of calculating pi, but a great way to show the idea behind Montecarlo simulations).Chapter 8 has a bold title, "The computer knows more math than you do". This provocative title is quickly diminished to put it in context though. The authors start by approaching a tough problem posed by Donald Knuth (of TeX andÃ Â Art of Computer ProgrammingÃ Â fame) to the readers of the American Mathematical Monthly. In an attempt to solve this the authors invite us to go on a journey involving the Lambert W function, the Pochhammer function, and Abel's limit theorem. The rest of the chapter illustrates another difficult problem whose solution obtained through the aid of Maple has important implications not only for mathematics, but also for quantum field theory and statistical mechanics.In chapter 9 a few infinite series are calculated in order to show how CAS systems and experimental methodology can still be useful when dealing with problems that involve infinite sequences, series, and products.Chapter 10 is dedicated to the limits and the dangers of this approach. Several examples showcase how one can be misled into making assumptions, and how to avoid this from happening.In chapter 11, conscious of the selective focus on analysis and analytical number theory throughout the book, Borwein and Devlin introduce other examples such as a topology problem whose proof was reached thanks to a deeper insight gained through computer visualization of a surface, a knot theory problem, the Four Color Theorem, the Robbins Conjecture, the computation of E_8, and so on. In truth, I feel that such a thin book could have used more examples like the ones in chapter 11, in order to make a stronger case for the applicability of experimental mathematics to areas outside of analysis.The book is well written and the tone is never heavy, despite the advanced mathematical examples within it. The authors include historical background and anecdotes which makes for a more interesting read and provides a human perspective behind the formulas presented. The (at times) funny illustrations and occasional jokes are definitely a pleasant addition.This book is relatively tool agnostic; Maple and Mathematica are referenced throughout, and so are a few online tools to identify number sequences and known numeric values. Overall though, the emphasis in on the methodology rather than a particular CAS (Computer Algebra System) or programming language. In fact, with the exception of a snippet of Maple code in one of the explorations in the first chapter, the book describe the examples from a mathematical and algorithmic standpoint. You won’t find source code for the examples illustrated.The ideal target audience for The Computer as Crucible is graduate students and researchers. A bright, motivated high-school student will get the gist of this book, but a more mature mathematical audience will actually be able to follow the steps within the examples and fully appreciate the insight on how an experimental approach can aid their research.Despite the numerous examples employed to make their case, the authors start the book by explaining that it is not intended to be comprehensive. It’s meant to be thought provoking and to whet your appetite as to what is now possible in mathematical research thanks to computers.As a computer programmer who’s passionate about mathematics, experimental mathematics fascinates me greatly. As such, I hope to work my way through the actual textbooks that are generally suggested as a follow up to this book. Namely, I’ve already started readingÃ Â Mathematics by Experiment, which is co-authored by Jonathan Borwein himself. Other textbooks referenced in this introduction areÃ Â Experimental Mathematics in ActionÃ Â andÃ Â Experimentation in Mathematics: Computational Paths to Discovery.In conclusion, The Computer as Crucible is a lovely little book which builds a strong case for experimental mathematics. Any practicing mathematician or serious amateur should consider checking out this introduction to a topic that will no doubt transform mathematics.Full disclosure: I received a complimentary copy of this book for review.

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