USING MATHEMATICA FOR SCIENCE: TWO NEW BOOKS SHOW THE WAY

Mathematica for the Sciences

Richard E. Crandall
Addison–Wesley, San Diego, Calif., 1991. 300 pp. $35.50 hc ISBN 0-201-151001-4

Mathematica in Action

Stan Wagon
Freeman, New York, 1991. 419 pp. $29.95 pb ISBN 0-7167-2202-X

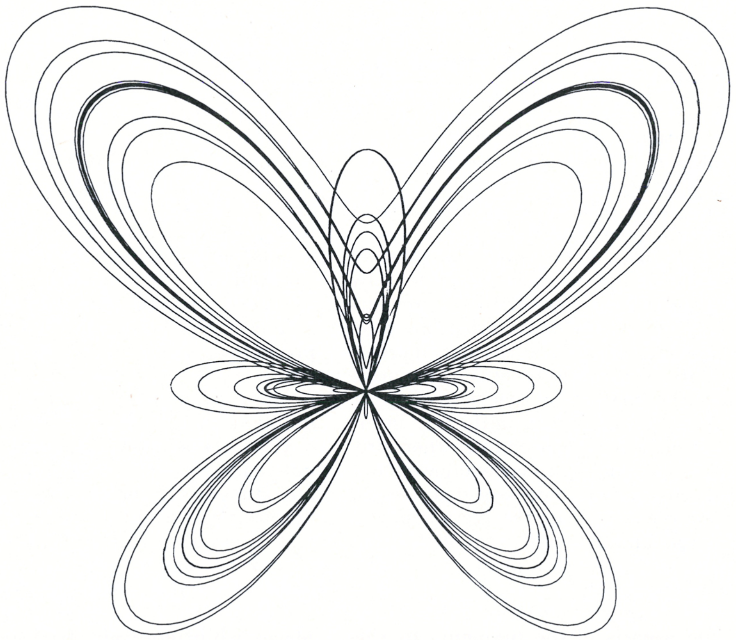
Reviewed by Cyrus Taylor

Mathematica, a software product of Wolfram Research, is billed as a "system for doing mathematics by computer." As such, it promises to revolutionize the way we do physics in the office or laboratory as well as in the classroom. In response to the interest generated by these promises a number of Mathematica instruction books have now appeared.

Mathematica for the Sciences, by Richard Crandall, is a book that, while not self-contained, is a delight to work through. After several introductory chapters on the graphical, analytical and numerical powers of Mathematica, the reader is led through a series of stimulating examples from physics, biology, chemistry, mathematics and engineering. Each example follows essentially the same format. First there is a very brief introduction to the problem together with an outline of the analysis leading to the equations to be solved. This analysis is followed by the Mathematica code, which implements the solution. Mathematica output is displayed at the end of each example.

In general, this format seems to be effective for stimulating users to apply Mathematica in a variety of fields.

Cyrus Taylor is an assistant professor of physics at Case Western Reserve University, whose research is in theoretical high-energy physics. His use of Mathematica in the classroom has been described in *Computers in Physics* **5**, 16 (1991).



Butterfly curve is the image (rotated 90°) of the polar function $r = e^{\cos\theta} + 2\cos 4\theta + \sin^5(\theta/12)$ generated with Mathematica commands. (From *Mathematica in Action*.)

Almost any reader with a background in some area of science or engineering should find a number of familiar problems together with the Mathematica input that will generate a solution. Problems of interest to physicists include an exploration of Hamiltonian dynamics, a variety of oscillator problems, a treatment of the action of relativistic particles, an introduction to solitons and quantum mechanical discussions of the hydrogen and helium atoms. The solutions frequently emphasize the graphical power of Mathematica, and I have found them to be very useful in suggesting applications suitable for classroom demonstrations.

The drawback of this format is that the introduction to each problem is usually too terse to be immediately accessible to readers who are not already familiar with the problem and, frequently, the method of solution. For example, I was happy with Crandall's discussion of the solution of the hydrogen atom by a finite element method, but perhaps only because I was already familiar with the reference on which the treatment was based. Conversely, the discussion of the Hodgkin–Huxley system governing the propagation of action potentials along nerve axons (a topic with which I am *not* familiar) was on first reading not very useful to me. To be fair, I doubt that it would be possible to approach the breadth of coverage in *Mathematica for the Sciences* at a depth suitable for the general reader without massively expanding the book. Crandall has adopted the necessary expedient of falling back on references to fill in these gaps, and his choice of references seems to be uniformly excellent.

Stan Wagon's *Mathematica in Action* is a more systematic guide to many of the more interesting uses of Mathematica. Wagon achieves a greater depth of coverage by narrowing the scope of the applications. These applications are largely mathematical in nature, ranging from a Mathematica implementation of a public-key encryption algorithm through Penrose tiles, the dynamics of the quadratic map, map-coloring on a torus and animations of the tautochrone and brachistochrone properties of the cycloid, to more formal problems, such as linear diophantine equations, prime certifications and properties of the Riemann ζ function.

The organizing principle of Wagon's book is the use of Mathematica in tackling such problems. The book begins with an introduction to Mathematica, and it should therefore be accessible to those with no previous experience using the program. Succeeding chapters introduce increasingly powerful uses of Mathematica in the context of specific examples, each discussed in a uniformly interesting way. Each chapter then presents Mathematica code followed by a discussion of important features of the code. Frequently, more sophisticated (and more efficient) approaches to the same problem are presented. The more efficient routines are then used to tackle more subtle or interesting aspects of the problem. In this way, *Mathematica in Action* is a marvelous textbook, allowing the reader to explore some fascinating areas of mathematics while at the same time developing proficiency in the use of Mathematica.

A Unified Grand Tour of Theoretical Physics

Ian D. Lawrie
Adam Hilger, Bristol, UK (US dist. AIP, New York), 1990. 380 pp. $39.00 pb ISBN 0-85274-01-5

What do relativity, gravitation, elementary particles, quantum field theory, statistical physics and phase transitions have in common? The short answer is that all these topics are described, with lucidity, depth and charm, in *A Unified Grand Tour of Theoretical Physics.*

To give the long answer is part of the task that the author, Ian D. Lawrie, has set for himself in this voyage through theoretical physics. His aim is to describe its foundations in a single, portable volume and to point out along the way the mathematical and physical similarities and the connections between the various fields that have led to fruitful interplay among them in recent years.

This is not a book about the incredibly diverse phenomena that are the concern of physics. Rather, the focus is on mathematical structures and tools. The first two-thirds consists of succinct but fairly complete reviews of the foundations of classical mechanics and electrodynamics, special and general relativity, and quantum theory, followed by a 100-page primer on relativistic quantum field theory. The primer includes not only the standard material on relativistic wave equations and second quantization but also an introduction to quantum electrodynamics, non-Abelian gauge theories, renormalization and path-integral techniques. Following an additional chapter on the theoretical framework of equilibrium statistical mechanics, the book reaches its climax with the application of the preceding formalism to the study of phase transitions, to unified theories of the fundamental interactions and finally to the early universe.

The intended audience includes "final-year undergraduates" and graduate students in physics as well as "professional scientists and engineers who are not theoretical physicsts." However, most college seniors and first-year graduate students will find the treatment too technical in some places, while more advanced students will sometimes find the discussion (in the treatment of renormalization, for instance) not technical enough. Sometimes neither group is well served. For example, the appendix on the Dirac δ function is too brief to be of help to someone who has not encountered it before and unnecessary for someone who has. But this book is not an ordinary "how-to" textbook; it is a panoramic guide for the serious tourist, who may want to supplement Lawrie's overall picture with further study. On the whole, Lawrie draws the line rather well: By keeping references to experimental facts to an absolute minimum, by adroitly using chapter-end exercises that prompt the eager reader to prove assertions made in the text and by stressing the essentials at all times, he largely succeeds in his goals.

Surprisingly, this is not a dry, mathematical tome. The writing is relaxed and conversational, spiced with humorous asides and leavened with an occasional refreshing admission of ignorance. For example, in a discussion of the 256-component Riemann tensor, we are warned: "Readers should not panic yet"; in connection with the Schwarzschild radius, Lawrie tells us: "Remember that . . . it does not follow that there is a black hole lurking at the center of the Earth!" Lawrie manages to infuse even a discussion of natural units with some drama: "The fact that momentum does not ordinarily appear to us as an inverse wavelength is, in my view, one of the deep unsolved mysteries of the interpretation of quantum theory."

Here and there I found typographical errors (practically impossible to avoid in a work of this kind), an occasional notational idiosyncracy and assertions that struck me as opaque or questionable. But by and large the book is remarkably free of such defects.

Passengers on this "unified grand tour" are not likely to emerge from the journey as practitioners, yet few will ask for their money back. While the exact degree of satisfaction will vary with the experience of the traveler, she or he will gain an overview of modern theoretical physics that would be difficult to get elsewhere in such an enjoyable way. Regrettably, the typical American undergraduate in physics lacks the background to reap the full benefit of this book. But it is perfect for an ambitious graduate student, an adventurous scientist in another field or even an aging physics professor who has devoted himself to a specialty and would relish an excursion into unfamiliar territory.

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Lonely Hearts of the Cosmos: The Scientific Quest for the Secret of the Universe

Dennis Overbye
Harper–Collins, New York, 1991. 438 pp. $25.00 hc ISBN 0-06-015964-2

Attempts to bring the scientific enterprise to popular audiences mostly fail by way of authorship. At one extreme are prominent scientists, whose license to write is won by concentrating on their subjects, not on writing. However, familiarity with the language and with their specialties supplies sufficient hubris to produce these works, and the beckoning maw of library standing orders encourages avaricious editors to speed these often