as it is true today for global navigation and the preeminence of US military capabilities.

Even more interesting to the physicist, perhaps, is the fact that the development of atomic clocks was inseparably intertwined with advances in spectroscopy. Who doesn't know the Stern–Gerlach experiment? Who hasn't heard of I. I. Rabi or Charles Townes? More recently, Hans Dehmelt, Wolfgang Pauli and Norman Ramsey received the 1989 Nobel Prize in Physics for their work on atomic beams and ion traps, which are at the core of today's atomic clocks. Even more recently, the 1997 Nobel Prize in Physics was awarded to Steven Chu, William Phillips and Claude Cohen-Tannoudji for their work on trapping and cooling atoms, work that may lead to a next generation of atomic clocks with precision in excess of 10^{-18}.

Fouad G. Major captures this excitement in his very impressive but slightly flawed (see below) book *The Quantum Beat: The Physical Principles of Atomic Clocks*. He begins with a description of celestial and mechanical clocks and ends with laser cooling of atoms. On this road, which takes him from prehistoric times to speculation about tomorrow's feats in physics and technology, Major's stops include quartz clocks, today's atomic clocks and trapped ion systems, as well as resonance-stabilized lasers.

The author's several decades of association with the field include developing NASA's mercury ion frequency standard. The authenticity of the book is enhanced by the author's close connection with leading physicists who were willing to review the text; they include Nobel laureates Ramsey and Cohen-Tannoudji, as well as Claude Audoin, who authored (together with Jacques Vanier) the most comprehensive and in-depth treatment available today of atomic clocks, *The Quantum Physics of Atomic Frequency Standards* (Institute of Physics, 1989).

The author claims that he wrote his book for nonspecialists with some knowledge of physics or engineering. He achieves this objective as far as the core portions of the book are concerned; most notably, this includes the chapters on clocks (mechanical, quartz, rubidium, cesium, hydrogen, lasers and, finally, trapping and cooling of ions and atoms). Using historical developments as his primary ordering principle, Major focuses correctly and instructively first on the discovery and use of periodic phenomena such as the day and the year, then on oscillators and, finally, in the heart and soul of his book, the quest for spectroscopy of atoms at rest, unperturbed in free space. The degree to which this ideal is approximated governs the accuracy and precision of the atomic clock, which today, with commercially produced devices, range between 10^{-11} and 10^{-14}. Just to remind the reader, 10^{-14} corresponds to timekeeping of 1 ns per day, and 1 ns translates into one foot positioning using electronic means—that is, distance determination through clocking the propagation of electromagnetic signals, which, as we all know, occur with the speed of light.

In view of this expert treatment of the core features of the book, it is somewhat disappointing to read the interspersed excursions into the fundamentals of engineering and physics. The reader is treated to the wave equation, Fourier analysis, the Schrödinger equation and the atom model, all subjects where the author's otherwise splendidly achieved avoidance of mathematics is reversed and equations are the explanation. Worse, these sections, which are not needed for the core sections, break the flow of thought and disengage, rather than engage, the curious reader.

In addition, two chapters give an unnecessarily detailed treatment to two relatively unimportant subjects: chapter 13 on the NASA mercury ion experiment and most of Chapter 10 on the ammonia maser. The former is obviously there because of the author's personal contributions; the latter is justified, in principle, by the historical significance of the ammonia maser as the first working quantum oscillator, but the account of physical and engineering detail is quite irrelevant to existing and future atomic clocks.

Finally, the book misses some excitement stemming from the role of atomic clocks and crystal oscillators as key drivers in the evolving global navigation and communication applications. From recreational use for locating and communicating to the decisive military advantage exploited by the US and its allies in the 1991 Persian Gulf War, from the control of electric power and fleets of trucks to the locator map in automobiles to high-speed digital data transfer, an increasing number of specialized as well as broad societal uses depend on this technology. The book does discuss the Global Positioning System, but even there fails to touch on differential GPS and most of GPS's key applications.

Nevertheless, the book is a welcome and valuable addition to this important field. As the author declares, it is for the nonspecialist but well-rounded physical technologist. The reader should have no hesitation in skipping whole chapters or subjects, especially those mentioned earlier. In doing so, the book becomes very accessible and will prove informative, stimulating and even enjoyable.

Helmut Hellwig
US Air Force
Washington, DC

Computational Physics

Nicholas J. Giordano
Prentice Hall, Upper Saddle River, N.J., 1997. 432 pp. $70.00 hc ISBN 0-13-367723-0

An Introduction to Computational Physics

Tao Pang
Cambridge U. P., New York, 1997. 374 pp. $85.00 hc ($39.95 pb) ISBN 0-521-48143-0 hc (0-521-48592-4 pb)

Computational Physics by Nicholas J. Giordano is an excellent introductory text for undergraduate physics students, taking them gently and systematically from a simple trajectory problem to advanced topics such as chaos, phase transitions and protein folding. In the process, Giordano covers all aspects of computational physics, including the stability and accuracy of numerical methods, programming style and, most important, the physics. This book stands out from the numerous other texts on this subject because it is written with a strong emphasis on the physics and not just as an introduction to numerical methods.

The first chapter lays a solid foundation for even the most elementary physics student. Giordano begins the book by introducing the concept of finite-difference approximations using the very simple problem of radioactive decay. After explaining the essentials of writing a working program, he uses this example to raise such important issues as code testing, programming style and presentation of the results. This comprehensive approach is maintained throughout the book, with particular emphasis on numerical accuracy. In chapter 3, Giordano illustrates the importance of numerical stability in a practical manner by leading the student through a simple pendulum problem using the Euler method (this approach produces a nonphysical answer).

Computational Physics is presented at a level that is perfectly suited for a course between the standard first-year physics course and advanced undergraduate physics courses. In addition to learning computational physics, students will get a reinforcement of first-year physics as well as a chance to extend their physics knowledge to problems closer to home. For example, chapter 2 begins with computing a parabolic trajectory using simple projectile motion—something students may have already done analytically. Giordano then shows the power of numerical methods by extending this familiar problem to the sidearm curveball and the flight of a golf ball. Similarly, the addition of a driving term to the pendulum problem introduces the student to the world of chaos.

The value of this text is not only in its teaching of numerical methods—which it does very well—but in its teaching of the power of numerical methods and of modern physics, something missing from most traditional courses tied to the analytic solution of idealized problems. A course based on this textbook could be the first step in modernizing many a traditional physics curriculum.

An Introduction to Computational Physics by Tao Pang is intended to serve two purposes. The first half of the book is an introduction to computational science, covering the standard topics from numerical interpolation, integration and root finding to Fourier transforms, eigenvalue problems and the relaxation method. The second half of the book is more a survey of advanced methods in computational physics, aimed at students who possess a strong background in physics, math and computing. The result is a book that touches on everything from linear interpolation to quantum lattice renormalization. This extreme breadth is both its strength and its weakness.

Pang divides his book evenly over this broad spectrum of topics, spending, for example, three pages each on numerical derivatives and on the finite-element method. Such limited discussion renders the coverage of more advanced topics virtually useless. For example, the discussion of hydrodynamics and magnetohydrodynamics (also three pages long) does little more than note the fluid equations in finite difference form. The Courant–Friedrichs–Lewy condition for stability of explicit methods is not even mentioned. In fact, issues like stability, efficiency and accuracy are largely ignored after the first couple of chapters.

On the other hand, this book is impressive for its breadth—touching on no less than 40 separate topics in physics and topping it all off with a few pages on symbolic computing and parallel programming. One could use this text in a cursory survey of computational physics. However, students would need a strong, complete background in physics and math (beyond the first year of graduate study) to get anything of value from such a rapid flyby, for this text contains minimal discussion of the physics and insufficient coverage of the math and computational science to prove useful to a less-prepared student.

As a true introductory text, *An Introduction to Computational Physics* falls short in teaching inexperienced students the ins and outs of computational science. As a more advanced text, it is far too cursory to be useful in any practical application. Perhaps the best use would be as a complement to a more introductory text, thereby providing a bridge between introductory material and detailed discussions of more advanced applications.

John M. Blondin
North Carolina State University
Raleigh, North Carolina

Quantum Chromodynamics and the Pomeron

Jeffrey R. Forshaw
and Douglas A. Ross
Cambridge U. P., New York, 1997.
248 pp. $34.95 pb
ISBN 0-521-56880-3

What exactly is a pomeron? This is the sort of question often heard after a talk on high-energy diffractive scattering or rapidity gap physics. Many particle physicists, especially those in the younger generation, have no idea what to make of the pomeron, if they have even heard of it at all. In their new book, *Quantum Chromodynamics and the Pomeron*, Jeffrey R. Forshaw and Douglas A. Ross aim to correct this by discussing the pomeron in the framework of quantum chromodynamics, a subject with which every young high-energy physics student should feel comfortable.

Strictly speaking, this book is concerned with what is known as the "perturbative" or "hard" pomeron. The original "soft" pomeron was invented in the early 1960s, from a combination of phenomenology and the general properties of the scattering matrix, to describe the rise with energy of the hadronic total cross section. By using the optical theorem, the total cross section can be related to the hadron–hadron forward-scattering amplitude, and at high energies this was argued to be dominated by the exchange of a single particle-like object that carries the quantum numbers of the vacuum. This object is the soft pomeron, and it is purely nonperturbative in nature.

The hard pomeron shares some general features with the soft pomeron. It carries vacuum quantum numbers, and, at high energies, it also produces a rise in the cross section with energy. But unlike the soft pomeron, it can be calculated directly in perturbative QCD as a resummation of Feynman diagrams, which are enhanced by logarithms of the energy over some other scale in the process. This result is encoded in the BFKL equation (named for Y. Y. Balitsky, V. S. Fadin, E. A. Kuraev and L. M. Lipatov), and it has been the subject of a great deal of interest in recent years. However, much of the literature on the subject is anything but pedagogical, so this book should be a welcome addition to the field.

The first chapter contains a rapid overview of the theory and phenomenology of the original soft pomeron. A derivation of the BFKL equation and its solution follow in the next three chapters. The authors use the traditional approach, defining effective high-energy vertices and introducing the reggeized gluon, which is shown to be self-consistent in QCD. Since this material is highly technical, the authors first derive the resummation in a simpler scalar field theory, where the leading logarithmic contributions come entirely from ladder diagrams. This simple example is useful for highlighting the general resummation procedure; however, the authors should have also introduced more detailed discussion of the approximations involved and their physical motivation and consequences in QCD before embarking on the details of the derivation. As it is, most of the physical intuition is built up during or after the derivation. Apart from this lapse, the book is relatively easy to read, considering the difficulty of the subject matter. In addition, the authors include a summary at the end of each chapter, reiterating the main line of argument. This is especially useful in the long derivations, where a student may not see the forest for the trees.

The remaining four chapters cover various aspects and phenomenology of the BFKL pomeron solution. Since the phenomenology and theory of the hard pomeron are still developing rapidly, the topics and presentation in these chapters can be considered only representative, with the understanding that much interesting research was excluded by necessity. Chapter 5 discusses the diffusion in transverse momentum of the BFKL solution, as well as some attempts to incorporate running coupling and nonperturbative effects to make contact with the original soft pomeron. Chapters 6 and 7 cover phenomenological applications to, respectively, deep inelastic scattering at small x and diffractive scattering. The last chapter discusses an attempt to restore unitarity to the total cross sec-