Atomic Physics: An Exploration Through Problems and Solutions

Dmitry Budker, Derek F. Kimball, and David P. DeMille
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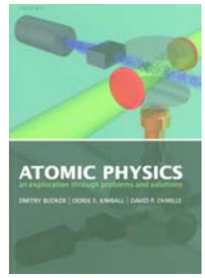
In the past 20 years, atomic physics has gone through a renaissance and has reemerged as a leading field of study, principally because of the continued development of lasers, trapping and cooling techniques, and precision experimental methods. In *Atomic Physics: An Exploration Through Problems and Solutions*, Dmitry Budker, Derek Kimball, and David DeMille present a series of problems that will serve as a sound introduction to graduate students entering the various subfields of modern atomic physics. The book will also serve as a reference for professional scientists who need quick summaries of old concepts and new ideas, and for readers who need concise summaries of theoretical techniques and results required for the design or interpretation of experiments.

In essence, the book provides all the background required to understand the theory and specific operation of most experiments in modern atomic physics. The authors, leading researchers in experimental and theoretical atomic physics, emphasize concise and crisp, yet complete, understandings of physical phenomena. Never valuing form over substance, the authors have been able to provide a nearly complete overview of modern atomic physics in a relatively short book, with ample references. I only know of one other text that covers the field with a similar scope: *Atomic and Laser Spectroscopy* (Oxford U. Press, 1977) by Alan Corney. Given the considerable progress of the field over the past 28 years, *Atomic Physics* is timely and will be of value to the present and next generations of graduate students in atomic physics.

As the authors state, the best way to learn something new is to ask concrete questions and try to work out the answers. The format of the book follows that philosophy by presenting the subject as a series of short tutorial questions followed by hints and solutions. The technique is very effective. For example, in the chapter on experimental methods, the basic ideas be-



hind the revolutionary development of frequency combs are presented as problems, and solved, in about five pages. After mastering the tutorial, a graduate student would have a sound, basic understanding of the relevant issues and would therefore be prepared to read the professional papers on frequency combs.

Because the book's focus is on atomic physics, the discussion of purely optical phenomena is primarily in relation to the interaction of light with atoms, the operation of lasers, or the limitations to experiments. The authors occasionally stray from mainstream topics and address a number of entertaining questions. For example, one might expect a compass needle to precess in a magnetic field because the needle, after all, comprises paramagnetic atoms that precess. I have thought about this problem before and have never come to a satisfactory resolution. The solution in the book suggests that a magnetized needle 0.01 cm in length will precess if the ambient magnetic field is sufficiently small.

The eight appendices do not follow the tutorial format, but they provide a reference section for conversion factors and units, tables of atomic properties, notation for polarization states of light, and general theoretical techniques. The final appendix provides a succinct discussion of the Feynman-diagram technique as it applies to atomic physics. The technique's utility is proven convincingly by the solution of a difficult problem: the Kerr effect in liquid helium. The solution to the problem is so sufficiently clear that it can be used as a model for applying the technique to other situations.

Atomic Physics is an extremely well-written book. The tutorials are scholarly and engaging and cover the complete spectrum of topics relevant to modern atomic physics. My impression is that the authors have written down all of the insightful and subtle questions that they themselves have had to answer or propose while teaching and supervising graduate students or when nobody else could or would answer the questions for them.

Atomic Physics bridges the gaps between advanced undergraduate and graduate course work, the professional literature, and the workings of the atomic physics laboratory. It does so through its emphasis on concise explanations and reliance on limiting cases, dimensional considerations, and approximation methods as opposed to formal mathematics, which more often than not is irrelevant to fundamental understanding. With the fundamentals that the book instills, a beginning graduate student will have an easy transition to the detailed, professional atomic physics literature.

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Game Physics

David H. Eberly
Morgan Kaufmann/Elsevier, San Francisco, 2004. $69.95 (776 pp.). ISBN 1-55860-740-4, CD-ROM

Although computer graphics researchers have long made reference to physical principles, only recently has physics assumed a prominent place in graphics textbooks. Increases in processor power now make it feasible to run complex physical simulations in real time, which greatly increases their practical importance. Thus there is an increasing need for books like David Eberly's *Game Physics* that can give graphics programmers a grounding in the physical principles that underlie realistic computer animation. The standard computer graphics textbook is the second edition of *Computer Graphics: Principles and Practice* (Addison-Wesley, 1995), written for programming in C, by James Foley, Andries van Dam, Steven Feiner, and John Hughes; that book, in contrast, makes only passing reference to physics-based simulation. Eberly has worked on physics engines (that is, software packages that calculate the dynamics of physical systems) that have been incorporated into some popular game titles and has written other game-engine texts, so he has the appropriate background for writing such a book.

At the heart of most modern physics engines is a simulation of the dynamics of rigid bodies. In the typical approach, the programmer determines the mass of each body in the system, identifies the forces and torques applied to each body, uses differential equations to specify the changes in position and orientation of the bodies in accordance with Newtonian dynamics, and then uses a numerical differential equation solver to compute the motion over time. In the case of bodies colliding, the engine must determine exactly when and where the collision occurs so that the dynamics of the collisions can be properly modeled.

Before presenting these simulation algorithms, Eberly covers the underlying classical mechanics in some depth. He shows how Lagrangian dynamics and Euler's equations can be used to model the motion of bodies under constraints, and analyzes a number of examples of such systems. Unfortunately, Eberly must present a lot of physics before the reader gets to any algorithms for computing motion. As I read the physics exposition, I found myself reaching for the CD that is included in the book to get a better sense of how the physics was actually going to be used.

There are still limits to how far one can go with physical simulations on commodity game hardware. It is difficult to model the dynamics of deformable bodies in real time, and programmers must resort to various tricks that are not physically based but give the impression of realism. For example, one can squash and stretch objects to give the appearance of elastic deformations during collisions. Although such techniques are necessary, Eberly's presentation of them seems out of place in a book that otherwise places such a heavy emphasis on physical principles. In any case, the techniques that Eberly describes do not yield very convincing results.

In other parts of the book, Eberly could have included more physics, not less. For example, the physics of illumination and reflection is increasingly important for games. Eberly describes techniques using common graphics cards to achieve various shading effects but explains the underlying physics only briefly. Nothing is wrong with that approach, but it is a surprising contrast to Eberly's in-depth treatment of rigid-body dynamics.

The book's organization makes it difficult to read from cover to cover. The mathematics and numerical analysis required to understand the physics simulations are appended at the end. Granted, it is hard to predict what material a given reader will need to review when approaching a topic such as this, but I think Eberly could have done a better job. For instance, the chapter on rigid-body simulation makes passing reference to quaternions, a famously difficult topic in computer graphics. The author's brief mention of the mathematics makes it necessary for the reader to skip ahead to the chapter dealing with that topic.

The figures in the book suffer from a number of problems. They lack realism and visual appeal, which is always a concern for a computer graphics text. A few renderings from commercial games that employ physics-based techniques would have helped illustrate the descriptions. Many of the images are difficult to make out in black and white. Moreover, the illustrations are not always consistent with the text that they accompany.

For readers who are more concerned with the basic practicalities of physics-engine programming, an alternative is *Physics for Game Developers* (O'Reilly, 2001), by David M. Bourg. Overall, *Game Physics* contains useful reference material for game-engine developers, but readers are likely to pick and choose the parts of the book that are of interest to them.

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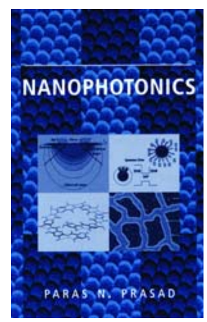
Nanophotonics

Paras N. Prasad
Wiley, Hoboken, NJ, 2004. $84.95 (415 pp.). ISBN 0-471-64988-0



Paras Prasad has once again produced an invaluable reference source related to photonics. *Nanophotonics* maintains the tradition of his earlier books, *Introduction to Biophotonics* (Wiley, 2003) and *Introduction to Nonlinear Optical Effects in Molecules and Polymers* (Wiley, 1991). Like Prasad's previous texts, *Nanophotonics* is aimed at advanced undergraduates and graduates studying chemistry, physics, molecular biology, and biochemistry, as well as various engineering disciplines.

I, as have many chemistry and physics faculty members, have used Prasad's books as key references for graduate courses, including the new nanotechnology graduate course "Frontiers in Nanotechnology" at the University of Washington in Seattle. All of the Prasad texts are excellent in introducing key concepts and mathematical derivations of key equations. In particular, Prasad's treatment of basic concepts such as electrons and photons is comprehensible and attractive to students. The crucial importance of nanoscopic confinement of both electrons and photons is emphasized early in *Nanophotonics*. The