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Nuclear and Particle Physics Simulations

Roberta Bigelow, John Philpott, Joseph Rothberg, Malcolm Butler, Susan R. McKay, and Wolfgang Christian

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BOOK REVIEWS: THE CUPS COLLECTION OF PHYSICS SOFTWARE AND BOOKS

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A group of 27 physicists, the Consortium for Upper-Level Physics Software (CUPS), has developed a nine-part series of software and books to accompany courses commonly offered to undergraduate physics majors (CIP 6:1, 1992, p. 90; CIP 7:5, 1993, p. 508; and CIP 8:4, 1994, p. 386). The collection includes software and books for courses in astrophysics, classical mechanics, electricity and magnetism, modern physics, nuclear and particle physics, quantum mechanics, solid-state physics, thermal and statistical physics, and waves and optics.

Below are reviews of the last eight of these packages, written by faculty from different colleges and universities. Our reviewers tested the version that runs on IBM compatibles, which requires at least a 386-level machine, preferably with a math coprocessor, plus a mouse and VGA color monitor. The astrophysics package was reviewed separately (CIP 9:4, 1995, p. 413). For each of the subjects, programs are written in Borland Turbo Pascal, and source code is provided.

Susan R. McKay

Nuclear and Particle Physics Simulations

Roberta Bigelow, John Philpott, and Joseph Rothberg

Wiley, New York, 1995; ISBN 0-471-54883-9; 218 pp., paper and diskette, $35.95.

Reviewed by Malcolm Butler

Modern nuclear physics is a computational science. Conventional textbooks can present the development of nuclear phenomenology in a qualitative way, but insight into the subtleties of real nuclear structure and dynamics cannot be achieved through analytic solutions of simple models. For example, the existence of the deuteron as a neutron-proton bound state comes about because of the tensor interaction. The central part of the interaction cannot support a bound state, and so simple square-well models and the like mislead the student as to the true nature of the nucleon-nucleon interaction.

Theoretical particle physics, with the exception of the study of lattice-field theory, can be presented in great depth using only analytical techniques and the elegance of symmetry. Experimental discovery, however, relies on comparison to numerical simulations in order to either confirm existing theory or provide evidence for new physics (the recent hint of quark substructure at Fermilab, for example).

We all try to avoid the nightmare of having to preach to keen students that "yes, the calculations are probably correct and yes, the simulation is sensitive enough to the measured parameter (quark mass, coupling strength, transition-form factor... pick one) that the experiments can be used to determine the parameter with reasonable precision." It is so much more powerful to let the students perform the simulations themselves and see the effects firsthand.

Nuclear and Particle Physics Simulations seeks to let students see how calculations really work. The authors clearly state that the package is supplemental to a standard text and will not try to teach from scratch the topics covered by the simulations. The level of presentation in the manual varies dramatically from chapter to chapter. However, with each chapter being a distinct module (no single chapter depends on the student's having studied another), this variation does not pose any real problems. There are minor inconsistencies in notation between chapters, but none is so dramatic as to cause confusion. The alert student should see them immediately. Also, in the attempt to present a quick overview of the topic before moving on to the simulation, there are occasional oversights and omissions that could be problematic if this package was used on its own.

The most important aspect of this package is the software that comes with it. The system requirements are quite minimal, namely a 386 system or better, running MS-DOS with a VGA monitor and a mouse. The installation of the software on my system was quite straightforward. However, some files seem to have been archived twice, and the many warning messages about already-existing files caused some concern that one file was supposed to be a replacement for the other.

The simulations themselves were quite easy to use, and most could be run without the assistance of the manual. The options were sufficient that the compiled simulations could be used quite effectively without having to try to modify the source code.

There were some minor glitches—I had some initial trouble getting the lab-frame vectors to rescale automatically in the relativistic-kinematics simulation (RELKIN), and energy-level labels occasionally overlapped in the shell-model simulation (SHELLMOD), making them difficult to read.

To me, one of the most useful simulations is TWOBODY, which allows the student to study nucleon-nucleon scattering and binding. TWOBODY presents a broad range of possible interactions, both simple and physical. Such

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breadth allows the student to explore the sensitivity of binding, and of scattering phase shifts, to the strength and character of each interaction channel. TWO-BODY has a useful role to play for particle physics as well, in that it illustrates the importance of scattering reactions as sensitive probes of interaction dynamics.

RELKIN, the simulation for relativistic kinematics, is also quite useful in that it allows the students to connect the sometimes confusing and nonintuitive (at least to a student who may be seeing special relativity for the first time) effects of Lorentz transformations on real dynamics. I would probably use RELKIN to help in teaching special relativity, since particle physics can be used as a direct example of how special relativity works for objects moving at speeds close to the speed of light.

Nuclear and Particle Physics Simulations is definitely a useful supplement to an undergraduate course on subatomic physics.

All the simulations are helpful in developing a student's intuition, and any course in subatomic physics, no matter what the slant, would find a number of the simulations useful. I hope that development of the simulations continues so that the package will remain relevant, especially on the particle-physics side, which appears somewhat neglected when compared to the nuclear-physics content. For example, simulations of how particle identification is accomplished in collider experiments might be a nice addition to a future edition. ♦

Waves and Optics Simulations

G. Andrew Antonelli, Wolfgang Christian, Susan Fischer, Robin Giles, and Brian James

Wiley, New York, 1996; ISBN 0-471-54887-1; 257 pp., paper and diskette, $35.95.

Reviewed by Carolus Boekema

Your reviewer is (somewhat) biased, as he likes computer simulations in physics and other computational fields. Part of the fun is developing and writing the computer codes together with physics students. We are not so much inclined to use prepackaged math software, because experience has shown on occasion (for instance, when degeneracy in energy is involved) that these mathematical "black boxes" can yield unphysical, unreasonable answers.

The book and software that constitute *Waves and Optics Simulations* provide the student and motivated reader with the opportunity to get inside the "box" and code; this is a great plus. As supplementary material for an upper-division physics course, the textbook is good. I am impressed with the Schrödinger-equation and electromagnetic-waves simulations. As self-study for physics majors, the text is an excellent source and has challenging materials. The exercises within each topic are good and sufficient for testing the gained knowledge. The fact that the problems have no "back-of-the-book" answers teaches the advanced student that in research there are no such answers.

Overall, on a scale from 1 to 10 (with 10 excellent), this reviewer rates this CUPS package in the range from 8 to 9. It is a 10 for those who wish to get inside the "box." ♦

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Modern Physics Simulations

Douglas Brandt, John Hiller, and Michael Moloney

Wiley, New York, 1996; ISBN 0-471-54882-0; 178 pp., paper and diskette, $35.95.

Reviewed by Daniel P. Snowman

Modern Physics Simulations is an extensive set of programs designed to complement traditional investigations in modern physics. The simulations included in this volume cover Rutherford scattering, electron diffraction, special relativity, lasers, nuclear properties, quantum mechanics, and hydrogenic atoms. A companion text comes with the simulation software and supplies details about each program. In particular, an appendix provides walk-through tutorials, giving the user a brief overview of each program.

The book emphasizes mainstream topics found in most modern physics textbooks. It should be stressed, however, that the book is meant to serve only as a supplement to a primary text that covers each topic more comprehensively. The book is organized in such a manner that the topics need not be covered sequentially.

The chapters are relatively independent of one another, giving the instructor the freedom to explore each topic as dictated by the pace and content of the course. The authors provide a sizable number of exercises at the end of each chapter.

Inclusion of the source code allows for alternative investigations suitable for an advanced undergraduate or introductory graduate course. Although the source code is well constructed, it is written in Turbo Pascal for MS-DOS, rather than in more commonly used Fortran, Basic, or C. In addition, the MS-DOS environment limits the names of programs to eight characters; this unattractive feature often requires the user to interpret cryptic program names. A Windows-95 version of this package would be preferable.

The text provides detailed outlines that explain the parameters associated with each simulation. For example, an attractive feature of the electron-diffraction package allows the user to choose precise wavelengths by varying the accelerating voltage with both coarse and fine adjustments. The angular range and gain of the detector are also adjustable via a fairly user-friendly interface. In addition to tuning "instrument" parameters, the user also has the freedom to vary "target" parameters that characterize the orientation and properties of each crystallite.

This flexibility allows students to investigate scattering phenomena associated with historic experiments involving electron diffraction.

The authors have done an outstanding job of creating a package that will serve as an excellent complement to any course in modern physics. ♦

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