

fall, Newton took this infinitesimal distance to be proportional to the square of the time. And once he had demonstrated Kepler's law of areas (Proposition I of the *Principia*)—namely that time is proportional to the area swept out by the line joining the center of force to the body—he had a geometrical measure of time incorporated into his diagrams.

Brackenridge's book falls somewhere between a textbook (for advanced undergraduate physics majors or graduate students in history of science) and a research monograph, for he also analyzes the other mathematical techniques that Newton had developed over the course of his career to solve orbital motion. De Gandt's book is directed at roughly the same audience.

Historians of science largely focus on the portions of the *Principia* devoted to Kepler's laws and terrestrial motion, which climax the scientific revolution of Copernicus, Kepler and Galileo. The *Principia*, however, also opened whole new areas of what we call "classical" mechanics. To grasp the truly awesome nature of Newton's achievement in the *Principia*, it is necessary to turn to Subrahmanyan Chandrasekhar's *Newton's Principia for the Common Reader*. Although Chandrasekhar, who died in August 1995, skipped most of Book II (on fluids) and a few other miscellaneous sections, he followed Newton from the opening pages through the development of universal gravitation and some of its applications to the real world. He fully treated such complex problems as perturbation theory, lunar theory, cometary orbits, precession, the shape of the Earth and the tides, problems that are generally ignored by historians.

One cannot fail to be impressed with Newton's ability to take these problems so far with such apparently primitive conceptual and mathematical tools at his command. Chandrasekhar's approach throughout was to present his own demonstrations of Newton's proofs first and then to give Newton's, so that he could illuminate Newton's "physical insight and mathematical craftsmanship." This is a valuable guide to the *Principia*—certainly beyond the level of the "common reader"—that will take its place in the succession of major commentaries on the *Principia* of the past three centuries.

The book does, however, have some limitations. While modern mathematics makes Newton's solutions more comprehensible, it tends to hide the path that he actually followed and to reveal things that were not necessarily apparent to him. It is unfortunate that Chandrasekhar chose not to utilize the historical literature on Newton and the

Principia, for his book would have been enriched at many points. There are also many small errors, and no index.

Feynman's "lost" lecture is one of five lectures that were omitted from the three volumes of *The Feynman Lectures on Physics* (Addison-Wesley, 1963–65). In 1992 Judith Goodstein, the archivist of Caltech, found them, as unedited transcripts and notes, in the office of Robert Leighton, who oversaw the publication of the *Lectures*. (A tape recording was found later.) Three of the five were problem-solving reviews, the fourth was on inertial guidance and the fifth (delivered in March 1964) was on Newton's demonstration of Kepler's laws and the inverse-square law. The aim of the recorded lecture (which is on a CD accompanying the now-published lecture) was to demonstrate that the planets move in ellipses if the Sun attracts them with an inverse-square force. Feynman's exposition of Proposition I of the *Principia*, Kepler's law of areas, follows Newton's, but because of all the properties of conics that Newton went on to utilize, Feynman found that he could not follow him further. Instead, after an "awful long time," Feynman devised his own "strange and unique" proof, one that replaces Newton's positional or orbital diagrams with velocity diagrams.

Feynman's demonstration is actually more difficult to follow than Newton's, as can be confirmed from the other books under review. David Goodstein did a fine job of restoring Feynman's lost diagrams and of elucidating his proof for the general reader, and his reminiscences of Feynman are moving. Yet one can seriously question whether the lecture would have been published were it by anyone but Feynman. His demonstration is not new, and it adds nothing to our understanding of Newton's *Principia*. In fact, it muddles things up a bit, since the proposition that Feynman proves—if the force is inverse square, then the orbits are ellipses—is the converse of what Newton actually proved—if the orbits are ellipses, then the force must be as the inverse square. Whether Newton's demonstration could be rigorously extended to apply to the converse has been a subject of contention since Johann Bernoulli challenged it in the early 18th century, and it is considered in the other three books.

Feynman's lecture, as I see it, was really an attempt to introduce students to the beauty of geometry:

It is not easy to use the geometrical method to discover things. It is very difficult, but the elegance of the demonstrations after the discoveries are made is

really very great. The power of the analytic method is that it is much easier to discover things than to prove things. But not in any degree of elegance. It's a lot of dirty paper.

De Gandt makes a similar eloquent plea for following Newton's own style of reasoning:

More than the more or less automatic methods of the "infinitesimal calculus," these forms of reasoning obliged Newton to use all his resources of invention, and they require of the reader an active intervention, an exercise in "seeing." It is necessary to learn to animate the figures and to follow the relations to the point at which the infinitesimal magnitudes vanish. This geometry, at once concrete and subtle, has its own kind of charm.

There are numerous guides to the great literary works, and it is a pleasure to welcome these four books on the *Principia*, because they make its majestic magic accessible to a wider audience. All of these books should be read with a copy of the *Principia* at hand.

Turbulence: The Legacy of A. N. Kolmogorov

Uriel Frisch

Cambridge U. P., New York, 1995.

296 pp. \$80.00 hc

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\$29.95 pb ISBN 0-521-457130

Turbulence is a subfield of fluid dynamics with its own history, heroes and language. Readers should distinguish among hydrodynamic stability (the careful account of how the first departures from laminar flow to more complicated flows occur), transition (where flows become ever more complicated as fluid velocities increase) and turbulence (where motions become so complicated that they evidently exhibit enormous numbers of degrees of freedom). The subject of fully developed turbulence, flows that some believe are nearly independent of the systems that produce them, is considered to be among the greatest challenges remaining in classical physics.

Uriel Frisch, the author of *Turbulence: The Legacy of A. N. Kolmogorov*, is a distinguished senior investigator in the field, and he has aimed this book at those wishing to learn something about fully developed turbulence; he wrote it at a level suitable for first-year graduate students in mathematics,

physics, astrophysics, geophysical sciences and engineering. *Turbulence* is also aimed at readers such as myself, who would like to learn something of the subject at a sophisticated level.

The title reveals an immediate advantage of this book: It is not a book on fluid dynamics with a chapter or so on turbulence; it is instead a modern, physics-oriented discussion of a difficult subject about which surprisingly little can be said to be known with confidence. The author discusses Andrei Kolmogorov's 1941 work on turbulence, employing in the process concepts from dynamical-systems studies such as symmetry breaking and deterministic chaos not developed until decades later. For instance, Frisch carefully rederives the main results of Kolmogorov's three 1941 papers, using assumptions of symmetries of the turbulent flow instead of Kolmogorov's assumption of "universality." There is an impressive chapter on the problem of intermittency and a final chapter that reflects the author's intuition as to where the field is heading. Examples include dynamical systems, fractals and turbulence, and two-dimensional turbulence. Discussions of almost all topics are linked to modern experimental data. Indeed, key experimental data are reproduced in the book.

This is a work of great scholarship. The author includes a number of illuminating historical discussions, something I find most helpful in learning a new subject. For example, I can recall Lars Onsager telling me about his own derivation of the Kolmogorov theory and the efforts of Werner Heisenberg and Carl von Weizsäcker along similar lines. The short historical discussion in section 6.5 is the first place I ever encountered the actual sequence of events. There are also complete citations to papers, including authors, titles and page ranges, as well as both an author and a subject index. All of these time-consuming labors of the author certainly make it easier for the reader.

This book belongs in the library of any college or university where physics is taught. It can productively be used as a reference in advanced undergraduate courses or as a text for a one-semester course on turbulence itself. For US physics students at least, a prior course in fluid mechanics would probably be a necessity if the book is to be covered substantially in 30 or so lecture hours. It would help the reader if, in a future edition, Kolmogorov's papers were included in some appropriate form in an appendix.

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Theory of Electron-Atom Collisions Part I: Potential Scattering

Philip G. Burke
and Charles J. Joachain
Plenum, New York, 1995. 293 pp.
\$69.50 hc ISBN 0-306-44546-8

This monograph is the first part of a three-volume set. Part II is to deal with the general theory at low energies and Part III with the general theory at high energies. Such a partition is completely natural, not only by virtue of the sharp division of methods in the two energy regimes, but because the two authors have themselves specialized in the respective energy domains and associated methodologies. How necessary the present volume (Part I) will be in the context of those future volumes one can only surmise.

The authors, Philip G. Burke and Charles J. Joachain, have each written a previous book in the field, Burke's *Potential Scattering* (Plenum, 1977) and Joachain's *Quantum Collision Theory*, (North Holland, 1983). The present volume is more detailed than Burke's but significantly less comprehensive than Joachain's.

The central theme of the four chapters and five appendixes of *The Theory of Electron-Atom Collisions, Part I*, is the scattering of a particle (think electron) in a fixed external potential. Although all of the material is available from many other sources, I found the current text to be sufficiently detailed to be reasonably self-contained yet sufficiently selective so as not to be unwieldy. The first chapter (general theory), for example, contains a nice derivation of the optical theorem wherein the relationship between the imaginary part of the forward scattering amplitude and the total cross section arises from the interference between the incoming and scattered waves. In most texts this relationship is rather formally derived, and one really does not appreciate the physics underlying its origin.

In the second chapter (approximation methods), the section on the R-matrix method is rather longer than one might think necessary. However, that method is the basis for an elaborate suite of calculational programs—initiated by Burke and now widely used—for electron scattering from many-electron targets (and related processes such as photoionization). As such, it will undoubtedly be an essential chapter of Part II, so the presence of the fundamentals of the approach here is well justified.

If there is one major flaw in this book, it is the absence of a section devoted to separable *nonlocal* potentials in chapter 3 (analytic properties of the scattering amplitude). Not only is that material less well known than the local potential results (which constitute the core of the included material), but nonlocal potentials reveal a much richer analytical structure of the amplitude on the negative real energy axis and would thus have served as an excellent introduction to the (still unsolved) problem of electron-atom dispersion relations (also likely to be dealt with in Part II).

Chapter 4 deals with spin and relativistic effects; all of its six subsections, especially those devoted to the Dirac equation, its nonrelativistic limit and density matrices, are clearly delineated, and will be useful in both Parts II and III.

Some of the appendixes are dispensable, in my view. This is especially true of Appendix E on Clebsch-Gordan and Racah coefficients, because that material is contained in so many places and is primarily of use in the many-particle situation which, as stated, is not properly the domain of Part I. Its inclusion here is clearly an attempt to make the book self-contained, its use being confined to the coupling of spin and orbital angular momentum for the total angular momentum (j) components characterizing the solutions of the Dirac equation. But Racah coefficients ($6-j$ symbols) are not used at all. Appendix C, on Dalitz integrals, is pedagogically superior to a similar appendix in Joachain's previous book.

The above criticisms notwithstanding, I found this book to be an excellent one, of considerable potential utility, particularly to those entering the field.

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Galaxies and Cosmology

Françoise Combes, Alain Mazure,
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Galaxies and Cosmology is intended as a graduate-level introduction to extragalactic astrophysics and cosmology. The first 7 of its 13 chapters, those dealing with normal galaxies and their interactions, are followed by chapters on radio galaxies and on quasars; the final section covers large-scale structure and galaxy formation and rapidly reviews Friedmann cosmologies and