DOUBT AS THE ESSENCE OF KNOWING: THE GENIUS OF RICHARD FEYNMAN

Genius: The Life and Science of Richard Feynman

James Gleick
Simon and Schuster, New York, 1992. 532 pp. $27.50 hc ISBN 0-679-40836-3

Reviewed by Freeman J. Dyson

Six years ago Richard Rhodes published his historical study, *The Making of the Atomic Bomb*. Like most of my friends, I thought the last thing the world needed was another fat book about the atomic bomb. But it turned out that Rhodes had done his homework and gone back to primary sources; he discovered a wealth of new facts that the earlier books had missed. I was forced to reverse my initial judgment. After all, the world did need a comprehensive and reliable history of the atomic bomb, and Rhodes had supplied it.

My initial reaction to James Gleick's new book was the same. After three books by Ralph Leighton and all the other published reminiscences of Feynman's life and work, who needs another book about Feynman? And again, after reading the book, I changed my mind. Like Rhodes, Gleick has made an extraordinarily thorough investigation of primary sources. He has interviewed a multitude of people who were involved with Feynman at every period of his life from beginning to end, including family, childhood friends, colleagues, students, government officials and medical doctors. He has had access to early personal notes and correspondence that amplify and sometimes correct the stories Feynman remembered many years later. Gleick has assembled out of this material a portrait of Feynman far more complete and authentic than any of the earlier accounts. Although I am a longtime friend and admirer of Feynman, I feel that I know him better after reading this book than I did before.

In a brief review I can mention only two aspects of the book that I found particularly illuminating. First, the picture of Feynman's family background and childhood in Far Rockaway is grittier and bleaker than the idyllic stories that Feynman told later. Feynman remembered his father as a kindly philosopher whose profound words shaped Feynman's own way of understanding the natural world around him. In reality, Feynman's father was a harassed and unsuccessful businessman who was forced to travel to earn a living and had little time left over for his children. The fact that Feynman could create a legend of the philosopher–father out of such a meagre reality is an important clue to understanding his character. One of the most valuable lessons I learned as a student of Feynman was a rule that he applied whenever a question about priority of discovery threatened to arise. Feynman's rule was to "always give them more credit than they deserve." Feynman consistently applied this rule throughout his life, and it saved him from many time-consuming irritations. It now appears that, consciously or unconsciously, he applied the same rule to his father.

The other part of the book that I found most novel and informative was the discussion of Feynman's view of scientific explanation. This view appears in a section with the title "The Explorers and the Tourists." In Feynman's view, scientists are explorers and philosophers are tourists. The tourists like to find everything tidy; the explorers take Nature as they find her. Feynman did not agree with the view prevalent among philosophers that the purpose of science is to reduce natural phenomena to a few fundamental laws. He believed that all natural phenomena are worth exploring and explaining, whether or not the explanation turns out to be fundamental. Gleick sums up Feynman's scientific credo in one sentence, the clearest statement I have seen of the true spirit of science: "He believed in the primacy of doubt, not as a blemish upon our ability to know but as the essence of knowing."

Freeman Dyson is a theoretical physicist who knew Feynman for 40 years and has himself written reminiscences about Feynman's life and work.

Fundamentals of Photonics

Bahaa Saleh and Malvin Teich
Wiley, New York, 1991. 966 pp. $69.95 hc ISBN 0-471-83965

I thoroughly enjoyed reading and working problems in *Fundamentals of Photonics*. A summer student working with me at AT&T Bell Laboratories between her junior and senior undergraduate years also found it her favorite source of background information for experiments on semiconductor microlasers.

It is a joy to see such a large amount of information on a broad range of basic and applied topics arranged in a coherent and readable book. Of course this requires a large book, and *Fundamentals of Photonics* is nearly 1000 pages long. The book is organized into four sections: Optics and Fiber Optics, Quantum Electronics, Optoelectronics, and Electro-Optics and Lightwave Technology. In the rapidly evolving field of photonics, terms referring to combinations of optics and electronics are often confusing, but the authors give reasonably precise and moderately useful definitions for them.

In attempting to cover nearly all the major issues in photonics, as well as including a fairly complete course on optics, the authors have covered a number of topics in very brief, almost encyclopedic form. For example, exciton effects at the band-edge absorption in a semiconductor are not discussed in detail, and most energy-

level spacings are merely stated. Many other topics—for example, squeezed light—include only a superficial introduction with no details on current research. However, the introductions are excellent in terms of readibility, directions for further study and references to the current literature. Especially interesting to me was the ease with which one is introduced to difficult topics. There is a large amount of well-organized basic information that is integrated with more difficult concepts, so that the reader feels truly "enlightened" at the end of a chapter. Pictures of the pioneers in each field and excellent illustrative figures also add to one's reading enjoyment.

The first half of the book is essentially an up-to-date optics text. A step-wise approach is used, beginning with ray optics, wave optics and beam optics. The approximations and applications in each case are made clear. The section on beam optics includes a clear treatment of Gaussian optics, essential for all experimental laser research. I wish the authors had included some simple software routines for Gaussian optics calculations, which are so useful in the laboratory. The optics section continues with Fourier optics (with a good section on holography), electromagnetic radiation and excellent chapters on guided wave and fiber optics. The optics section concludes with very good introductions to statistical and photon optics.

One clear advantage to the moderately complete coverage of optics and other photonics topics in this book is the consistent notation throughout the book and, in the applied chapters, references to the basic topics covered earlier in the book.

The interaction of light with atoms and solids introduces lasers, LEDs and semiconductor photodetectors. Again, I enjoyed reading all of these chapters. The authors treat photodetection and photodetector noise especially well. This is no surprise considering the excellent research Bahaa Saleh and Malvin Teich have contributed in this area. Next comes electro-optics, nonlinear optics and acousto-optics. There is a good section on liquid crystals, which are very important today for displays. The authors even include a reasonable introduction to optical solitons, important for future optical communications. I was pleased to see that they included details such as the conversion factor from n_2 (the nonlinear optical index) to χ^3 (the corresponding third-order nonlinear susceptibility) in electrostatic units.

The last two chapters include topics of current interest in the applied fields of photonic switching and computing and fiberoptic communications. Again, I might complain that the treatments here do not go into enough depth. For example, the authors do not point out that nonlinear phase shifts required for all-optic switches are difficult to achieve over short lengths because of fundamental absorption limits. When discussing the important topic of optical interconnects, the authors do not include the length scale where optics is preferred to unterminated electrical transmission lines typical of silicon electronics. In the section on long-distance optical fiber transmission, the major limits due to nonlinear phase shifts and the use of optical solitons to overcome this difficulty are not discussed in sufficient depth. In general these last two chapters should only be taken to indicate directions of current interest. Applications of photonics are too widespread and too rapidly evolving to be covered adequately in this book. The authors do present a balanced view of the promise and problems involved in photonics.

Overall I think this is an excellent book. One obvious comparison is with Amnon Yariv's *Quantum Electronics* (third edition, Wiley, New York, 1989). The section on optics in Yariv's book is not nearly as complete as that in Saleh and Teich's text. The treatment of devices and applications in the two books is complimentary. I'll certainly have both books on my bookshelf.

The introduction includes a list of seven possible courses ranging from optics to lightwave systems. Having never taught a course on optics or photonics, I cannot comment on the quality or range of courses that can be taught from this text. For a full-time researcher like myself, this book is a very useful and enjoyable source for refreshing or updating a broad range of topics. If photonics is a largely unexplored ocean, this book allows a very pleasant wading trip almost all the way around the shore.

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Energy

Roger Hinrichs
Saunders (Harcourt Brace Jovanovich), Philadelphia, 1992. 540 pp. $32.00 pb
ISBN 0-03-054954-X

A reviewer of one my own books once castigated me for not writing the book he thought I should have written, ignoring the book I actually wrote. This experience has made me much more sensitive to the ways in which reviews can distort people's perceptions. Partly as a result, I think it is extremely important for a reviewer to judge a book on the basis of what the author intended to write. Roger Hinrichs, the author of this book, wanted to do three main things: cover the physical principles of power generation (and also include an exposition of the mechanics, electricity and magnetism, thermodynamics and atomic and nuclear physics involved); examine different aspects of each energy resource; and integrate these technical issues with questions of energy policy and strategies for the future, thus allowing the student to see the complexity of the questions addressed by energy planners and citizens.

My difficulty with attainment of the author's first aim lies in the superficiality with which the author addresses the underlying physics, especially the mechanics. His coverage of other areas is less superficial. Hinrichs is most successful in his discussion of thermodynamics, despite the fact that he uses the term "heat energy" rather than distinguishing between heat and thermal energy. His initial explanation of heat is correct, but his usage is incorrect, and it continued to bother me throughout the book, because I think it will confuse students.

The strongest parts of the book are those on residential energy use, radiation in medicine, uses of waste heat and gasification. The sections on home energy use are particularly thorough, and Hinrichs includes a form in an appendix that allows the reader to do a home energy audit. His book contains more material on radiation detectors than do any competing texts, which virtually ignore the subject. The ideas in the student activities that Hinrichs appends to some of the chapters are very well thought out. He has clearly used the demonstrations and tested the activities pretty thoroughly, and he shines through at his very best here. I found these activities generally outstanding.

In addition to the lack of a firm foundation for the mechanics, the book's weakest points include the lack of discrimination in reporting on the "dangers" of microtesla phenomena from ac devices (so that the author loses the opportunity to point out overstatements common in the media) and the exclusive use of English units. (It would appear that Hinrichs never met an SI unit he liked.) There