

may be the only physics they ever will take. We can no longer assume that our students will see the material again and again and eventually understand it when they themselves begin to teach. Changing the boundary conditions of a problem often changes the nature of the solutions. We need to substantially rethink the way we teach.

For decades, Arnold Arons has been helping physics teachers understand their students through insightful articles in journals such as *The American Journal of Physics*, *The Physics Teacher* and *Daedalus*. With publication of *Teaching Introductory Physics*, he has created for physics teachers a tool of great and lasting value.

The book consists of three parts. The first is a reprinting (with small corrections and additions) of *A Guide to Introductory Physics Teaching*, Arons's 1990 volume that became an immediate classic (reviewed in *PHYSICS TODAY*, December 1990, page 67). This volume contains the essence of 30 years of experience of a thoughtful, skilled teacher—one who listens carefully to his students and works to understand their difficulties. The joy of this part of the book begins with the numerous nuggets of surprising insight about student responses. (Try giving your introductory physics students the task of writing an equation for the statement: "There are six times as many students as professors at this university. Use S for the number of students and P for the number of professors." The results may surprise you.) It becomes doubly valuable when you realize that rethinking your students' understanding requires that you rethink your own. The book is full of subtle, small surprises and puzzles that delight, inform and deepen one's understanding of introductory physics.

As a result of Arons's deep and abiding interest in the process of science, much of the presentation is enriched with philosophical and historical insights. The final chapters of part I on "Achieving Wider Scientific Literacy" and "Critical Thinking" are, in my opinion, among the best essays ever written on the subjects and alone are worth the price of the book.

Part II has been previously published as *Homework and Test Questions for Introductory Physics Teaching*. It contains more than 400 problems in introductory physics that are more conceptually challenging than the plug-and-chug exercises in most textbooks. I have successfully used them as starting points for building supplementary homework and exam problems for my introductory physics classes since this part first appeared in 1994.

They are great problems, but I have

two warnings for the casual user: First, the problems are often worded in Arons's characteristic eloquent style. For my students, I often have to rewrite them using simpler vocabulary and shorter sentences. Second, many students will not like them! These are not motivational problems (as is: "In this problem you will learn to build a radio that will allow you to listen in to your friends' cellular phone calls in secret."). They are thinking problems. In my experience, many students would prefer to do an hour of mindless plug-and-chug to ten minutes of thinking. When used with care and persistence, however, these problems can be used as part of a consistent effort to introduce beginning students to the joy of figuring things out for themselves.

Part III is the only part of the book that is truly new. For those of you who already have parts I and II: Tough luck! Wiley apparently has no intention of releasing this third part as a separate volume. Part III is a 150-page monograph on teaching mechanical and thermal energy. Although it is presented as a text, it is more a guide to the instructor about subtle and interesting issues concerning energy. It assumes that the reader has a well-developed understanding of the concept of force, Newton's laws and calculus. Arons carefully analyzes what we know about energy, why we choose to construct the concepts the way we do and why we believe the traditional results. Difficult concepts are treated with care and clarity. A number of activities and problems are presented that can serve as the basis for excellent labs or extended class discussions.

All in all, this three-part volume is probably the best introduction to physics teaching presently available. Every teacher of introductory physics should have a copy and consult it often.

EDWARD F. REDISH

University of Maryland, College Park

Teaching Introductory Physics: A Sourcebook

Clifford E. Swartz
and Thomas Miner
AIP, Woodbury, N.Y., 1997.
558 pp. \$75.00 hc
ISBN 1-56396-320-5

The introductory college physics course has become the subject of intensive research, especially during the past decade. Where can someone turn to learn about this course? While Arnold Arons has written several books about the philosophy of his approach to the introductory course (see the previous review), these very detailed statements of (very

well-informed) opinion are probably not turned to by many who need them. Many simply rely on the already-selected textbook and think no more about the matter. However, the introductory course needs more attention from those teaching it. For many of the 97% of students who will take this as their terminal course in physics, the course will be an unsatisfactory experience.

Teaching Introductory Physics by Clifford Swartz and Thomas Miner is intended for new teaching assistants, first-time teachers, and faculty who are returning to the introductory course after an absence of some years. It is meant to fill the need for renewal in physics education and to provide a useful context for the teacher. It succeeds at much of this. The drawings by Art Ferguson are wonderfully clear and helpful and will make all of us who do not have access to such an artist jealous. Perhaps the book will even help its readers to become better teachers and to have fewer dissatisfied students.

Both authors are expert at teaching and communication. Swartz has been editor of the *Physics Teacher* for most of the past 30 years. Anyone who has seen one of his presentations knows how successful a teacher he is. Miner was associate editor of the *Physics Teacher* for many years, until shortly before his death in April 1993, and taught at both the high school and college levels. Both brought their wealth of experience in teaching and knowledge to the book.

Its title suggests that *Teaching Introductory Physics* is not a textbook in the usual sense but focuses rather on issues dealt with in an introductory course. This is only partly true, since some of the chapters were excerpted from Swartz's out-of-print textbook *Phenomenal Physics* (Wiley, 1981). The introductory chapters (especially chapters 1 and 2) will be the most worthwhile for the book's intended audience. The authors give their opinions on various aspects of the course, including ways of managing it, with manifold annotated references to articles in the *Physics Teacher* and the *American Journal of Physics* that will prove an invaluable help to the reader. Indeed, anyone who has ever been even slightly confused about error analysis should read chapter 2. It is the best presentation I have yet seen of this sometimes confusing subject.

I wish I could report that every chapter is as useful to an introductory teacher as the first two. I do not find that to be the case. Nevertheless, in the remaining chapters, the reader can encounter fascinating aspects of friction, a discussion of transfer of tension by a rope, one of the clearest expository

tions of the difference between diffraction and interference ever written, a nicely written explanation of the difference between phase and group velocity and a wonderful discussion of many aspects of ferromagnetism. One factual gem I enjoyed is that a car's two headlights can be resolved at distances as far as 17 km!

There are some unfortunate lapses. Occasionally, there are mysterious statements such as "the frequency is 9." We are left to wonder, 9 what? Other proofing errors are not uncommon. Swartz and I have disagreed at times about the significance and use of units, and I can find more to disagree with here than I would have wished. In a "sourcebook," it would have been best to get all units correct and to eschew non-SI units for the most part. This has not been done: We find, among others, the gal, the poise and the gauss. The British thermal unit is sometimes printed correctly (Btu), other times as BTU. Worse, the calorie is emphasized at the expense of the joule.

An even more unfortunate failing for a sourcebook is a muddiness about the distinction between weight and mass and the failure to denote vectors as vectors uniformly, which can, in places, lead to awkward presentation. Velocity is often incorrectly used to mean speed. Most physicists speak of atomic mass, not atomic weight.

A few other things would have made this work more valuable. Some figures could have been bigger to help the reader. One figure (figure 4.11) was so tiny I would have had a hard time reading it if I hadn't remembered the original! More annotated references in the later chapters similar to those in the first few would have been a very welcome addition.

Overall, the first two wonderful chapters and the very nice treatments of various topics in the rest of the book overwhelm any reservations about recommending the book. This will indeed be a valuable addition to a teacher's bookshelf. I hope the next edition will be even more valuable.

GORDON J. AUBRECHT, II
Ohio State University, Marion

Radio-Frequency Electronics: Circuits and Applications

▶ Jon B. Hagen.
Cambridge U. P., New York, 1996.
358 pp. \$49.95 hc
ISBN 0-521-55356-3

In the first figure of *Radio-Frequency Electronics*, Jon Hagen delineates the

eight decades of the electromagnetic spectrum occupied by radio frequencies: from above 10 kHz to 1000 GHz, the latter corresponding to a wavelength of 0.3 mm. Within that range, we can identify several approximate lines of demarcation, where changes in circuit behavior occur. For example, above several megahertz, the inductance of relatively short lengths of wire can become significant. Above about 300 MHz, lumped constant elements (resistors, capacitors and inductors, which are each effectively concentrated at a single point) give way to distributed constant circuits typified by coaxial and waveguide transmission lines. This is the frequency regime generally referred to as microwaves.

Back in the late 1940s, several volumes in the MIT Radiation Laboratory Series (McGraw-Hill) dealt with rf circuits, devices and design philosophy. The driving force at that time was wartime-spawned radar. Hagen has recognized the need for a fresh look at rf systems and their applications. In addition to radar, his book includes communications (increasingly wireless), radio astronomy and, in the medical field, magnetic resonance imaging.

Hagen developed his text for a one-semester course in electrical engineering for students unfamiliar with rf circuits, devices and systems; for that purpose, I believe the book will be successful. There are 34 chapters covering transmission lines and matching networks, radio receivers and the associated problem of amplifier noise, modulation and detection schemes, oscillators, phaselocked loops and elements such as mixers, filters, transformers and couplers.

That coverage is indeed broad, but I believe that two other topics should have been included. The first concerns broadband—that is, untuned—rf amplifiers of both the small-signal and power variety. It is not the circuit design details that are needed so much as an idea of the many commercially available models. Modern nuclear magnetic resonance spectrometers and imagers depend heavily on those instruments, as well as on the pulse technology associated with pulsed NMR. Although Hagen does treat the transmission line modulators that are useful in radar, it is the more general types—originally referred to as hard-tube modulators—that deserve some discussion.

The book contains problem exercises for each chapter. They appear well designed to test a student's comprehension. The illustrations are well chosen and nicely complement the author's writing, which I found to be both informative and enjoyable to read. Hagen introduces the subject of

waveguides in this manner: "The ability of a hollow metal pipe to transmit electromagnetic waves can be demonstrated by holding it in front of your eye (you can see through it)."

I wonder how old-timers other than myself will react to Hagen's first reference to vacuum tubes. An asterisk leads the reader to a definition that begins, "A triode vacuum tube is analogous to an npn transistor." *Sic transit gloria mundi!* Incidentally, I would have chosen an *n*-channel field-effect transistor as a better analog.

Hagen believes that his book could be a reference for working engineers. That poses a problem. Most of the chapters are only about ten pages long; there is simply not enough in-depth material provided for each topic to satisfy that audience. An experienced rf engineer doesn't usually need an overview so much as detailed answers for solving some knotty problems. But that still leaves a potential readership of rf neophytes, who are enrolled in a formal course or are interested in self-study or who have some knowledge of the field and wish to browse to find out what's new. To that audience, I can and do recommend Hagen's book.

LAWRENCE G. RUBIN

Massachusetts Institute of Technology
Cambridge, Massachusetts

Anomalies in Quantum Field Theory

▶ Reinhold A. Bertlmann
Oxford U. P., New York, 1996.
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In quantum field theory, the word "anomaly" has come to stand for a situation in which a conservation law that follows from naive manipulation of the Lagrangian is not present in the full-fledged quantum theory. It follows that any deductions based on such a conservation law could run counter to experiment. Indeed, this is what happened when David Sutherland and Martinus Veltman showed independently in 1967 that, according to current algebra, the neutral pion could not decay into two photons, when, in fact, it does. The resolution was provided in 1969 by John Bell and Roman Jackiw and, independently, by Stephen Adler. Through a careful analysis of the divergences of certain Feynman diagrams, they found a violation of the naive conservation law of axial charge that gave a decay rate in accordance with experiment.

The following years showed that