AIP

PHYSICS
TODAY

Solid-State Physics: Introduction to the Theory FREE

Walter Harrison

Physics Today **61** (1), 59–60 (2008);
https://doi.org/10.1063/1.2835156

books

The cosmos from a different point of view

Endless Universe

Beyond the Big Bang

Paul J. Steinhardt and Neil Turok

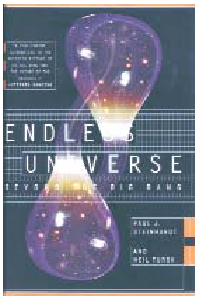
Doubleday, New York, 2007. $24.95 (284 pp.). ISBN 978-0-385-50964-0

Reviewed by Glenn D. Starkman

Should scientists write popular books about their alternative theories even when they have admitted that the ideas are controversial? Many of us in science would instinctively answer that the proper—nay, the only—place for discussions of such theories is in the peer-reviewed literature. And yet there are historical examples of controversial science that first gained traction from public dissemination. Charles Darwin's *On the Origin of Species*, published in 1859, and Rachel Carson's *Silent Spring* (Houghton Mifflin, 1962) come to mind. Such works should make one pause before denigrating the public presentation of alternative theories.

But do those lessons apply to a technical field such as string cosmology, in which almost none of the target audience has the tools or the knowledge to critically assess the science? And if the audience is unequipped to evaluate the authors' claims, are those authors obligated to be particularly clear that their theory is not widely viewed as a compelling alternative and that some of their fundamental claims have been challenged in the scientific literature?

Readers should keep those questions in mind as they delve into Paul Steinhardt and Neil Turok's *Endless Universe: Beyond the Big Bang*. The book is first and foremost a popular exposition of their cyclic theory of the universe, in which the universe goes through cycles of apparent growth and contraction, heating and cooling. The cycling is driven in part by the interactions between our three-dimensional universe and another parallel universe that is our close neighbor, but is off in a direction perpendicular to the three with which we are familiar. The book also positions the cyclic universe as an alternative to the widely revered and accepted concordance model, which posits that the universe initially underwent a period of inflationary growth and is presently dominated by dark energy and cold dark matter.



To present their story, the authors, who are both theoretical physicists, use biographical vignettes that focus on personal scientific developments, especially as they relate to the emergence of the cyclic and inflationary models. Thus readers learn that Steinhardt, Albert Einstein Professor in Science at Princeton University, was one of the early and principal developers of the inflationary model while Turok, chair of mathematical physics at Cambridge University, was an early and influential investigator of alternatives to inflationary theory.

Despite its ambitious agenda, the book is eminently readable and refreshingly brief. It should be widely enjoyed by nonexperts for its lucid descriptions of both the inflationary model and the cyclic alternative. Vested experts will quibble over particular descriptions and challenge certain historical narratives. Others will suggest, either because they disagree with Steinhardt and Turok's calculations or because many of the observational results predate the cyclic model, that the cyclic universe's consistency with cosmological observations is significantly less persuasive than inflation's. I would have preferred a more critical examination of the evidence for both theories. The authors are far from unique in feeling "a growing concern with the conventional picture." Nor are they alone in believing that science benefits when the canonical theory is challenged by alternatives, just as the cyclic theory and its ekpyrotic predecessor, proposed by Justin Khoury, Burt Ovrut, Steinhardt, and Turok, challenge the worldview of the inflationary paradigm.

Still, I strongly believe that Steinhardt and Turok were capable of creating not just a readable book but a truly compelling one. Instead, their weaving of autobiographical interludes into *Endless Universe* seems too short on deep insights and on details of their intellectual processes, and thus too much of a deliberate hook, to be compelling. The authors might have seized the opportunity, and the space, to promote not just the particular cyclic concept that they profess such enthusiasm for but also the more general value of alternative theories to science. Steinhardt and Turok could have far more clearly opened up to the public the process by which scientific theories are developed, debated, challenged, and defended. That book is one I would want not just to read but to recommend whole-heartedly.

Glenn Starkman is a cosmologist and particle physicist at Case Western Reserve University in Cleveland, Ohio. Much of his work focuses on testing cosmological models—both standard and alternative.

Solid-State Physics

Introduction to the Theory

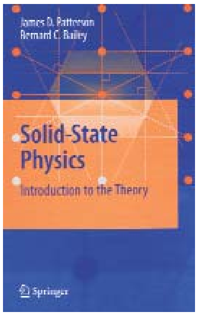
James D. Patterson and Bernard C. Bailey

Springer, New York, 2007. $99.00 (717 pp.). ISBN 978-3-540-24115-7

How does one choose a text when teaching a graduate course in condensed-matter physics? Certainly for an undergraduate course, Charles Kittel's *Introduction to Solid State Physics* (Wiley, 1953), whose eighth edition was published in 2005, comes immediately to mind. The many tables presented in the book were an indispensable resource to me, at least before the advent of Google. Neil Ashcroft and N. David Mermin's *Solid State Physics* (Holt, Rinehart and Winston, 1976), which makes for more comfortable and leisurely reading than Kittel's text, is an alternative. Neither text, however, would seem to have the depth needed for a graduate course. The remarkable early texts *The Theory of the Properties of Metals and Alloys* (Clarendon Press, 1936), by Nevill Mott and Harry Jones, and *The Modern Theory of Solids* (McGraw-Hill, 1940), by Frederick Seitz, are at a more appropriate level for a graduate course, but too much has happened in the past 70 years for either to serve as a modern text.

In the 1960s and 1970s, a flood of

condensed-matter physics books appeared on the scene: Philip W. Anderson's *Concepts in Solids: Lectures on the Theory of Solids* (W. A. Benjamin, 1963), John M. Ziman's *Principles of the Theory of Solids* (Cambridge U. Press, 1964), my own *Solid State Theory* (McGraw-Hill, 1970), James Patterson's *Introduction to the Theory of Solid State Physics* (Addison-Wesley, 1971), Ashcroft and Mermin's text, and Otfried Madelung's *Introduction to Solid-State Theory* (Springer-Verlag, 1978). The range of material and of approaches covered in the texts seems surprisingly similar. But years later, Harald Ibach and Hans Lüth's *Solid-State Physics: An Introduction to Theory and Experiment* (Springer-Verlag, 1991) offered a distinctive approach. For most of us condensed-matter theorists, the first question asked when we consider a property is, "How do we estimate it?" But for Ibach and Lüth, the first question is, "How do we measure it?" That point of view suited my colleague Zhi-Xun Shen when we each taught part of a course at Stanford University: Shen used Ibach and Lüth's text; I used my own. Even today, another distinctive possibility for a graduate text is Anderson's book, because of the author's unique insight. But the subjects covered are limited, with most of the content surprisingly centered on questions related to electronic-band structure.



Beyond the texts mentioned above, one faces a dazzling array of choices, including *Solid-State Physics: Introduction to the Theory* by Patterson and Bernard Bailey. An update to Patterson's 1971 text, it adds a great deal of modern material, nearly doubling the size of the original. This expansion makes it definitely a candidate for a contemporary class. It was a prodigious task, as the authors indicate, to bring the book up to date. They included such developments as the Coulomb blockade, nanostructures, the quantum Hall effect, and fullerenes, all of which had not yet been discovered at the time of the first edition. The authors even went so far as to add in a model of the structure of white dwarfs and discuss crystal growth in space, although I found both subjects unsettling in their presentation. The discussion on the structure of white dwarfs is a jumble of equations, some of which, such as the relation between the volume of a sphere and its radius, are unnecessary. Others look wrong, such as equation 5.78, which is supposed to follow from equation 5.77; the error is presumably a misprint, but because so many factors are omitted, one cannot be sure. The section on crystal growth in microgravity, which I think has turned out to be the same as crystal growth in normal gravity, is an unbelievably convoluted explanation of why one who is in free fall does not feel gravity.

As the table of contents reveals, Patterson and Bailey's book meets a requirement my colleague Volker Heine of Cambridge University once shared with me: He wanted a text to cover all the standard topics so that he could lecture only about the most interesting ones. When choosing a text, instructors should always check the contents first, then sample topics with which they are familiar to see how they are handled. Judging the topics covered may be subjective, but finding a text with which one is comfortable teaching is a subjective undertaking.

I found it instructive to try the approach on other texts first. For example, I looked at how several authors treated conduction in metals. Anderson asserts that "the only reason why an actual metal or semiconductor carries a current is the presence of relaxation effects." True and perceptive, but seldom stated. Ziman writes that "the high conductivity of metals is to be ascribed to the high velocity of the few electrons at the top of the Fermi distribution, rather than to a high total density of free electrons which can be set slowly drifting." Not true, but perhaps frequently thought. After deriving the conductivity, Madelung notes that "separating conductivity into charge, electron concentration, and mobility, the latter is seen to be $\mu = e\tau(\mu)/m^*$." True, but not very informative. It seemed to me that each of those comments was characteristic of the book from which it came. After Patterson and Bailey derive the formula for conductivity, they assert that "equation (3.214) is a basic equation for the electrical conductivity. Again, (3.214) agrees with experiment more closely if m is replaced by a suitable m^*."

For my own taste, Patterson and Bailey's book might prove problematic as a graduate text: It has too much algebra and too little physical insight. For example, the first analysis in chapter 1 is of the van der Waals force. That section takes up two pages of equations, qualifications, and assumptions when one clear paragraph would have sufficed. The next topic is Max Born's theory of bonding in ionic crystals, but it is not done as nicely as the way Born had described it. That section offers a few introductory equations, including some irrelevant ones on thermodynamics and a table of cohesive energies in kilocalories per mole, so a physicist will have little idea of the physical magnitudes. And where are such modern insights as the realization that the energy per molecule required to separate the rock-salt crystal into neutral atoms is approximately equal to the difference in ionization potentials of the sodium and chlorine atoms? Too often the reader is left with many equations whose terms are incompletely defined and whose motivations are misleadingly described. The section on the Ginzburg–Landau equations seems to exemplify such cases. How the authors deal with that topic might prevent students from searching for a clear understanding of it, the kind of clarity that instructors hope to motivate their students with in class.

But, again, the choice of a text for a solid-state physics course, or any other physics-related course, is a personal one. The style of Patterson and Bailey's *Solid-State Physics* might well fit that of some physics instructors.

Walter Harrison
Stanford University
Stanford, California

Richter's Scale

Measure of an Earthquake, Measure of a Man

Susan Elizabeth Hough
Princeton U. Press, Princeton, NJ, 2007. $27.95 (335 pp.).
ISBN 978-0-691-12807-8

Having dabbled in the theory of earthquake dynamics, I was intrigued by the request from PHYSICS TODAY to review Susan Elizabeth Hough's *Richter's Scale: Measure of an Earthquake, Measure of a Man*. I had worked enough in the field to be fascinated by its challenges and curious about its history. Hough is a professional seismologist and writer. Surely, I thought, her biography of Charles F. Richter (1900–85) will address important questions in the history of modern science.

I knew that Richter, along with colleagues such as Beno Gutenberg and Hugo Benioff, had laid down the foundations of modern seismology before there was any understanding of plate tectonics, in an era when a "computer" was a person, usually female, who was hired to do arithmetic. How did Richter do this? How did he visualize earthquakes? What physical principles did he invoke? How could he possibly have