Modern Introductory Physics FREE

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Statistical Mechanics: A Short Treatise

Giovanni Gallavotti
Springer-Verlag, New York, 1999. $68.00 (339 pp.)
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Statistical mechanics is a little more than a hundred years old. The foundational work was done by James Clerk Maxwell, Ludwig Boltzmann, and Josiah Willard Gibbs. The development of the field since then has been phenomenal. Statistical mechanics played an essential role in the beginnings of quantum theory (with Max Planck and Albert Einstein), and its entropy concept has been central to the creation of information theory by Claude Shannon. In fact, the ideas of statistical mechanics appear unexpectedly in many areas of physics and pure mathematics. So writing a comprehensive treatise of statistical mechanics seems at present to be a superhuman enterprise. What, then, does Giovanni Gallavotti mean when he proposes to us his "short treatise"?

The prospective reader should first be told what this book is not. It is not application oriented. It does not display rules and techniques for the solution of problems that occur in practice. It does not, for instance, have a list of definitions of critical exponents. In fact, it has basically nothing about renormalization group or critical points. While Gallavotti himself has done important work using the renormalization group, this is not what he chooses to discuss here. Then what?

The "short treatise" is a conceptual (one might almost say ideological) presentation of statistical mechanics. It is not very mathematical, stresses ideas rather than proofs, and is ideally suited to learning rapidly the difficult principles of the subject. I would see it most useful as a second book after a basic introduction.

Equilibrium and nonequilibrium are discussed, and the historical dimension is not forgotten. (Gallavotti shows that he has studied the writings of Boltzmann and others in depth.) The reader thus gets a competent evaluation of what is known and what is not known. For example Gallavotti explains (p. 108) that "very important phenomena, such as the liquid–gas transition or the crystal–liquid transition, are not really understood." Apparently, the thermodynamic functions have essential singularities at phase transitions, and one has to give up the theory of "metastable states" for short-range interactions, although metastability occurs as a dynamical phenomenon (p. 206). These facts are known to the experts, but it is good to have them plainly stated in an accessible text.

Part of the charm and interest of Gallavotti's book is in the way he relates Boltzmann's ideas to modern concepts. Boltzmann's ideology was discrete rather than continuous, and Gallavotti quotes Boltzmann, for example: "The concepts of differential and integral calculus separated from any atomistic idea are truly metaphysical, if by this we mean, following an appropriate definition of Mach, that we have forgotten how we acquired them." (See p. 140 for further Boltzmann quotations.) Thus, phase space should be a finite set, and time evolution should give rise to periodic orbits. One can see how such ideas could (and did) infuriate some mathematicians. But Gallavotti shows (for instance in appendix 9.A3) how Boltzmann got the physics right.

Most of this "short treatise" deals with equilibrium statistical mechanics and allows the reader with a reasonable background to see what is currently known about phase transitions and coexistence of phases. The last chapter, however, is on nonequilibrium and puts this subject in a very modern perspective. Stated succinctly, the modern view is that chaotic microscopic dynamics is essential for nonequilibrium. In more mathematical words, positivity of the entropy production requires "hyperbolicity" of the underlying dynamics. Therefore, the older approaches to nonequilibrium, which did not take into account the chaotic dynamics, missed an essential fact. This may explain why the study of nonequilibrium has progressed so slowly compared with that of equilibrium. The "chaotic hypothesis" developed by Gallavotti and his colleague Ezekiel Cohen has been central to the new developments. As in the rest of the book, this last chapter insists on the ideas, basic formalism, and history, and leaves out most of the mathematics.

Gallavotti has written a somewhat ideological and quite personal book. Certainly one may disagree with him on some issues. But he has expert knowledge of what he discusses and also of many things he chooses not to discuss. And since he also knows the history of the subject, his opinion must be taken seriously. We may thus thank Gallavotti for giving us a fresh, authoritative, and readable introduction to a fundamental area of conceptual physics.

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Modern Introductory Physics

C. H. Holbrow, J. N. Lloyd, and J. C. Amato
Springer-Verlag, New York, 1999. $59.95 (519 pp.).
ISBN 0-387-98576-X

Some time ago, I came across a set of notes on approximation techniques useful in physics. They were so clear, well-motivated, and literate, I wanted permission to give copies to my students. In tracing them to Colgate University, I learned that they were part of the relativity chapter in a textbook being developed there for an innovative, one-semester, introductory physics course. I remember hoping that the book would be completed quickly, because it looked like such a welcome change of pace. It is now out as *Modern Introductory Physics* by Charles H. Holbrow, James N. Lloyd, and Joseph C. Amato. Recalling that earlier brush, I happily agreed to review it. In brief, the book is a delight and, for the correct audience, it will be very successful.

I wish that I could reproduce the authors' preface; it is hard to summarize the thinking that went into this effort. I recommend that teachers of introductory physics read it or the authors' more extended description (with E. Jose Galvez) in the *American Journal of Physics* volume 63, 1078, 1995. Although this is a book for likely physics majors (and other students you'd like to lure into the major), it represents somewhat of a return to the liberal arts tradition in that it is written to be read, and it respects the student's intelligence. And by avoiding simply repeating high-school material at a higher level, it offers a more enticing entrée to the college-level curriculum.

The book follows a single story line: the physics of the atom and how it was discovered. This allows coverage of much material included in the typical year-long introductory course and more 20th-century physics than usually fits in even a two-semester course. And there are nice applications, telling, for example, how ink-jet printers steer blobs of ink or how scanning tunneling microscopes work. While the book is not explicitly part of the IUPP (Introductory University Physics Project), the authors have done a fine job of implementing the project's principles.

Many of the book's stylistic features stimulate engagement and comprehension. First, a sense of intelligent inquiry permeates the book.

Equally appealing is the droll humor, as in the following example:

> STATEMENT: . . . are central to Einstein's special theory of relativity. The consequences of this theory are necessary to understand the behavior of atoms or their components at high energies. This behavior is surprising and unfamiliar to beings whose experience with the physical world is limited to velocities much less than that of light.
>
> EXERCISE: What beings might these be?

The answer is human beings unless, I suppose, they happen to be sitting on the bridge of the star ship *Enterprise*. Exercises of this sort are frequently embedded in the text and are intended to be considered in the course of the reading. (Problems also appear at the end of each chapter and these, in keeping with the discovery story line, emphasize experiment more than is typical, often presenting actual data for analysis.) Readers are instructed to test their understanding in real time by doing all the exercises as they read, and by making up and answering their own questions. (That's intelligent inquiry!) The authors then demonstrate how that should be done, and bluntly tell the student to expect a slow reading pace. Of course, instructors will need to enforce this doing of the exercises, but it is helpful to have the authors weigh in so convincingly.

Recognizing that many well-prepared college students may have encountered calculus but are still shaky on the basics of quantitative reasoning, the authors include activities to build or resuscitate those skills. Also, critical patterns of thought are repeated with explicit reference to earlier uses.

The less didactic style permits the more frequent deployment of metaphor and imagery. Richard Feynman's great conservation of energy analogy in section 4, volume 2, of *The Feynman Lectures on Physics*, which he wrote with Robert B. Leighton, and Matthew Sands (Addisdon Wesley Publishing, 1965) makes an appearance. Another example of an apt metaphor is the one adopted to explain $v = \lambda\nu$: "The situation is analogous to a passing railroad train. If the length of each car is L meters and N cars pass per second, then the velocity of the train is NL meters/sec." (I know that will work better than my laboriously drawn blackboard sketches.) Moreover, the book has an up-to-date feel: There are, for instance, references to Web pages, and data tables from ancient experiments are related to spreadsheets. However, the book contains fewer figures and photographs than usual, and color is not used.

The experienced physics instructor will recognize the veteran's touch in the extra focus devoted to many topics that are especially difficult for students. One topic that does not get sufficient attention, however, is the visualization of vector fields, including light waves and static electric and magnetic fields. The book has other imperfections: (1) The style is a bit parochial (spatially and temporally); it seems targeted at American students and some aspects may go out of date rather quickly. Even the wonderful cover photo—scanning tunneling micrographs of dissociating O_2 atoms, discussed in the epilogue—will be superseded in a few years by even more wonderfully revealing atomic images. (2) Although in their preface the authors suggest that the book, while intended for students with a solid high-school background in physics, might be used in a year-long course for less well-prepared students, I doubt that it would succeed for that audience. Too much prior knowledge is assumed. (3) How to proceed after digesting this

book? The student will not yet be ready for typical sophomore-level physics, but it seems retrograde to fill in the gaps by following with a Halliday and Resnick type-course. So downstream curricular adjustments will be required. (To see how Colgate addresses this, go to http://departments.colgate.edu/physics/curricular/general.html)

Despite the flaws, this book very much deserves consideration, and you, too, will really enjoy reading it. A longer version of this review can be consulted at http://www.haverford.edu/physics-astro/Roelofs/Texts/

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