with the complex interplay between stellar evolution and stellar dynamical processes, and, in particular, the way in which close interactions between stars (such as exchange interactions with binaries and physical collisions) can completely change the observable properties of the stars. Those processes are responsible for the very large formation rates in dense clusters of the most interesting and "exotic" sources, such as millisecond pulsars, x-ray binaries, and blue stragglers. This "star cluster ecology," an expression coined by Heggie more than 10 years ago, is discussed rather briefly and superficially in about the last 30 pages of the book. That is probably a reasonable choice, because a more detailed discussion would have likely turned off many nonastronomers.

Researchers and graduate students who need to learn more will find in the book plenty of up-to-date references to the recent literature. What the authors provide in *The Gravitational Million-Body Problem* is just enough to give outsiders a taste of how messy but fun real astrophysical systems can be. Both the specialist and the nonspecialist will enjoy what Heggie and Hut have to offer in this exciting field.

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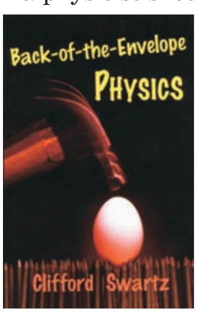
Back-of-the-Envelope Physics

Clifford Swartz
Johns Hopkins U. Press, Baltimore, MD, 2003. $65.00, $19.95 paper (155 pp.).
ISBN 0-8018-7262-6,
ISBN 0-8018-7263-4 paper

In science, physicists are unusual in their emphasis on the primacy of magnitudes and their ability to estimate the numerical values of quantities. Physicists are "numerate"—as in "literate"—but not everyone else is. Enrico Fermi is said to have claimed that a physicist should be able to estimate anything, such as the number of barbers in Chicago or the binding energy of the deuteron, within an order of magnitude. Clifford Swartz mentions Fermi's position in the preface of *Back-of-the-Envelope Physics*, which presents 104 "back-of-the-envelope" calculations that use physics to make quantitative estimates of interesting properties.



The problems are divided into 10 chapters ranging from "Force and Pressure," which contains a calculation of the density of nails required for a comfortable fakir bed, to "Particles and Quanta," in which Swartz outlines a calculation of the intensity of light from a synchrotron light source. Overall, about half of the book's problems describe estimates made without recourse to references or other textbooks and thus fit my interpretation of Fermi's dictum. Other problems in the book require handbook values of quantities that either were not part of my mental arsenal or required textbook relations that were not evident to me. For example, Swartz's essay on ice skating requires detailed knowledge that I did not have for the ice–water phase diagram.

In all, I enjoyed Swartz's book and found it fun. Solving the problems became a kind of game, and sometimes I believed I could solve them in a simpler and more persuasive manner than how Swartz had done. In a few cases, his approach seemed unconvincing; at times, I thought of variations or additions that might have found a place in his book. But having known him for a half-century, I am sure that he did not write the book to amuse or test me. Swartz, who served as editor of the *Physics Teacher* for three decades and was the 1987 recipient of the Oersted Medal of the American Association of Physics Teachers, is a teacher—and his book is meant to teach.

From observing incoming graduate students at my university, I have found that the educational system for training young physicists is effective in bringing students to a reasonable level of formal sophistication. Thus, our students can solve difficult, formal problems on qualifying exams. But when we put a set of back-of-the-envelope problems on the exams, the students don't do as well as I would like. We don't teach quick magnitude reasoning, but perhaps we should. It is so important to be able to dispose of bad ideas quickly—not only after one has completed long calculations. And if we can estimate magnitudes competently, we can play a significant role in public affairs, an area in which important questions are too often answered incorrectly by the innumerate. Although Swartz does not ask his readers to estimate the amount of environmental tobacco smoke a nonsmoker inhales in a smoky bar or the limit that thermal noise places on biological effects of weak power-line magnetic fields, back-of-the-envelope calculations strongly suggest that—contrary to what some scientists in other fields and some politicians claim—those environmental factors cannot affect health.

Hence physicists young and old should follow Fermi and Swartz and hone a competency in back-of-the-envelope physics. In that endeavor, Swartz's little book can serve as a pleasant tutorial. And if, like me, you have given up all hope of improvement, the book is still fun—even for a physicist.

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Foundations of Nanomechanics: From Solid-State Theory to Device Applications

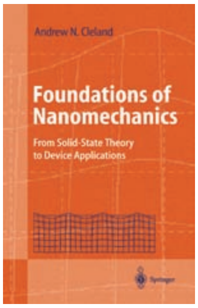
Andrew N. Cleland
Springer-Verlag, New York, 2003. $69.95 (436 pp.).
ISBN 3-540-43661-8

The potential for the field of nanotechnology to transform civilization—with major applications in areas that span materials, biology, manufacturing, and information technology—is breathtaking. Examples of such applications include self-repairing materials, quantum computers, regenerative biological tissues, in situ drug delivery, and space exploration by microcraft that are smaller than a sugar cube! Such dreams are realized only through the training of today's and tomorrow's scientists and engineers in the new arena of nanoscale phenomena; that training is largely absent in present undergraduate and graduate curricula.

Current technologies and university science courses that cover this field have originated largely from an understanding of either the very large scale of bulk materials properties or the very small scale involving atoms and molecules. Progress in nanoscale technology requires a fundamental understanding of the intermediate realms between those scales and a concomitant educational effort to transform into applications the knowledge that scientists have gained in those realms. *Foundations of Nanomechanics: From Solid-State Theory to Device Applications*, a text on the solid mechanics of very small objects, addresses this educational need head-on.

Andrew Cleland is intimately familiar with the task he undertakes in this book. He is a professor of physics at the University of California, Santa Barbara, a position he has held since 1997. His research involves the experimental development of nanomechanical and nanoelectronic devices. Cleland's work covers ultrasensitive force and displacement detection, single-electron effects, bolometry and calorimetry, and explorations of linear and nonlinear effects in mechanical systems.

The book, aimed at advanced undergraduates and beginning graduate students, joins in one treatise an engineering treatment of solids as continuum objects with a condensed matter physics focus on the quantum mechanical nature of solids. Beginning with a bottom-up atomistic description of matter, Cleland seamlessly works his way up, in the first seven chapters, to a continuum description of matter. Topics range from the dynamical motion of a two-atom system and the quantum and thermodynamic behavior of linear chains to atomic lattices, elasticity and deformation of solids, and the dynamical behavior of solids. The final chapters are devoted to dissipation and noise—topics that loom large at the nanoscale—and experimental fabrication techniques for today's nanostructures.



Some of the material covered in the book, especially with respect to phonons in solids, necessarily overlaps with material included in standard texts on condensed matter physics. Books that cover the theory of continuum mechanics include *Acoustic Fields and Waves in Solids* (R. E. Krieger, 1990) by Bertram A. Auld; *Theory of Elasticity* (Pergamon Press, 1986) by Lev D. Landau and Evgenni M. Lifshitz; and *History of Strength of Materials* (Dover, 1983) by Stephen Timoshenko. Those are all excellent summaries of the theory of mechanical systems but stop short of extensions into nanomechanical systems and the special aspects of very small mechanical systems. Books that provide excellent summaries on the experimental fabrication and measurement aspects of micro- and nanomechanical systems include *Handbook of Microlithography, Micromachining, and Microfabrication, Vol. 2: Micromachining and Microfabrication* (SPIE Optical Engineering Press and Institution of Electrical Engineers, 1997) edited by P. Rai-Choudhury and *Fundamentals of Microfabrication: The Science of Miniaturization* (CRC Press, 2002) by Marc J. Madou. No book, however, fills the unique role provided by Cleland's monograph.

The most apparent use for Cleland's book is in a semester- or year-long, special topic course on nanomechanics. The author also suggests it as a useful reference for the practicing scientist or engineer. Given the highly distilled discussions of the underlying physics, students enrolled in a nanomechanics course who wish to use this text ideally should have a very fresh knowledge of undergraduate classical and quantum mechanics. Instructors could also supplement and update existing physics and engineering courses by inserting the book's material on nanoscale phenomena into the curriculum.

Used a little or used a lot, *Foundations of Nanomechanics* will be useful all around!

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