Simon Laplace, Johannes Kepler, Edouard-Albert Roche, and Johannes Matthaeus Wackher von Wackenfels, one gets the feeling we may all be part of history. If the tale is somewhat better in the telling, so be it.

The Gravitational Million-Body Problem: A Multidisciplinary Approach to Star Cluster Dynamics

Douglas Heggie and Piet Hut
Cambridge U. Press, New York, 2003. $100.00, $55.00 paper (357 pp.). ISBN 0-521-77303-2, ISBN 0-521-77486-1 paper

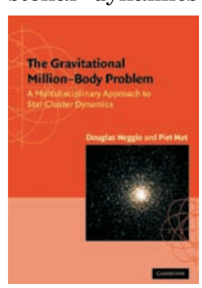
Stellar dynamics, the study of systems containing large numbers of stars bound together by gravity, is usually divided into two main subfields: *collisionless* and *collisional* systems. Except for their central nuclei, galaxies are collisionless systems. In such systems, described mathematically by the collisionless Boltzmann equation, stars follow unperturbed orbits in the mean gravitational potential as though they were alone in a smooth sea of background matter.

In collisional systems, fluctuations in the potential that are caused by close encounters with other stars can perturb the orbits. Very often those perturbations are small, and the dynamical evolution can be treated as a slow diffusion process in phase space using the Fokker–Planck approximation. However, in the most extreme environments with very high stellar densities, as in the cores of the densest star clusters or the innermost parts of galactic nuclei close to their central massive black holes, very strong interactions—even physical collisions—between stars can occur.

Douglas Heggie and Piet Hut's new book, *The Gravitational Million-Body Problem: A Multidisciplinary Approach to Star Cluster Dynamics*, provides a very modern and refreshingly new perspective on collisional stellar dynamics based on interdisciplinary themes. The book is aimed at a broad audience of graduate students and professional researchers in astronomy, computer science, and mathematical physics. The various parts of the book oscillate between statistical mechanics (from the continuum limit to large but finite "million-body" systems) and the dynamics, or "microphysics," of close interactions between small numbers of stars (usually two, three, or four).

Overall, the book contains a very good balance of more formal mathematics and practical questions. Mathematical topics vary from the mundane, such as motion in a central potential, to the esoteric, such as the use of Cayley numbers to regularize the two-body problem. More practical topics include numerical algorithms and computer simulation methods. Such balance reflects the authors' own tastes and expertise: Both Heggie and Hut have been major contributors to this field for almost three decades; Heggie has contributed more on the mathematical side, and Hut more on the computational side.

Although several excellent textbooks on galactic dynamics exist, such as the graduate-level, modern classic *Galactic Dynamics* (Princeton U. Press, 1988) by James Binney and Scott Tremaine, collisional stellar dynamics has been less well served. Lyman Spitzer's now out-of-print *Dynamical Evolution of Globular Clusters* (Princeton U. Press, 1988) is rather old-fashioned and terse. Books on galactic dynamics or more general textbooks on astrophysics typically relegate collisional stellar dynamics to a single chapter, which does not do the subject justice.



In Heggie and Hut's book, the emphasis placed on the interdisciplinary aspects of the field is rather unconventional but very effective. The great variety of topics and styles adopted in the many different short chapters makes this book pleasant to read, even for the nonspecialist. Many physics and astronomy departments have been revising their graduate curricula to place more emphasis on interdisciplinary topics, and this book could provide an ideal opportunity to teach a new course jointly in two or more departments (for example, astronomy and applied math). I am planning such a course in the near future, and I know that this book will make it a lot more fun.

Experts will also find this interdisciplinary approach very stimulating because it always offers something new to learn. I was enchanted by the many small gems hidden throughout the book. For example, the discussion of the Kustaanheimo–Stiefel regularization method, covered in only a couple of pages in chapter 15, is remarkable in both its conciseness and lucidity. Similarly, box 20.2 presents, in just half a page, a clear, almost purely qualitative proof that capture orbits in the three-body problem represent a set of measure zero, which is one of those "intuitively obvious" results that are extremely difficult to prove. On the more pedestrian side, box 1.1 on units will be cherished by beginning graduate students (who will understand the material quickly) and their advisers (who will not have to explain it for the nth time).

Traditionally, the study of collisional stellar dynamics has been almost synonymous with the study of the old globular clusters of our Milky Way. They are spherical clusters of typically about 10^5 stars and approximately 10 light years across. Our galaxy contains more than 100 such clusters scattered throughout its halo. Thought to have formed very early during the process that assembled the Milky Way, they contain some of the oldest stars known, with ages exceeding 10 billion years. Other galaxies also contain globular clusters, sometimes in much larger numbers than those in the Milky Way. Over the past decade, astronomers have revolutionized the study of extragalactic globular clusters by using powerful space-based observatories such as the *Hubble Space Telescope* and the *Chandra X-ray Observatory*.

Renewed interest in the study of collisional stellar systems has also come from the recent realization that most—and perhaps all—stars form in some kind of dense cluster environment, where interactions could even help shape such fundamental properties as the initial stellar mass spectrum and the fraction of stars that end up in bound pairs (binaries). The connection to globular clusters comes from observations of bright clusters of young stars in *starbursts*, regions where star formation appears to be on steroids. These starbursts are commonly found in interacting galaxies, and they seem to have dominated the star formation landscape early in the history of the universe when the first galaxies were forming and interacting often. Most stars within starbursts appear to form in very large, dense clusters, sometimes called "super star clusters," which may well be the younger siblings of our old globular clusters. These younger clusters are observed very early after their birth, when they are only about 10^7 years old and still contain lots of young, massive, and very bright stars.

Most of the current research on dense star cluster dynamics deals 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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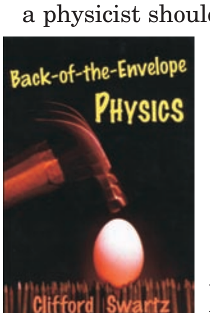
Back-of-the-Envelope Physics

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
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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