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Entropy and the Time Evolution of Macroscopic Systems

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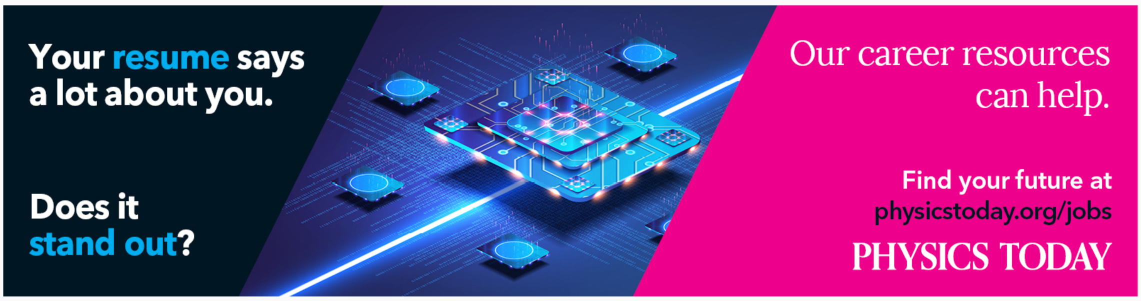
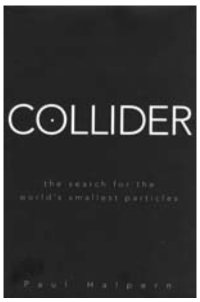


Collider

The Search for the World's Smallest Particles

Paul Halpern
Wiley, Hoboken, NJ, 2009. $27.95 (260 pp.). ISBN 978-0-470-28620-3

Theoretical physicist Paul Halpern is a prolific, award-winning author and a respected popularizer of science. In his latest book, *Collider: The Search for the World's Smallest Particles*, Halpern offers the general reader a historical perspective on the development of particle physics in the 20th century and a peek into its future. The collider in the title refers to CERN's Large Hadron Collider, a major international scientific facility located outside of Geneva, Switzerland.



Never have particle physicists felt as assured of achieving groundbreaking discoveries as with the onset of LHC operations. When Congress stopped funding the Superconducting Super Collider in 1993, US particle physicists, with strong support from the Department of Energy and NSF, joined the international scientific community in developing the LHC's scientific program. The US LHC project was funded in 1995 with scientific goals similar to those that had been proposed for the SSC, namely, to find the long-sought Higgs boson and to discover new phenomena expected to augment the currently incomplete standard model of particle physics. The LHC is planning to restart operations soon, following an incident a year ago in which a faulty electrical connection between two of the accelerator's superconducting magnets caused mechanical damage and helium to leak into the LHC's tunnel (see PHYSICS TODAY, October 2009, page 25).

The book jacket for *Collider* promises a "comprehensive guide to the theory, mechanics, and science behind experimental high-energy physics." The book is not Richard Rhodes's scholarly epic, *The Making of the Atomic Bomb* (Simon & Schuster, 1986), but it has the flavor of that work. It is quite chatty, interesting, and a fun read. Halpern has a captivating style that can keep the reader engaged and wanting more. Unfortunately, the book doesn't provide much in the way of visual aids; more diagrams, pictures, and even simple equations would certainly have helped elucidate some of the material.

Additionally, the manuscript contains misstatements and imprecise remarks, which reflect poorly on the competence of and degree of scrutiny provided by the proofreaders and editors, and even on the author's understanding of the subject matter. In many places, changes in wording would have yielded a far clearer picture, one without errors and confounding descriptions. For example, the book confuses "beam energy" with "energy in the center of mass," is sloppy about distinguishing between mass and energy (and the meaning of $E = mc^2$) and about the scattering angles in Rutherford scattering, and appears to misconstrue the meaning of beam luminosity. If such errors are caught and removed in a second edition, or if explanatory pages of errata are contained in a subsequent printing of the book, I could recommend it with enthusiasm to high-school students or other nonscientists interested in learning about the origins of modern particle and astroparticle physics.

Finally, to paraphrase Carl Sagan, in science, it is the way of thinking that matters. From that perspective, it seems that Halpern does not fully appreciate the nature of experimental particle physics. At the end of the book, he bemoans the imminent demise of collider research not only because of its increasing costs but also due to the limited access students and researchers have to the field's technical aspects, such as experience in the design, construction, and commissioning of scientific equipment. During the 1960s and 1970s, there was similar concern for the education of students and postdocs who chose to analyze bubble chamber pictures, and therefore did not develop many technical skills. Nevertheless, when new tools were eventually required, they were developed by those very same individuals, because they were physicists who asked searching questions and were able to devise different experiments; they were not automatons wedded to a specific methodology. The increasing cost of colliders is certainly an issue, but we can expect inventiveness as in the past, and new, clever means for complementary investigations. So I do not share Halpern's gloomy outlook for particle physics.

Although I disagree with some of Halpern's views and pedagogical approaches, I think the reader will find that *Collider* has much to recommend it. Unfortunately, its value has been undermined by careless editing that I hope will be corrected in a follow-up edition.

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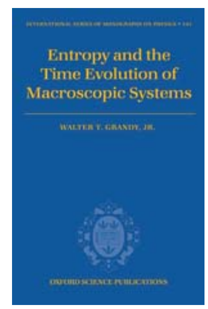
Entropy and the Time Evolution of Macroscopic Systems

Walter T. Grandy Jr
Oxford U. Press, New York, 2008. $110.00 (209 pp.). ISBN 978-0-19-954617-6

In his delightful little book, *Entropy and the Time Evolution of Macroscopic Systems*, Walter T. Grandy Jr aims to bring a wider appreciation for the meaning of entropy from the probability-based point of view. Grandy is no newcomer to the topic: His books *Foundations of Statistical Mechanics* (Reidel, 1987) and *Maximum-Entropy and Bayesian Methods in Inverse Problems* (Reidel, 1985) first appeared more than 20 years ago. The deep insights he brings to his latest text draw on those books and a long career spent pondering the subtleties of the entropy concept.



Grandy is a student of E. T. Jaynes, who developed the principle of maximum entropy, or maxent. In this latest book, Grandy carefully develops his mentor's formalism and then explores how an entropy function defined via the maxent principle can be used to describe time evolution and entropy production in a macroscopic system. Assuming that the reader has had a prior course in statistical physics or thermodynamics, Grandy focuses on the meaning of entropy.

The author takes the reader on a tour of various descriptions of irreversible macroscopic processes, including the Navier–Stokes equations in fluid mechanics, the Boltzmann equation in statistical mechanics, and Onsager's flux–force equations in irreversible thermodynamics. For each process, Grandy considers whether the procedure of maximizing the entropy based on the available information suffices to unambiguously define an entropy function. The topics that he discusses, although fraught with subtlety, are vitally important for this generation of physicists (also chemists, engineers, and even biologists).

Filled with many examples, Grandy's thought-provoking exposition will be of interest for years to come. He presents many of the standard debates at greater length than one is likely to find elsewhere, and he augments them with insights afforded by the maxent point of view. For example, he gives an excellent account of the usual mischaracterization of entropy as disorder and a lengthy discussion regarding whether entropy can be assumed to be extensive. The book's style, and to some extent the subject matter, are reminiscent of Brian Pippard's classic, *Elements of Classical Thermodynamics for Advanced Students of Physics* (Cambridge University Press, 1957), which explained the more subtle aspects of thermodynamics to a previous generation.

Grandy's subtleties, though, are not those of Pippard. The concern of the present monograph is exclusively entropy and its meaning as derived by probability theory. And Grandy's obtaining meaningful entropies for some of the systems he discusses is an impressive feat. The examples on which his presentation relies are often surprisingly complex. Consider the familiar box divided by a partition—one side is filled with gas, the other side evacuated. Grandy discusses whether a valid expression can be given for the entropy of that system in the time interval between the instant when the partition is removed and the time when the gas has equilibrated in the full volume. In a real achievement for the book, Grandy shows that the maxent approach can find a meaningful entropy for any relaxation process, including the partition example.

While impressed with the derivations, I confess to some annoyance with the book's repeated questioning of the "existence" of entropy. Even though I am aware that by "existence" Grandy means "existence in the maxent formalism," I still find that usage irksome. Since Grandy seems to accept the density matrix ρ as an always-valid description of the state of the system, I cannot help but wonder why he objects to John von Neumann's expression, $S = -k\,\mathrm{Trace}[\rho \log(\rho)]$, which guarantees that the entropy exists at each instant. Admittedly, we might not be able to explicitly write down an expression for the density matrix, but its existence and well-definedness are not in question.

That peccadillo and the associated tone of a zealot notwithstanding, *Entropy and the Time Evolution of Macroscopic Systems* is a scholarly and refreshing text that explores in detail the subtleties of carrying out a maximum entropy approach to describe irreversible processes. Written in an accessible style, the book makes numerous little-known connections between macroscopic and microscopic expressions for entropy and entropy production. I would recommend it to any serious student of statistical physics.

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Boulevard of Broken Symmetries

Effective Field Theories of Condensed Matter

Adriaan M. J. Schakel
World Scientific, Hackensack, NJ, 2008. $79.00 (390 pp.). ISBN 978-981-281-390-9

These days interest in many-body condensed-matter physics is at an all-time high. New high-T_c superconductors