

graduate student: Its relaxed and intellectually adventurous style would provide a welcome contrast to the demanding technical problem-solving of the curriculum, and the student would learn about interesting areas of physics not generally covered in graduate courses.

Carroll keeps the reader aware of connections between the topics he chooses and current cosmology research, but his discussion of contemporary research is rather brief. Most of the book considers well-established material. Research on the arrow of time currently has more unresolved questions than concrete results; Carroll faithfully reports that fact and argues that it is therefore most important to treat such fundamental ingredients as Poincaré recurrences or decoherence, which are traditionally absent from the physics curriculum. On that point, I agree. Cosmologists will find places where they disagree with Carroll on modern research topics, but that is a natural consequence of problems being unresolved. For example, I regard Carroll's willingness to dismiss the finite-universe scenario as a mistake. In many ways that scenario, I believe, offers the most promising path to reconciliation.

The relationship between Carroll's book and others on related topics is addressed quite nicely in a paragraph preceding the extensive bibliography. Publicity material on the jacket sleeve and press release contrasts *From Eternity to Here* with Stephen Hawking's *A Brief History of Time* (Bantam, 1998). Those are indeed two very different books. Carroll's emphasis is almost entirely on the thermodynamic arrow of time in cosmology, whereas Hawking gives much less emphasis to that topic, and removes the corresponding chapter entirely in his newer *A Briefer History of Time* (Bantam, 2008). Still, many will bristle, as I did, at the suggestion in *From Eternity to Here's* publicity material that Hawking, in contrast to Carroll, does not appreciate the importance of asking what was before the Big Bang.

From Eternity to Here is an important book that explores topics related to the arrow of time and explains why they are essential to current cosmology research. Carroll's ambitious effort to reach and challenge both a lay and technical audience can feel awkward in places. Still, I expect many PHYSICS TODAY readers will find the book both provocative and rewarding and will be glad to recommend it to less technically trained individuals who hunger for a window on exciting problems in science.

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Information, Physics, and Computation

**Marc Mézard and
Andrea Montanari**
Oxford U. Press, New York, 2009.
\$99.00 (569 pp.).
ISBN 978-0-19-857083-7

One great physics achievement has been the statistical approach to determining the behavior of interacting-particle systems; surprisingly, certain macroscopic behaviors turn out not to be strongly related to their deterministic laws of interaction. Particles can be assumed to

behave randomly, and macroscopic transitions are revealed as the parameters of the random model are changed. Those transitions, observed at the large scale where fluctuations due to microscopic interactions are averaged out, manifest the behaviors of the most probable concentration.

In their book *Information, Physics, and Computation*, statistical physicists Marc Mézard and Andrea Montanari masterfully show that the concept is also pivotal to computation and information theory. The authors argue that the information-theoretic view of communication put forth by Claude Shannon in 1948 is based on a similar strategy of

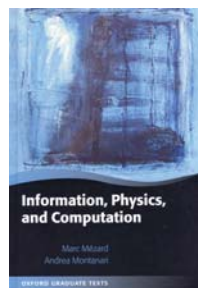
looking at the large scale. Shannon considered the limit of long code words, which when picked at random, revealed a “concentration” around the most typical sets and identified the low-error-probability decoding region. Similarly, if a computer scientist considers a large ensemble of random inputs where the parameters are restricted to a certain region, then certain combinatorial optimization problems, such as the random satisfiability problem, can be solved efficiently and with high probability.

Many approaches are available to study the set of problems that are defined by concentration behaviors, such as those outlined above. The information theorist might take a purely statistical approach. The probability theorist might consider a combinatorial approach or study the problem from the point of view of ergodic theory, which analyzes the behavior of a dynamical system when it is allowed to run for a long time. The applied scientist might be more interested in the experimental performance of different algorithms and codes. Mézard and Montanari choose to follow the statistical physicist's approach, which is to reveal the macroscopic fluctuations of computational or communication systems by finding their minimum “energy” configuration in the thermodynamic limit.

Following that path, the authors describe many statistical physics tools developed over the years: replica theory, the cavity method, density evolution, mean-field theory, and simulated annealing, among others. They also discuss methods that are familiar to non-physicists such as large deviations, Monte Carlo simulations, Markov chains, and belief propagation. And they always manage to draw interesting parallels with the underlying physics of the problems to which those methods are applied.

Information, Physics, and Computation is self-contained and should be accessible to any graduate student with a good background in probability theory and analysis. It is not an easy book though. It begins mildly, but rapidly develops into a tornado, pulling in theory and tools from the furthest reaches of mathematics and physics. The presentation naturally becomes more heuristic when the book gets to the most recent research advances.

By the authors' own admission, their choice of presenting in detail a selection of problems, primarily from computing



and modern coding theory, resulted in a number of interesting topics being left aside. The reader will not find a treatment of networking systems, communication systems with multiple inputs and outputs, or learning theory. Other topics, such as source coding, are relegated to a few introductory notes.

As those omissions and abbreviations show, writing a cross-disciplinary book is a somewhat dangerous endeavor. Nonetheless, *Information, Physics, and Computation* stimulates that cross-disciplinary dialog, which is always desirable because from it, new perspectives emerge. However, the implementation of such a dialog comes at a cost: Like Odysseus, Mézard and Montanari chose to sacrifice part of the crew to Scylla, rather than lose the whole ship to the whirlpools of Charybdis. In any circumstance, their choice must be considered honorable.

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