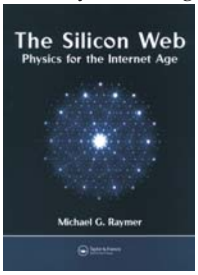
The Silicon Web

Physics for the Internet Age

Michael G. Raymer
Taylor & Francis, New York, 2009. $89.95 (571 pp.). ISBN 978-1-4398-0311-0

The internet—and the technologies that underlie it—has revolutionized the world. But a cursory survey of most of today's undergraduate science curricula would reveal that the revolution has had little impact on what science majors learn and that those curricula have been in a cryogenically frozen state. When I was a student, more than 50 years ago, the transistor had just been invented, but most undergraduate science majors still do not learn how transistors or other related technologies work. I even wonder whether many academic theorists can, for example, explain the difference between digital and analog noise.



It might be easy enough to imagine a textbook that addresses the science behind the internet, but actually writing it would be much more difficult. It would have to talk about how physical concepts are applied to computers and the internet and how electronic computation has transformed mathematics from an abstract logical exercise into an essential everyday tool. It would have to explain how billions of semiconductor components are assembled on computer chips and how they transmit information across an optical-fiber network. The text would also have to include the branches of physics that contribute to such technologies—classical and quantum mechanics, thermodynamics, and electromagnetism, to name a few. One might think that mastering all of the book's material would require years of graduate-level study taught by a team of professors from solid-state chemistry, computer science, electrical engineering, physics, and even pure mathematics.

Into this apparently hopeless situation, University of Oregon physics professor Michael Raymer has brought *The Silicon Web: Physics for the Internet Age*, a text perfect in itself and perfect for its time. Raymer developed the book to supplement his Physics Behind the Internet course for nonscience majors, which, according to his website, covers "the basics of information, communication, atomic physics, semiconductor device physics, and optical physics and technology." *The Silicon Web* covers all those topics and many more, with an average of more than one illustration per page. It provides a rich historical background of the key developments, some of which I witnessed at Bell Labs; Raymer was not there, but he has a rich imagination, and he has reinvented the excitement by himself. He introduces the key industry and scientific terms, uses them, explains them, and uses them again, always in an appealing context. Every few pages feature quick reality-check questions that connect the technical material to real-world applications. If there is a pedagogical trick that Raymer has not used, it is one unknown to me.

Having built a perfect mousetrap—this beautiful book with its lavish assortment of topics—I imagine the author supposed that the world would beat a path to his door. That hasn't happened, perhaps because the book is mistakenly marketed primarily to nonscience majors. As written, *The Silicon Web* is ideal for an undergraduate course required of all physical science, engineering, computer science, and mathematics majors. I acknowledge that its physics may be "too easy" (is that really possible?) for physics students, but such a cross-disciplinary course would give them exposure to other specialties that they would otherwise not receive. That kind of multidisciplinary interaction could lead to cross-disciplinary friendships and the formation of a startup business—or simply enrich a student's learning environment.

Of course, physicists worldwide are doing impressive work in all of the field's traditional subdisciplines and many nontraditional ones. But why has everyone become so specialized that few—apart from Raymer and a hardy but lonely band of others—seem to care, or even to be aware of how the greatest scientific revolution in history took place in their time?

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From Eternity to Here

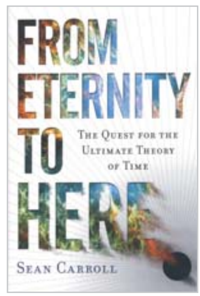
The Quest for the Ultimate Theory of Time

Sean Carroll
Dutton, New York, 2010. $26.95 (438 pp.). ISBN 978-0-525-95133-9

Many cosmologists seek theories in which the early universe's properties emerge naturally or generically from the dynamical laws that govern cosmic evolution. Inflation is often held up as an exemplar of such a theory. However, the thermodynamic arrow of time tells us that the entropy of the early universe was lower than the entropy today, which suggests that the state of the early universe was *not* dynamically typical or natural. So how does one reconcile inflation theory with the second law of thermodynamics?

That is a defining question of *From Eternity to Here: The Quest for the Ultimate Theory of Time* by Caltech theoretical cosmologist Sean Carroll. He asserts, and I agree wholeheartedly, that this reconciliation lies at the core of modern cosmology research and should be addressed head on. He also recognizes the wide appeal of the inflation theory–thermodynamics puzzle and ambitiously reaches out to a very broad audience—much broader than the readership of PHYSICS TODAY.

From Eternity to Here covers a comprehensive range of topics related to the arrow of time and the universe: Poincaré recurrences, entropy, ergodicity, coarse graining, decoherence, closed timelike curves, holography, cosmic inflation, eternal inflation, and many more. Carroll assumes his readers have no prior knowledge of those focuses and provides introductory material on special and general relativity, quantum mechanics, quantum field theory, and other topics. His writing style is relaxed and conversational, with quotes from the movies *Annie Hall* and *Ghostbusters* and chatty reflections on the historical progression of science. The arrow of time is a topic susceptible to purely philosophical musings; Carroll runs them through the "does it really matter?" filter that is familiar and reassuring to physicists.



Most readers will need to make compromises to enjoy this book. Advanced physicists will want to skim past much of the introductory material and may wish they could trade the conversational reflections for the dry and efficient style of professional physics writing. They may also wish for more technical depth on the topics they're most interested in. Less expert readers will appreciate the introductory material but may not have the appetite for the many technical topics that follow. Still, Carroll gives some wonderfully intuitive discussions of difficult material, and the nonexpert will benefit much more from this book than one might guess considering the large number of challenging topics treated. The book may work well for a first-year 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