ing Two New Sciences, University of Wisconsin Press, 1974, pp. 11–13). Indeed, Galileo's commentary provides the key for understanding the basis of prescientific engineering successes as well as grounds for Petroski's assertion that "engineering is part art" (p. 183).

Unfortunately, the editing of the text is disappointing. Several chapters read like stand-alone articles little altered for publication in book form: key concepts as well as historical background material, already fully elucidated in earlier chapters, are irritatingly reiterated. Nonetheless, *Design Paradigms* provides a cogent argument for reintroducing engineering history—albeit taught by engineering faculty who can interpret the underlying technological inferences—into primary engineering study. Once considered an essential part of the engineering curriculum, such courses were forced aside early in the 20th century to make way for the more advanced mathematics and engineering analysis courses deemed far more important. In addition to providing needed instruction in engineering judgment and design, as Petroski indicates, well-planned courses in engineering history might also be used to illustrate the vital process of transferring ideas from one field to another.

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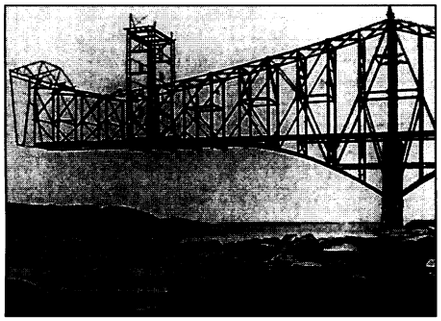

The Quebec Bridge across the St. Lawrence River, under construction in 1907 and after collapse the same year. "Although the span of the Quebec Bridge was essentially the same as that of the colossal Firth of Forth Bridge . . . the belief that the stocky Forth Bridge was very much overdesigned generated a confidence that paring down the members of the Quebec span carried little risk. In effect, the bones of the bridge were too slender to carry its own weight. . . . The structure was subsequently redesigned . . . , and the (second) Quebec Bridge stands today . . . as a symbol to Canadians of perseverence in the face of adversity." [From *Design Paradigms*; Canada Department of Railways and Canals report, 1919]

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Interpretations

The Undivided Universe. An Ontological Interpretation of Quantum Theory. D. BOHM and B. J. HILEY. Routledge, New York, 1993. xii, 397 pp., illus. $29.95 or £25.

When the late David Bohm devised his hidden-variable version of quantum theory in 1952, which is experimentally indistinguishable from the conventional one, he accomplished a feat most physicists thought impossible, because they believed that Von Neumann had ruled out such a possibility. This started John Bell on his researches, which not only found the limitations in Von Neumann's proof but also led to Bell's theorem, which spawned a whole new field of experimental and theoretical work.

So now it is over 40 years later and most physicists are still barely aware of the fact that there exists a viable deterministic interpretation of quantum theory. New students won't even find the theory mentioned in their texts. A typical reaction from working physicists is, "The usual interpretation works, so why do I have to learn another one?" This from physicists who in classical theory pride themselves on knowing the Newtonian, Lagrangian, Hamiltonian, and Hamilton-Jacobi approaches!

The answer of course is that each approach offers its own set of insights into the same material. At the very least, the Bohm interpretation ought to make one skeptical of the claim that probabilities are the essence of quantum theory. Rather, the feature the two interpretations strongly share is non-locality.

This book, by Bohm and his long-time associate Basil Hiley, is an attempt to make the Bohm theory plausible. They call it the ontological interpretation, to emphasize that individual events can be tracked down to particles following trajectories, and in that sense at least the theory is conceptually closer to classical theory. However, besides the ordinary force potential, there is also a "quantum potential," which can cause the particles to suddenly veer aside to produce interference patterns and the like. The quantum potential can act instantaneously over great distances and acts without being in turn acted upon, giving phenomena their non-local nature. The analogy the authors give is that of a radio signal that can control a large ship from great distances. It is information, not energy transport, that is important here.

Bohm and Hiley also call their version a causal interpretation, since one can follow events in detail beyond what one can actually measure, as contrasted to the usual interpretation, where one does not ask questions about mechanisms one cannot verify. I think "causal" here is a misleading term, however, since the quantum potential can act like a *deus ex machina*, disrupting any effectively predictable behavior.

The book is loaded with clever insights, as anyone familiar with Bohm's writings can expect, and there are long and sometimes deep philosophical asides on many aspects of the subject. There is also a good and critical discussion of other recent interpretations of quantum theory, such as the "many worlds" interpretation, the Ghirardi-Rimini-Weber interpretation, "decoherence," and the "consistent history" cosmology of Gell-Mann and Hartle. The book is well worth it for these add-ons alone, but in fact this is a very important book, an attempt to open the minds of physicists to understand that what they are used to is not necessarily uniquely true. There is also another good recent book on this subject, Peter R. Holland's *The Quantum Theory of Motion* (Cambridge University Press), which tends to be more like a textbook.

There are certain problematical aspects to the theory, which from the conventional point of view seem like drawbacks but from the standpoint of the theory itself seem like inevitable consequences. One of these is the relativistic extension, which violates Lorentz invariance for individual events, though it preserves it over ensemble averages, so that it gives the usual experimental results. Ugly, one says. But the authors point out that if non-locality exists for individual events, this necessitates a breakdown of relativity, at this level. So who's to say? Maybe all the infinities in field theory come from a too-rigid insistence on pointwise Lorentz invariance. I think it would be foolish to prejudge this point, even though it runs counter to one's preferences.

Now that there are two books clearly explaining the theory, a development made possible by recent advances in understanding the application of the theory to standard problems, it will seem inexcusable if future textbooks on quantum theory continue to make believe that this interpretation doesn't exist. In the future, one will have to come to terms with its insights. And if you are a fan of Bohm's book on

conventional quantum theory (which should include anyone who's ever looked at it), you will certainly want to own this one. Even if you will continue to think in terms of the conventional interpretation (and I confess that I will), you will be very impressed by this wise and deep book that will certainly broaden your horizons and start you thinking about many things you thought you were sure of.

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Books Received

Analytical Sedimentology. Douglas W. Lewis and David McConchie. Chapman and Hall, New York, 1994. x, 197 pp., illus. $49.95.

Angiotensin Receptors. Juan M. Saavedra and Pieter B. M. W. M. Timmermans, Eds. Plenum, New York, 1994. xxiv, 413 pp., illus. $95.

Antigen and Antibody Molecular Engineering in Breast Cancer Diagnosis and Treatment. Roberto L. Ceriani, Ed. Plenum, New York, 1994. xii, 222 pp., illus. $75. Advances in Experimental Medicine and Biology, vol. 353. From a workshop, San Francisco, Nov. 1992.

At the Center of the World. Polar Symbolism Discovered in Celtic, Norse and Other Ritualized Landscapes. John Michell. Thames and Hudson, New York, 1994 (distributor, Norton, New York). vi, 184 pp., illus. $24.95.

Basic Mathematics for Chemists. Peter Tebbutt. Wiley, New York, 1994. xii, 244 pp., illus. $64.95; paper, $29.95.

The Bengal Monitor. Walter Auffenberg. University Press of Florida, Gainesville, 1994. xxviii, 560 pp., illus. $79.95.

Benthic Foraminiferal Biostratigraphy of the South Caribbean Region. Hans M. Bolli, Jean-Pierre Beckmann, and John B. Saunders. Cambridge University Press, New York, 1994. xii, 408 pp., illus. $150.

Cellular Immunology. P. J. Delves, Ed. Academic Press, San Diego, CA, 1994. xx, 259 pp., illus. Spiral bound, $59.95. Labfax Series.

Chaotic Logic. Language, Thought, and Reality From the Perspective of Complex Systems Science. Ben Goertzel. Plenum, New York, 1994. xviii, 278 pp., illus. $72.50. IFSR International Series on Systems Science and Engineering, vol. 9.

The Choice. Evolution or Extinction? A Thinking Person's Guide to Global Issues. Ervin Laszlo. Putnam, New York, 1994. viii, 215 pp., illus. $17.95. Jeremy P. Tarcher/Putnam Book.

CRC Handbook of Chemistry and Physics. A Ready-Reference Book of Chemical and Physical Data. David R. Lide and H. P. R. Frederikse, Eds. 75th ed. CRC Press, Boca Raton, FL, 1994. Variously paged, illus. $99.95.

The Creation of Scientific Effects. Heinrich Hertz and Electric Waves. Jed Z. Buchwald. University of Chicago Press, Chicago, 1994. xiv, 482 pp., illus. $75.00; paper, $32.95.

Creativity in Invention and Design. Computational and Cognitive Explorations of Technological Originality.