Quantum Implications: Essays in Honour of David Bohm

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Citation: **41**, 7, 72 (1988); doi: 10.1063/1.2811503
View online: http://dx.doi.org/10.1063/1.2811503
View Table of Contents: http://physicstoday.scitation.org/toc/pto/41/7
Published by the American Institute of Physics

ing field of knowledge. But pity today's students: They need to know so much more by the time they receive their PhDs. This trend tends to force more and more specialization, just when we need to expand our horizons across interdisciplinary lines.

And then there is the recruitment problem: How, and from where, do we draw students into the fold? This question is an issue for debate and concern among oceanographers. Considering the importance of climate- and resource-related scientific problems, which we seem to be at the threshold of tackling, we are drawing too few students to oceanographic careers. Part of the problem may be that the ocean sciences are diverse and interlock with a broad array of traditional science disciplines, but have no clear place in traditional university departments. Students of physics, chemistry, mathematics and engineering—all potential oceanographers—may be unaware of the excitement of ocean studies. Perhaps the establishment of departments and schools of oceanography isolates the field undesirably from the other science departments and their students, diminishing contact still further.

Principles of Ocean Physics, a text by John R. Apel, and *General Circulation of the Ocean*, a book of review articles edited by Henry D. I. Abarbanel and W. R. Young, represent steps to alleviate both problems for physical oceanography. Apel's book presents the field in terms of the basic physics in which it is rooted. The other book presents the student with a much needed synthesis of information about modern views of large-scale ocean circulation.

Perhaps because of the academic identity crisis in oceanography, there has been no really good text by which students of physical oceanography, not to mention physics students, can obtain a core knowledge of the field. There are many simple survey texts to meet the needs of undergraduates who must satisfy their science requirements, though I often wonder if these texts turn away the serious student of science. There are a few very good advanced texts on geophysical fluid dynamics, which meet the needs of the graduate student and the professional researcher but do not provide the introductory material.

Apel does an excellent job of filling the gap in physical oceanography texts. *Principles of Ocean Physics* provides a solid text for the beginning oceanography graduate student and for students of physics and other sciences who want to learn more about physical oceanography. Apel writes, "The preparation of this book was originally undertaken in the hope that it might stimulate a few physics graduate students to the serious study of the oceans, perhaps even as a life's work." It also provides the core of knowledge for those already committed to the field.

He presents a broad and thorough view of ocean physics, the essentials of modern physical oceanography and a smattering of history. Relevant aspects of atmospheric and geophysical science appear in the first two chapters. The book's explanations of ocean physics are clear and concise, with enough equations to provide balance and rigor. Observational data, many from satellite sensors, are provided for further understanding. Topics of interest to physics students but often not covered in oceanography texts are also included, such as acoustical, optical and electromagnetic aspects. (About 40% of the text is devoted to these subjects.)

Each chapter begins with a quote—the sources range from the teachings of Buddha to a 1985 rock song. Bibliographies, many of which include atlases and journal articles, appear at the end of every chapter, and appendices list frequently used constants, parameters and dimensionless numbers for the fluids that are studied in physical oceanography.

The book would have benefited from problem sets. Problems efficiently bring home fundamental concepts of a science. There could be somewhat more observational data from direct ocean measurements of the thermohaline (density) and velocity structure. Perhaps one always hopes for an update of the chapter entitled "The Water Masses and Currents of the Oceans" in *The Oceans*, by Harald Sverdrup, Martin Johnson and Richard Fleming (Prentice–Hall, Englewood Cliffs, N. J., 1942)—but that's another book. Apel's text is already 634 pages long and packed with enough content to satisfy me. I recommend *Principles of Ocean Physics* as a text for a first-level graduate course in physical oceanography, though it should be supplemented by some more general background on large-scale distribution of ocean properties. It would also make good "summer reading" for those physics students with a curiosity about the ocean.

General Circulation of the Oceans forms a nice complement to the Apel text. It provides a broad synthesis of several topics in large-scale circulation: the observational basis, thermocline theory, inverse methods for circulation studies, and baroclinic and barotropic wind-driven circulation. Lectures given by five prominent oceanographers—Pearn Niiler, Joseph Pedlosky, George Veronis, William Young and Myrl Hendershott—in 1983 at the University of California's Scripps Institution of Oceanography are included. The book also contains a long list of references as a guide to further reading.

While one cannot do without journal articles, they are an inefficient way to build the broad array of knowledge necessary in the ever expanding field of oceanography. There is an increasing need for syntheses of information in review articles for the serious student. The collection of lectures in *General Circulation of the Ocean* does the job nicely. I would like to see more such overview compilations.

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Quantum Implications: Essays in Honour of David Bohm

Edited by Basil J. Hiley and F. David Peat
Routledge & Kegan Paul, New York, 1987. 455 pp.
$49.95 hc ISBN 0-7102-0806-5

The discussion of fundamental issues in the interpretation of quantum mechanics has gained much momentum during the last decade after lying dormant for about 30 years. The issues are not how to relate the theory to experiment or whether the theory is correct, because quantum theory is probably one of the most successful theories ever invented. The questions are much deeper: What does this theory teach us about the world? Or, as others would put it, what does it teach us about the possibilities and ways of acquiring knowledge? David Bohm has made invaluable contributions to this discussion, and this book is a timely collection of 30 articles written in his honor.

Bohm's contribution to the field started in the 1950s, when he did what at that time most physicists considered impossible, namely constructed a hidden-variables theory that is consistent with quantum mechanics. In Bohm's theory every individual particle always has both a definite position and a definite momentum. The motion of this particle governs a Hamilton–Jacobi equation with a "quantum potential" acting on the particle in addition to any classical potential. An ensemble of particles starting at different positions traces out a set of possible trajectories and finally accumulates in just the distribution predicted by quantum mechanics. So Bohm's theory seems to have added something the Copenhagen interpretation explicitly denies, namely a very simple ontological interpretation, and our ignorance of the quantum world would then be similar to the situation in thermodynamics, where we also can observe ensemble averages only.

Yet there is an important difference. In thermodynamics we can in principle design an experiment where we trace in detail the motion of, say, an individual molecule in a gas. At least nothing prevents us from constructing clever *gedanken* experiments doing that without contradicting the laws of classical mechanics. In contrast, there is no way in quantum mechanics to do this, not even on the *gedanken* level within Bohm's approach, because any attempt to trace out the trajectory of an individual particle involves some specially suited apparatus that clearly changes the wavefunction and hence the quantum potential. It therefore is at least a confusion of terms to call Bohm's theory the "causal" interpretation, as claimed particularly by Jean-Pierre Vigier, because the individual event cannot be traced in detail. This uncontrollability of individual events and the nonlocality signified by the quantum potential's instantaneous dependence on all features of the whole experimental apparatus again teach us the lesson that there is no escape from the epistemological problems of the quantum world.

The diversity of the physics contributions to the book also signifies the unresolved state of those problems. For example, Richard Feynman argues quite convincingly that negative probabilities make as much sense as negative integers do, while Ilya Prigogine and Yves Elskens search for a new way to look at the role of time so as to account properly for the order-creating properties of some irreversible systems. In two related papers, Geoffrey Chew and Henry Stapp propose that light is at the very foundation of being and order. Bernard d'Espagnat compares the conflicting views of John Bell, for whom a physical theory should tell us about *what is*, and of John Archibald Wheeler, for whom the basic concept is "meaning." It is impossible to do justice to all the contributions, so it must suffice just to mention that another interesting group of papers deals with how quantum phenomena in the macroscopic domain make the measurement problem even more striking than it is already.

In the book Bohm himself tells the story of how, starting from his quantum potential ideas, he was led to more general philosophical considerations. He proposes the scheme of an implicate order of the universe, as opposed to its more or less directly accessible explicate order, and a relationship between the two such that the implicate order unfolds itself into the explicate order, which again is enfolded back into the implicate order. Some segments of the general public accepted these ideas enthusiastically. Their holistic aspect fits perfectly into the postmodern *Zeitgeist*. The book documents very well this broader implication of Bohm's ideas; the contributions range from biology and holistic approaches to brain functions all the way to gestalt considerations in the arts. It is certainly an homage to Bohm that this book bridges the cultural gap between the "two cultures" of humanities and the physical sciences. Such a bridge is important for the future intellectual development of our present technological society, if not for its survival. This may ultimately be David Bohm's most important contribution.

In summary, this book should be of interest to anyone for whom physics is more than just a set of calculational recipes. It contains brain food for everybody from the formal theorist all the way to the artist searching for new concepts.

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Black Holes: The Membrane Paradigm

Edited by Kip S. Thorne, Richard H. Price and Douglas A. Macdonald
Yale U. P., New Haven, Conn., 1986. 365 pp.
$40.00 hc ISBN 0-300-03769-4; $14.95 pb ISBN 0-300-03770-8

Einstein's relativity simplifies the laws of physics by melding space and time together into the single structure of space–time. The Newtonian version of Maxwell's equations consists of four equations coupling two vector fields, **E** and **B**, with scalar and vector field sources, ρ and **J**. Relativity reduces this to only two equations—a single integrability condition for a vector potential, $\nabla_{[a}F_{bc]} = 0$ (where brackets denote antisymmetrization), and a single divergence equation, $\nabla_a F^{ab} = 4\pi J^b$. Relativity halves the number of equations, and reveals the tricky couplings between **E** and **B** and between ρ and **J** as an unnatural projection into three dimensions of a four-dimensional space–time symmetry. In a less transparent way, general relativity simplifies gravity by moving its effects from the left- to the right-hand side of $\mathbf{F} = m\mathbf{a}$, thus making gravity the provider of the space–time geometry.

This simplification of the laws of physics is not without cost. We normally measure distance with rulers and time intervals with watches. Gauss's law and Ampère's law are two different chapters in most texts. And an electric motor is most easily described in a Newtonian framework. Furthermore the force of gravity is introduced in freshman physics courses, far before differential geometry has been mastered. While relativity makes physics elegant, it sometimes obscures physical intuition.

This obscuration is perhaps no more evident than in the study of black holes, which is rife with sophisticated mathematics and unusual and surprising phenomena. The membrane paradigm removes some mystery by formulating black hole physics from a Newtonian perspective. Perhaps the membrane paradigm's greatest success is the description of a black hole rotating in an external magnetic field. An induced emf drives a current through a black hole, and the attendant Poynting flux carries energy away into a surrounding plasma. This may be an important energy source for quasars and active galactic nuclei.

This pedagogical treatise rewrites the mathematical description of black holes in an $\mathbf{F} = m\mathbf{a}$ style. It develops Newtonian physical intuition along with powerful calculational techniques that allow for a thorough understanding of black hole physics. However, some of the elegance of general relativity is lost along the way, and the subject remains difficult. *Black Holes: The Membrane Paradigm* is a workingman's approach to black hole physics—a hard hat must be worn when one enters this area.

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BOOK NOTE

Enigmas of Chance: An Autobiography

Mark Kac
U. of Calif. P., Berkeley, 1987 [1985]. 163 pp.
$8.95 pb ISBN 0-520-05986-7

"Physics made me sick the whole time I learned it. What I couldn't stand was this shrinking everything into letters and numbers." So wrote Sylvia Plath, the poet, in her novel *The Bell Jar*.

Scientists consider mathematics the language of science; however, to a nonscientist it often signifies utter incomprehensibility instead. But the Alfred P. Sloan Foundation encourages the public understanding of science through a series of books by and about some of its most outstanding and articulate practitioners.

Mark Kac, in his Sloan-sponsored autobiography *Enigmas of Chance*, has described a young person's intellectual awakening. For him mathematics led to significant contributions to probability theory. But Kac's story is also a reminder that a scientist's life must be lived within the matrix of its historical situation. In one place Kac remarks, "As I look back on my life I marvel at the improbable assortment of people who, independently of each other, cooperated to keep me from being incinerated in the ovens of Auschwitz or Belsen." From the Polish city of Lwów—notable for mathematical physicists such as Marian Smoluchowski, Stefan Banach and Hugo Steinhaus—the Jewish Kac came on a fellowship to the US and there to a distinguished career at Johns Hopkins, Cornell and Rockefeller University. Even when working on abstract topics, Kac never lost sight of down-to-earth applications.

Discussing his own work leading to the Feynman–Kac formula, which appears in quantum physics and probability theory, Kac mentions Norbert Wiener's work on Brownian motion: "It is only fair to say that I had Wiener's shoulders to stand on. Feynman, as in everything else he has done, stood on his own, a trick of intellectual contortion that he alone is capable of."

Kac died shortly before the book's publication. Kac's life-affirming story, written with great charm in a seemingly effortless conversational style, cannot fail to impress even nonspecialists to whom the technical details of Kac's work would be opaque.

—PER H. ANDERSEN

NEW BOOKS

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Astronomical Optics. D. J. Schroeder. Academic, San Diego, Calif., 1987. 352 pp. $45.00 *hc* ISBN 0-12-629805-X. *Text*

Astronomy and Astrophysics Abstracts, Vol. 43: Literature 1987, Part 1. S. Böhme, U. Esser, H. Hefele, I. Heinrich, W. Hofmann, D. Krahn, V. R. Matas, L. D. Schmadel, G. Zech, eds. Springer-Verlag, New York, 1987. 1291 pp. $138.00 *hc* ISBN 0-387-18640-9

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Cool Stars, Stellar Systems and the Sun. *Lecture Notes in Physics 291.* Proc. 5th Cambridge Wksp., Boulder, Colo., July 1987. J. L. Linsky, R. E. Stencel, eds. Springer-Verlag, New York, 1987. 537 pp. $55.80 *hc* ISBN 0-387-18653-0