for introducing astronomers to the wealth of optical observations on these objects and to their physical interpretation. Astronomers are on a much weaker footing in modeling quasars than in modeling other nebulae, because the great distance to quasars precludes obtaining a "picture" of an AGN broad-line region. One is therefore forced back on theoretical models and spectral diagnostics. These two chapters provide valuable discussions of these diagnostics and how they are used to build models of the distribution and nature of gas in these regions. Osterbrock's book could work well in complement with Lyman Spitzer's text, *Physical Processes in the Interstellar Medium*, with its extensive discussions of gas dynamics, shocks and thermal physics of nebulae.

One leaves the text wishing for many more chapters on quasars and Seyferts. However, that is probably because one feels so expertly prepared by what *has* been provided. Osterbrock's new book is a tribute to the power of "nebular physics" in interpreting the physical conditions around many astrophysical objects. The book does its job very well, and I highly recommend it.

J. Michael Shull
University of Colorado and Joint Institute for Laboratory Astrophysics

The Structure and Interpretation of Quantum Mechanics

R. I. G. Hughes
Harvard U. P., Cambridge, Mass., 1989. 370 pp.
$39.50 hc ISBN 0-674-84391-6

Because of its radical departures from classical physics, quantum mechanics and its interpretation have long attracted the attention of philosophers. Unfortunately, it has not been possible to state the essence of quantum theory in informal, nonmathematical terms. Philosophers who have not mastered the mathematical formalism are therefore at a severe disadvantage in trying to understand the interpretation and significance of the theory. In the past the philosophers have tended to take the assertions of physicists as gospel and have devoted much of their effort to interpreting the meaning of the words written by the founders. Gospel, unfortunately, is not always a reliable guide to truth, and this method of exegesis of the canonical texts of Niels Bohr, Werner Heisenberg and others did not lead to a satisfactory solution of the problems of interpretation of quantum theory.

"No real insight into quantum theory is possible without an acquaintance with the mathematics it employs," says R.I.G. Hughes (an associate professor of philosophy at Yale) in the opening sentence of part 1 of *The Structure and Interpretation of Quantum Mechanics*, on the mathematical structure of quantum theory. This assertion sets the tone for the book, and places the author's attitude much closer to that of a physicist than to that of the older generation of philosophers, who gave us seemingly endless verbal analyses of concepts like causality and complementarity.

It is part 2, on the interpretation of quantum mechanics, that is most interesting to me. Here I would identify three major results. The first is rooted in the Einstein–Podolsky–Rosen argument of 1935, now superseded by John S. Bell's 1964 theorem. It establishes—or appears to establish, for alternative views are sometimes proposed—a conflict between the predictions of quantum theory and the demand that there be no instantaneous nonlocal causation. The second is rooted in Schrödinger's cat paradox, also from 1935, now succeeded by the analysis of quantum mechanical measurement processes. It demonstrates that quantum uncertainties can not be confined to the microscopic domain. If a macroscopic apparatus measures some observable, and if the initial state of the measured object is not an eigenstate of that observable, then according to the linear Schrödinger equation the final state of the system (that is, object plus apparatus) will be a coherent superposition of macroscopically distinguishable states (that is, a superposition of apparatus pointer-position eigenstates). The third is the 1965 theorem by Simon Kochen and E. P. Specker, which shows that it is not possible to assign instantaneous values to all observables if they are constrained to satisfy certain relations involving only commuting sets of observables. To be viable an interpretation of quantum mechanics must be compatible with these three results.

Among physicists Bell's theorem is the best known of the three. It is discussed in Hughes's book, but does not play a major role in the argument. Hughes recognizes the importance of the measurement problem, but his response to it does not seem satisfactory (as I shall discuss below). The Kochen–Specker theorem has received more attention from philosophers than from physicists, and it (along with A.M. Gleason's related theorem) sets the tone for the second

half of the book.

The first interpretation that Hughes considers is the well-known statistical interpretation, according to which a state vector describes an ensemble of similarly prepared systems, rather than an individual system. (One of its merits is a resolution of the measurement problem, although Hughes does not discuss this aspect.) After a brief description of this interpretation, he says "a natural, *though not necessary* [emphasis added] concomitant of this is the view that quantum mechanics is a classical statistical theory." He then demonstrates that this view cannot be maintained in light of the Kochen–Specker theorem. Unfortunately there is a danger that the reader may infer that this conclusion applies to the statistical interpretation, when in fact it applies only to the author's caricature of it.

After a discussion of quantum logic, which Hughes regards as useful in formally characterizing the Hilbert-space structure but physically unhelpful, Hughes turns to probability. Here he commits an elementary (but unoriginal) error in treating the two-slit experiment. He considers the formally well-defined but unmeasurable probability p(X&A) that a particle reaches position X on the screen via the slit A. His notation does not emphasize the fact that quantum mechanical probabilities are conditional on the state preparation, and hence on the configuration of the apparatus. Hence he illegitimately reinterprets p(X&A) as the probability that the particle would reach X if the other slit, B, were closed. This leads him (and has led others before him) to deduce a contradiction that does not exist.

After discussing several aspects of the measurement problem, Hughes asserts that a satisfactory solution of it must have the following characteristics: a measuring apparatus must have a set of orthogonal possible states corresponding to the possible outcomes of the measurement (pointer positions), and no nontrivial superpositions of those states are allowed. But the latter requirement is just what the analysis of the measurement process, from Schrödinger's cat paradox until the present day, has shown to be impossible. Small wonder then that he is forced to conclude that he can provide no explanation of how that state of affairs is to come about! The book ends on this rather unsatisfactory note. Hughes does not consider that, rather than follow the failed attempts to exclude superpositions of states with different pointer positions, one should seek an interpretation that is not embarrassed by them.

This book may be compared with Michael Redhead's recent book *Incompleteness, Nonlocality and Realism* (reviewed in PHYSICS TODAY, September 1988, page 104). Both treat the same subject, and at similar levels of sophistication. Hughes's style is more readable. Both treat the consequences of the Kochen–Specker theorem well. Redhead discusses Bell's theorem more adequately, but he does not treat the measurement problem. Hughes considers the measurement problem, but he fails to find an interpretation that is satisfactory in the light of it.

LESLIE E. BALLENTINE
Simon Fraser University
Burnaby, British Columbia, Canada

Experimental Techniques in Condensed Matter Physics at Low Temperatures

Robert C. Richardson and Eric N. Smith
Addison–Wesley, Redwood City, Calif., 1988. 338 pp. $45.25 hc ISBN 0-201-15002-6

It has been more than a decade since the last practical book on experimental techniques in low-temperature physics was written, and during that period there have been advances on several fronts. *Experimental Techniques* is a current book that attempts to bring these techniques up to date. In addition to background pedagogy, the book includes some discussion of principles. It gives practical insight as well as tricks of the trade. The book is filled with recipes, practical data and advice; it reflects certain prejudices that are obviously based on some bad experiences.

The book is edited by Robert Richardson and Eric Smith and grew out of a collection of notes written originally in 1981 by students and research associates at Cornell. These manuals for designing and performing experiments became so popular internally and in the outside community that in 1984–85 a new generation of students upgraded and revised them. *Experimental Techniques* is the result of those efforts. Cornell has the reputation of training some of the best students in the design, construction and measurement of low-temperature experiments, and so I expected a book that reflected this expertise. I was not disappointed.

The book is divided into four major