vanced workers who want some information outside their own area of specialization. Most of this information is available in other places, but not always in a collected, easily accessible form. Except for the section on defects, the book cannot stand on its own as a unified introduction to the subjects treated. But considering the wide range of subjects and their complexity, the contributors have done a creditable job of giving the intended audience a starting point for further study.

L. A. GIRIFALCO
University of Pennsylvania
Philadelphia

The Interpretation of Quantum Mechanics

M. Audi
200 pp. U. of Chicago Press, Chicago, 1974. $11.50

Quantum Mechanics in a New Key

A. Landè
131 pp. Exposition Press, Jericho, New York, 1973. $6.50

"Matter particles and electromagnetic fields have physical reality, but matter waves and photons have not, although they may be helpful for calculation purposes in special cases," (Landé, page 26). This is the common point of view espoused by these authors. Alfred Landé is a senior physicist who has written many books and articles on quantum theory. Michael Audi is a philosopher, and this, his first book, is based on his doctoral dissertation.

The arguments in favor of the above-quoted statement range from convincing to merely suggestive. The best of them, in favor of the reality of material particles and against that of "matter waves," was pointed out by Landé long ago. It is that the wave-like appearance of an electron diffraction pattern is in fact nothing but a statistical pattern of particles, and that diffraction-like scattering of particles takes place because the momentum transferred to or from an object with spatial period l (such as a crystal) is quantized in multiples of $\Delta p = h/l$. This rule, proposed *ad hoc* by W. Duane in 1923, becomes a theorem in modern quantum theory. On the other hand, the arguments against the reality of photons are only suggestive, and neither author has taken account of the interesting recent discussions of the degree to which the photon hypothesis is or is not necessary in electrodynamics.[1]

Audi sees a contradiction between two assertions of the Copenhagen interpretation: firstly, that classical concepts, in particular the *particle* concept, cannot be accurately applied to physical systems, and yet, secondly, quantum theory requires these classical concepts for its formulation. In classical physics a *particle* is a point-like object having a continuous trajectory and hence simultaneously possessing position and momentum, but an old interpretation of the uncertainty principle denies this to be possible. Audi resolves this contradiction by emphasizing that the uncertainty relations refer to the dispersion among the paths of an ensemble of particles, not to a single particle. The difference of quantum theory from classical theory is not that electrons do not possess definite particle properties like position and momentum, but rather that they lack laws that determine the future values of those properties.

Audi's thesis, that the possession of definite properties need not require the existence of laws determining their future values, is important. However it is less original than he believes, for Einstein's claim that quantum mechanics is incomplete was based on the inability of a state vector to describe such properties as simultaneous position and momentum, and not (as Audi erroneously states on page 137) merely on its lack of determinism.

In addition to expounding an interpretation, Landé attempts to *derive* the essential features of quantum mechanics from the principles of *symmetry, correspondence,* and *covariance.* He has devoted three earlier books to this problem, and this, his "final version," is disappointing for its failure to answer the criticisms of the earlier volumes. Much of Abner Shimony's penetrating criticism[2] of Landé's 1965 book is applicable to this one as well.

A good illustration is provided by his derivation of the relation between a coordinate q and its conjugate momentum p:

$$\psi_{pq} = C \exp(2\pi i\, pq/h) \qquad (A)$$
$$(= \langle q|p\rangle \text{ in the usual notation})$$

From the postulate of covariance, or independence of the dynamics from arbitrary zero points of coordinates or momentum, he obtains equations equivalent to: (i) $\psi_{pq_0}\psi^*_{p'q_0}$ = function of q_0 and $p-p'$ only; (ii) $\psi^*_{p_0q}\psi_{p_0q'}$ = a function of p_0 and $q-q'$ only. Although the argument leading to them is not unobjectionable, these equations form a well-defined mathematical problem, to which Landé asserts that (A) is the unique solution. But that claim is not true, for $\psi_{pq} = \exp(iaq - ibp)$ also satisfies (i) and (ii). The existence of this unwanted solution was pointed out by Landé in an earlier book,[3] where he eliminated it with an *ad hoc* argument. Now he merely ignores it although it is not excluded by his postulates.

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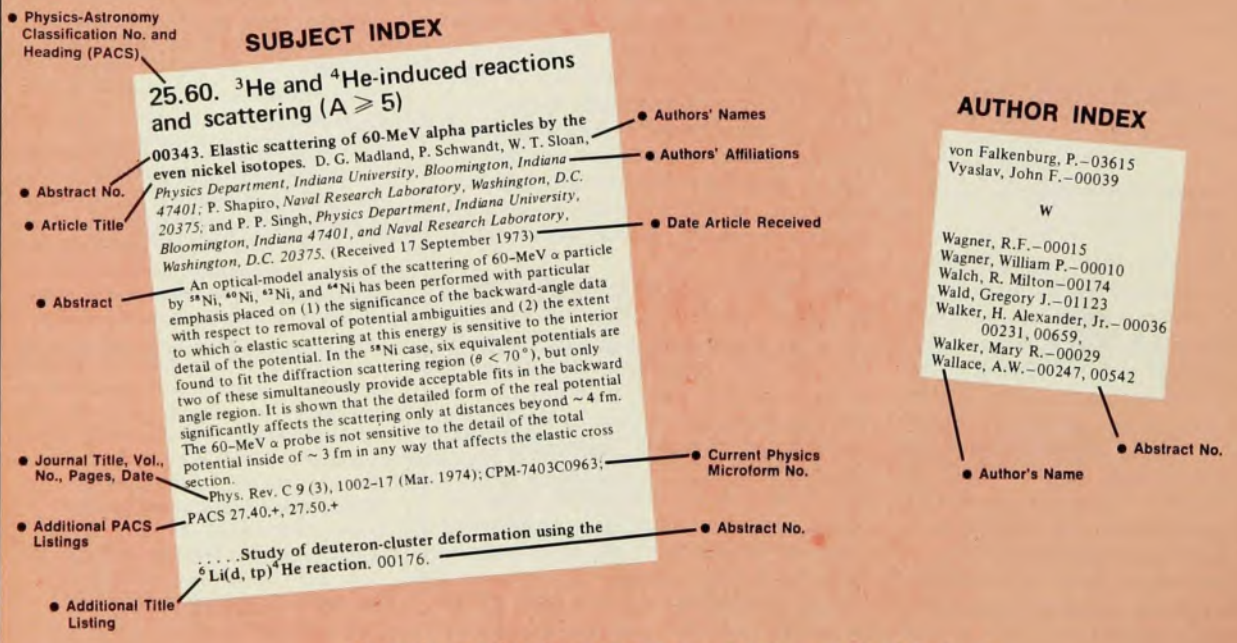

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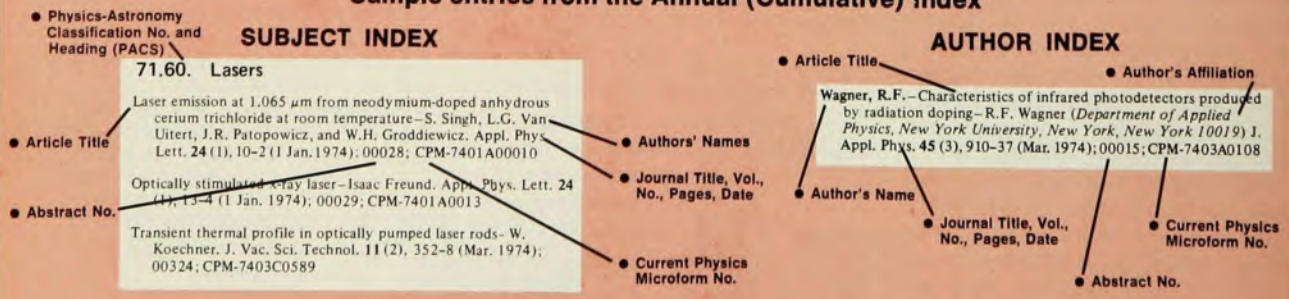

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is the fact that he has implicitly assumed the most non-classical feature of quantum theory, namely that coordinates and momenta are incompatible observables. That is to say, he specifies a state by q alone, or by p alone, rather than by both q and p.

Although the interpretation defended by these authors may be sound, Landé's attempt to derive the theory from intuitively acceptable principles has not succeeded.

References

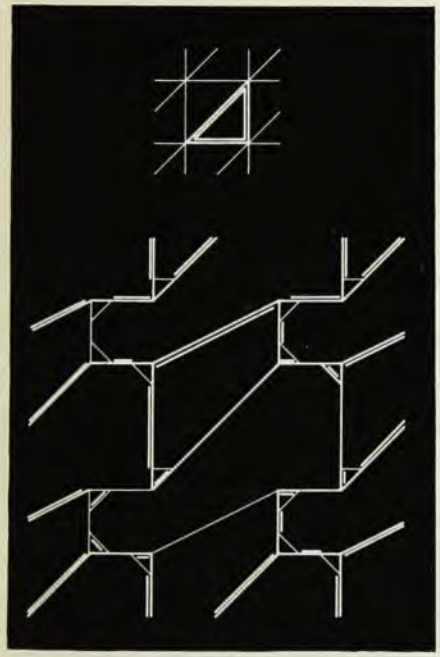
1. See M. O. Scully, M. Sargent III, PHYSICS TODAY, March 1972, page 38. The August, December 1972 and February 1973 issues contain further correspondence on this subject.
2. A. Shimony, PHYSICS TODAY, September 1966, page 85. A review of *New Foundations of Quantum Mechanics* by A. Landé (Cambridge U. P., London, 1965).
3. A. Landé, *Foundation of Quantum Theory*, (Yale U. P., New Haven, 1955) pages 69–71.

LESLIE E. BALLENTINE
Simon Fraser University
Burnaby, British Columbia

The Two-Dimensional Ising Model

B. M. McCoy, T. T. Wu
418 pp. Harvard U.P., Cambridge, Mass., 1973. $25.00

One of the nicer ironies in the history of statistical mechanics is buried in the final section of E. Ising's analysis of W. Lenz's model of a ferromagnet. Having shown by explicit computation that the model has no ferromagnetic ordering in one dimension, Ising presents a simple "proof" that ordering cannot occur in higher dimensions either. Take as an explicit example the subject of the book under review here—the two-dimensional model with nearest-neighbor interactions on a square lattice: Suppose one were to increase the strength of the ferromagnetic coupling along the horizontal bonds, a process that can only increase any spontaneous magnetization. When the horizontal coupling becomes infinitely large, the spins in each horizontal row become locked together, and the problem reduces back to a one-dimensional array of two-state systems, where the spontaneous magnetization has already been proved to be zero at all temperatures.



The one-to-one correspondence between closed polygons on the counting lattice and closest-packed dimer configurations on the associated dimer lattice is shown. From the book, *The Two-Dimensional Ising Model.*

Apparently not everybody succumbed to this alluring argument, but a decade passed before R. E. Peierls outlined the proof that the two-dimensional model does indeed order. Only after another decade did L. Onsager publicly reveal the formula for the spontaneous magnetization.

This tale should be a cautionary one for those (and they probably include most physicists today) who feel in their hearts that care over the interchange of limits is best left to those whose concern for proper mathematical diction exceeds their interest in physical results. As everybody now knows, not only is there a transition in two dimensions, but the properties of the critical point revealed by Onsager have led to the revolution in our understanding of critical phenomena that still rages about us.

In spite of its vast impact, however, few physicists have savoured the delights of an intimate knowledge of the two-dimensional Ising model, because of the intricate and rather specialized mathematics that underlie exact computations. Now, however, two able practitioners of this arcane art have attempted to make its pleasures more widely available, by setting down, with great care, patience and good humor, a guide for the mathematically innocent to the exact results of Onsager and Yang, as well as to several more recent results (largely due to themselves) on boundary properties and the effects of random impurities. Because the authors' stated aim is to teach the reader all the necessary mathematics that is "not known by the average graduate student in physics," a non-trivial fraction of the volume is devoted to selected nuggets of pure mathematics (for example, Weiner–Hopf sum equations) presented in terms that the non-mathematician can actually hope to grasp. The approach to the subject is via Pfaffians, entities that the average graduate student in physics can barely pronounce,

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