An Initiation in Physics

Quantum Mechanics. P. J. E. PEEBLES. Princeton University Press, Princeton, NJ, 1992. xiv, 419 pp., illus. $39.50.

A year course in quantum mechanics is both the centerpiece and the cornerstone of the first year of graduate study in physics. It offers a chance to show the next generation of physicists this marvelous and successful theory that has shaped our present understanding of nature. Each person faced with the task of teaching the subject will select from the wealth of available material those topics that he or she believes will best initiate the students into its rites and practices. Peebles in this book presents in a very personal style a set of topics that represents the conceptual development of quantum mechanics as a burgeoning theory, together with some concrete applications for which the mature theory calculates measurable quantities. By intention, many usual topics and much mathematical detail are omitted.

A long first chapter—about a quarter of the book—takes us from Planck's 1900 dictum that energy is quantized in thermal blackbody radiation to its application by Einstein and Debye (1907) to calculate heat capacities of solids at low temperatures. Bohr's model for hydrogen is reconciled with Schrödinger's wave equation (1926) by means of de Broglie's wave-particle duality. Rereading these "old ideas" reminds us that the birth of quantum mechanics actually took about 30 years. The time and space taken to recall this historical development are paid for by the absence of customary examples of solutions to Schrödinger's equation: the square-well potential, full detail for the hydrogen wave functions, a Kronig-Penney model to illustrate that not all physics is invariant under the full translation group.

Quantum mechanics and the general theory of relativity were conceived in close proximity, and both took the mathematical modeling of physical laws beyond the advanced calculus and special functions of the 19th century. Today's mathematical developments in quantum physics have led to new results in functional analysis, knot theory, and the topology of three- and four-dimensional manifolds. Von Neumann's belief that quantum mechanics would prompt essential contributions to some areas of pure mathematics has come to pass. His legacy, as well as that of Feynman's ideas on path integrals, continues to bear fruit for both physics and mathematics. The mathematical setting for quantum mechanics is an inner-product space of square-integrable wave functions with a finite-dimensional space tacked on for spin degrees of freedom. Peebles indulges in the customary ad hoc account of completeness for eigenfunction expansions for self-adjoint operators. The term "Hilbert space" is never mentioned, and I always feel that completeness of the inner-product space, say for periodic boundary conditions in a box, reveals part of the mystery connected with the spectral theorem. Momenta and position also appear to be everywhere defined operators, without examples of boundary conditions that make them (different) unbounded self-adjoint operators in Hilbert space. Though such distinctions are rarely made in the first-year graduate curriculum, they are, I believe, a fair reflection of how our understanding of quantum mechanics has progressed since the beginning of this century. The conceptual development closes with a most welcome chapter on how a quantum mechanic is to interpret a physical measurement. A Stern-Gerlach experiment serves as the occasion for a nicely reasoned discussion of pure and mixed spin 1/2 states, and the celebrated "paradoxes" of the double-slit experiment and Einstein, Podolsky, and Rosen are debunked with the uncertainty relation and Bohr's complementarity principle. The parable of Wigner's friend illustrates the difficulty that arises in trying to separate the measurer from the measurement, and Bell's theorem elegantly disposes of conventional hidden variables as a deterministic framework for the probabilistic interpretation of measurements in quantum mechanics.

No course in quantum mechanics would be complete without applications to physical systems composed of atoms, molecules, and scattering experiments. Perturbation theory for discrete eigenstates is used to find the hyperfine splitting of spectral lines in atomic hydrogen and the Rayleigh-Ritz variational procedure for estimating ground-state energies for helium. A brief account of scattering amplitudes with s-wave bound states and resonances precedes the treatment of the final topic, Dirac's relativistic wave equation for the electron with its prediction for the electron spin magnetic moment. The account is clear and accomplished with a minimum of mathematical and calculational detail.

This book certainly has a place among textbooks on quantum mechanics. It will not satisfy those who need a full-scale account of the mathematical details or a wide range of applications. It is a guide to the physics of quantum mechanics and will serve those who seek a clear account of a selection of important examples unencumbered with calculational detail. Instructors who must provide homework problems and students who must prepare for exams will find an excellent selection of problems ranging from the conceptual to the applied.

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