

Robert Hofstadter, using electron scattering, determined the charge distribution in the proton. Frederick Reines and Clyde Cowan Jr showed that antineutrinos are absorbed by protons. (The 1950s were a great time for elementary particle experiments.) Later papers examine the properties of K mesons and excited states of the nucleon, including the Ω^- . The quark structure of nucleons and mesons was established. Heavy quarks, and the corresponding mesons, were studied.

"Particle Theory" contains a lot of general theory papers, notably the quantum electrodynamics of Richard Feynman and Freeman Dyson's unification of this theory with that of Schwinger. (Schwinger appears separately in the book, in the "Atomic Physics" chapter.) Parity nonconservation is represented by the original papers by T. D. Lee and C. N. Yang. Many of the papers on particle theory are concerned with symmetries and the breaking of symmetries and feature authors such as Murray Gell-Mann, Peter Higgs and Steven Weinberg. There is the proof of asymptotic freedom of many non-Abelian gauge theories by David Gross and Frank Wilczek. The volume concludes with a chapter on science and technology, followed by one on quantum mechanics.

One thing is striking when looking at the timing of papers reproduced in this book: They are concentrated in the 1950s and 1960s. That would be my view of physics, as an old man. But did papers in the 1970s and 1980s turn out to be much less important?

Once more, this is a monumental book. It will be most useful as a way to find important papers and, from the references in them, to be guided to others that have marked the development of physics.

The Quantum Theory of Fields, Vol. 1: Foundations

Steven Weinberg
Cambridge U. P., New York, 1995.
609 pp. \$49.95 hc
ISBN 0-521-55001-7

Paul Dirac, Werner Heisenberg and Wolfgang Pauli introduced quantum field theory in the late 1920s. They proposed it as a generalization of quantum theory that allows the description of systems with many (even infinitely many) degrees of freedom and of systems in which particles are created and destroyed. Quantum field theory originally focused on the

interactions of electrons with the electromagnetic field (quantum electrodynamics). It later found applications to the many-body problem in nuclear and condensed matter physics as well as to the two legs of the standard model of elementary particle physics: the theory of the strong interaction (quantum chromodynamics) and the partially unified electroweak theory. Its use in studying cosmology and the early universe has brought much of contemporary physics into the domain of quantum field theory.

Steven Weinberg, who contributed to the development of quantum chromodynamics and shared the Nobel Prize in physics for his contributions to the electroweak theory, has written a definitive book on the physical foundations of quantum field theory. His book differs significantly from the long line of previous books on quantum field theory going back to Gregor Wentzel's *Einführung in die Quantentheorie der Wellenfelder* (Franz Deuticke, 1943) and including *Quantum Field Theory* by Lowell S. Brown (Cambridge, 1992) and *Quantum Field Theory: A Modern Introduction* by Michio Kaku (Oxford, 1993). (Brown's and Kaku's books were reviewed in PHYSICS TODAY, February 1994, page 104.) The difference is that Weinberg does not start with quantum fields as a given object. He argues instead that quantum fields are the only construct that allows the union of quantum mechanics with the notions of special relativity (excluding string theory, which has an infinite number of particle species).

Two conditions are essential for this union. First, experiments that are widely separated in space at a given time must be independent of each other. This leads to the "cluster decomposition" requirement that, for scattering experiments that are widely separated in space, the S -matrix element for the total process must be the product of the S -matrices for the individual experiments. Even in nonrelativistic quantum physics, the simplest way to satisfy cluster decomposition is to use quantum fields to describe the scatterings. Secondly, the S -matrix must be Lorentz invariant. This requires the Hamiltonian density at x to commute with itself at y whenever the points are separated by a spacelike distance (at least in the simplest case). The combination of these two requirements can only be satisfied using quantum fields, and these fields themselves must either commute or anticommute at a spacelike separation. Weinberg dismisses the case of parafields (that do not obey this last requirement but do

lead to a Lorentz invariant S -matrix) as equivalent to a set of ordinary fields with an internal symmetry.

Weinberg's *Foundations* differs from several recent field-theory books, such as Brown's, mentioned above, and Pierre Ramond's *Field Theory: A Modern Primer* (Addison-Wesley, 1989) that take the Feynman path integral as the basic object in field theory. Instead, Weinberg introduces the canonical formalism first and considers the path integral as an efficient device to derive Feynman rules for a given theory, rather than as the fundamental object in quantum theory. His arguments for doing this are that, unlike the canonical formalism, the path integral does not allow a proof of unitarity and that the path integral based on the canonical formalism allows a straightforward treatment of nonlinear theories.

Foundations, the first volume of Weinberg's planned *The Quantum Theory of Fields*, treats other topics in the context of Abelian theories, particularly quantum electrodynamics. These other topics include radiative corrections, renormalization theory, infrared phenomena and bound states, among others. More recent advances in quantum field theory, in particular non-Abelian theories, will be treated in Volume II.

To summarize, *Foundations* builds the structure of quantum field theory on the sure footing of physical insight. It is beautifully produced and meticulously edited (I found only one misprint, and that only in the spelling of the name of an author of a cited article), and it is a real bargain in price. If you want to learn quantum field theory, or have already learned it and want to have a definitive reference at hand, purchase this book.

O. W. GREENBERG
University of Maryland
College Park, Maryland

About Time: Einstein's Unfinished Revolution

Paul Davies
Simon and Schuster, New York,
1995. 294 pp. \$24.00 pb
ISBN 0-671-79964-9

Elementary geometry has an intuitive quality. As Plato believed, it seems to express what we knew all along. This has never been true of the way physics represents time. The time line of Aristotle and Galileo leaves out essential elements of time as we experience it—in particular, the distinctions among past, present and future, and what we call the "passage" of time.