

BOOKS

Old Friends Among the Giants on Whose Shoulders Physics Stands

The Physical Review: The First Hundred Years. A Selection of Seminal Papers and Commentaries

H. Henry Stroke, ed.
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Reviewed by Hans A. Bethe

The Physical Review: The First Hundred Years is a monumental work. How could the editor, Henry Stroke, manage it all? I suppose he first selected the chapter subeditors, who wrote introductions for and summaries of the various fields of physics, then he helped select, from the pages of *The Physical Review* and *Physical Review Letters*, the 200 papers reprinted in this 1266-page volume and the additional 800-plus papers reproduced (along with the 200 reprints) on the accompanying CD-ROM.

The book has fourteen chapters, the first two being introductory in nature. The opening one, by Abraham Pais, gives an overview of the *Physical Review* and *Physical Review Letters* over the years. In the second, Victor Weisskopf gives the personal story of his own relation to the *Physical Review* and to physics in general. The book contains delightful pictures—of, for example, Wolfgang Pauli, whose photographs look very much like his caricature.

The following dozen chapters consist of the selected papers organized by fields of physics. It is a pleasure to find old friends among the papers that marked the development of the field and equally to see the photographs of the men and women who wrote them. The selection of papers is excellent. An advanced student (or practitioner) of physics might do well to study the papers collected here (but might do better sticking with one

field at a time). The editors of the dozen chapters were Morton Hamermesh, Edward Gerjuoy, Herman Feshbach, Joel Lebowitz, James Peebles, John Simpson, Paul Martin, Marshall Rosenbluth, Wolfgang Panofsky with George Trilling, Sam Treiman, Charles Townes and Sheldon Goldstein with Lebowitz.

Now to the actual collection of papers: “The Early Years” includes the papers that were truly the foundations of our science: Robert Millikan’s measurement of the charge of the electron, Arthur Compton’s discovery of the Compton effect and Clinton Davisson and Lester Germer’s electron diffraction. The chapter also gives us the quantum mechanics of alpha-particle decay by Ronald Gurney and Edward Condon, obviously quite independent of George Gamow, and the discovery of deuterium by Harold Urey and collaborators.

“Atomic Physics” contains “The Theory of Complex Spectra” by John C. Slater. This paper was a revelation to me: It was not necessary to use group theory to understand atomic energy levels; antisymmetry of the wave function and spin multiplets were enough. The later paper, by Giulio Racah, of almost the same title, gives everything the theorist needs to work on the subject. The school of I. I. Rabi contributed greatly to our understanding of the interaction of electrons in the atom and the properties of nuclei. The method of measuring nuclear magnetic moments is reproduced in this chapter as is the discovery of the quadrupole moment of the deuteron. Using similar methods, the Lamb shift and the anomalous magnetic moment of the electron were discovered in quick succession after the end of World War II. Julian Schwinger explained the magnetic moment, using his reformulation of quantum electrodynamics. Martin Deutsch observed the formation of positronium in gases. Hans Dehmelt measured the spin resonance of free electrons.

“Nuclear Physics” begins with the papers on the basic accelerators, by Robert Van de Graaff and by Ernest Lawrence and M. Stanley Livingston. The Gregory Breit and Eugene

Wigner paper on the shape of resonances follows; then there is a more general discussion by Wigner of resonance reactions. The basic paper on fission by Niels Bohr and John Archibald Wheeler is reproduced. The nuclear shell model is given in the paper by Maria Goeppert Mayer and that by Otto Haxel *et al.* Feshbach *et al.* combine the one-particle features of nuclear reactions with the compound nucleus. Chien-Shiung Wu *et al.*’s basic demonstration of the violation of parity in beta decay is here.

“Statistical Physics” offers fundamental papers by Lars Onsager and also includes the renormalization theory of Kenneth Wilson and of Leo Kadanoff and Michael Fisher. “Gravity Physics and Cosmology” reproduces a number of experimental verifications of general relativity, as well as Alan Guth’s “Inflationary Universe.”

After a short chapter on cosmic radiation, there is “Condensed Matter,” which includes, near its beginning, the paper by Wigner and Frederick Seitz on calculation of wavefunctions in a solid. Nuclear magnetic resonance is discussed by Felix Bloch and by Edward Purcell in separate papers. John Bardeen is represented by his paper, with Walter Brattain, on the transistor and by his paper, with Leon Cooper and Robert Schrieffer, on the theory of superconductivity. The quantized Hall effect is discussed by Klaus von Klitzing and others, but strangely there is no paper on high-temperature superconductivity.

Next, after a fairly short chapter on plasma physics, comes “Elementary Particle Physics Experiments,” the first of two chapters on particle physics, which has a record number of papers; also, the number of authors on each of the more recent papers far surpasses those in all other fields. The first paper in the chapter is that by Marcello Conversi, Ettore Pancini and Oreste Piccioni. In it they showed that the cosmic-ray mu meson is not the one responsible for nuclear forces. Panofsky *et al.* showed the existence of a neutral pi meson. The paper on scattering by protons, by Enrico Fermi *et al.*, gave the basic properties of pi mesons. Emilio Segrè and collaborators observed antiprotons.

The contributions of HANS BETHE, of Cornell University, are represented in The Physical Review: The First Hundred Years and the accompanying CD-ROM by 12 papers—more than anyone but Norman Ramsey (13) and Eugene Wigner (13)—ed.

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.
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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.

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About Time: Einstein's Unfinished Revolution

Paul Davies
Simon and Schuster, New York,
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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.