SCHWEBER ON THE HEROIC ERA OF QUANTUM ELECTRODYNAMICS

QED and the Men Who Made It: Dyson, Feynman, Schwinger and Tomonaga

Silvan S. Schweber
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Reviewed by Sam Treiman

The quantum theory of electromagnetism was born along with—as part of—the birth of quantum mechanics in the mid 1920s. The heroic era for quantum electrodynamics stretches from that period to the late 1940s, especially the intense few years toward the end of that span, around the time of the Shelter Island Conference in 1947. It was there that the insights of earlier years were pulled together and clarified, the tools developed and the rules established for what still stands, quantitatively, as the most accurate theory of nature in our possession.

In its operational form, the theory is perturbative. The success of QED in its application to phenomena involving photons and electrons rests on the smallness of the fine-structure constant and on the fact that the electron does not participate directly in strong interactions (so that indirect strong-interaction effects enter only into nonleading orders of the fine-structure constant and the ratio of electron-to-hadron masses). It doesn't matter if the perturbation expansion fails to converge; the "remainder" terms are evidently very small.

The development of QED not only yielded a successful theory in its own domain of phenomena, it also lent confidence more broadly to the general ideas of quantum field theory. In the later years of hadron physics, those ideas ran into stormy weather. The true believers were eventually vindicated, however, as QED was absorbed into electroweak unification and as its non-Abelian analog, quantum chromodynamics, took over for the strong interactions. But that's another story.

Silvan Schweber's book covers the whole of the heroic QED period, nominally 1927–50, with the greatest attention devoted to the triumphant final years. Schweber has produced a magisterial, carefully researched work, richly documented not only in reference to published scientific papers but also to correspondences, interviews, conference proceedings and other sources. These marks of the serious scholar might seem forbidding. But not to worry: The author moved into the history of science after an earlier career in quantum field theory, a field he knows well and clearly approaches with both love and a critical eye. The story is very well told. It is deeply enlivened by sensitive sketches of the principal players, not only the four whose names appear in the title of the book but many more. For historically illiterate contemporaries, what may come as news is the great importance and originality of the contributions of Pascual Jordan to the foundations of quantum field theory.

In his very thoughtful way, Schweber is not unwilling to express personal judgments. He believes, for example, that Freeman Dyson's role in QED, honored though it is, has not received the full recognition that it deserves, a view that I can endorse. He also sets out a perceptive description of the contrasting personalities of Richard Feynman and Julian Schwinger; among other things,

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The four who made QED: (from left) Freeman Dyson, Richard Feynman, Julian Schwinger and Sin-Itiro Tomanaga. (Photographs courtesy of AIP Segrè Visual Archive.)

Schweber pictures them as representatives of two different "styles of reasoning," the particle picture and the field picture, both of which can be traced down the years. The particle picture: Heisenberg, Dirac (with his hole theory),. . . Feynman. The field picture: Schrödinger (his wave equation), Jordan (second quantization),. . . Schwinger. This theme has merit, though it should perhaps not be pressed too far. For the most part, physicists are shameless opportunists. Their philosophies tend to follow the science.

For all its heft, *QED and the Men Who Made It* cannot cover everything. As is proper, much attention is given to the divergence headaches that preoccupied the community and that drove many of the founders to despair (the expressions of which appear in many delightful writings and utterances quoted in the book). But almost nothing is said about the enormous successes encountered in lowest order—for Compton scattering, pair production and the like. Similarly, the experimental side of QED is described only in passing. The focus is on theory and on the people who played a role in its development. Fair enough. This book should appeal to a very wide audience.

Encyclopedia of Applied Physics

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Funding in physics is changing. Collaboration between universities and industry, with the aim of increasing competitiveness, is heavily emphasized by the funding agencies, and so applied physics assumes ever-increasing importance. Thus the work under review here, the *Encyclopedia of Applied Physics* comes at a highly appropriate time.

The encyclopedia is an unusually ambitious work, even as science encyclopedias go. Twenty or twenty-one volumes, containing 578 articles of 10 to 30 pages each, are projected. (Volume 1 came out in 1991, Volume 10 in 1994, and the last is expected, at the rate of three a year, in 1997 or 1998.) Because of the extent of the work, this review is a team effort by the editors of the *Journal of Applied Physics*.

The articles are written at a level suitable for college science students or specialists in different fields, but they are not at the specialized level of articles in *Applied Physics Letters* or *Reviews of Modern Physics*. The encyclopedia is superb for browsing, exactly right for a researcher interested in a field in which he or she is not expert. It is appropriate for libraries at colleges, universities and research institutes, but the size and cost put it beyond the range of most personal libraries. The presentation, including diagrams and typography, is excellent; in our limited perusal, only a few errors were found.

Each article contains a glossary and a list of further readings; these are quite useful and up-to-date. However, cross-referencing among the articles is sometimes lacking or else embedded in the article rather than gathered at the end. The articles are arranged alphabetically by title. The articles have also been classified into twenty sections similar to those of the AIP Physics and Astronomy Classification Scheme. Each article has additionally been assigned a two-digit code number and letter denoting the section and article. This code should be useful for selecting articles from the table of contents. The last volume will be an index for the entire set.

Trigg is well-known to physicists as the former editor of *Physical Review Letters* and one of the editors of the *Encyclopedia of Physics* (VCH, 1991). His talent for choosing reviewers, a *sine qua non* for a journal editor, is evident here in his choice of outstanding authors.

The coverage of applied physics in the volumes under review seems quite broad. Its comprehensiveness is difficult to evaluate because the entire work is not available, but useful background articles were found for most of the topics of a day's submissions to the *Journal of Applied Physics*: the structure of amorphous materials and diffusion, the latter of which is covered in three articles—one on solids in volume 9 and one each on thin films and liquids in volume 5; scintillation, semiconductors and calorimetric detectors are covered, but not superconductor detectors; ferroelectricity is in there, but not ferroelectric materials. We could not find an article on computer simulation, but there are solid articles on computers, computer-aided design in electronics, computer data bases, computer graphics, computer hardware and programming languages.

The three articles on diffusion mentioned above differ from each other in tone. "Diffusion and Ionic Conduction in Liquids" by Derek G. Leaist is rather basic and concerns itself with aqueous solutions and electrolytes; liquid metals are not mentioned. Devendra Gupta's "Diffusion in Thin Films," on the other hand, is written very much from the point of view of semiconductor technology, with many examples of diffusion problems in metallization during very large-scale integration. Alan V. Chadwick's "Ionic Conduction and Diffusion in Solids" deals with classical solid-state diffusion, emphasizing the connections among mass transport, the transport of charge in ionic solids, and point defects, on about the level of the usual diffusion text—for example, Paul Shewmon's *Diffusion in Solids* (Minerals, Metals and Materials Society, 1989). Metals and ionic crystals are covered, but nonstoichiometric oxides are not. There is only a slight overlap, mainly on fundamentals, among the three articles.

The interaction of radiation with matter is covered in two articles: "Interaction of Solids with Particles and Radiation" by Stephen E. Schnatterly covers the effect of both particle and electromagnetic radiation on insulating materials and is written from an atomic physicist's point of view, with emphasis on the spectroscopy of the excitonic transitions induced by the radiation. "Ion-Beam Modification of Materials" by Robert S. Averback covers ion and neutron damage to metals and semiconductors, implantation, channeling, cascade damage and radiation-enhanced diffusion, from the point of view of a materials scientist interested in atomic defects.

Intercalated between the articles by Schnatterly and Averback is a lovely one by Mildred S. and Gene Dresselhaus on intercalation compounds. The article describes the structural organization and characterization of intercalation compounds as well as their electronic and magnetic properties. It is an excellent introduction to the subject, with many suggestions for further reading.

The article on cohesive energy by James Chelikowsky is a short treatment of bonding in solids. It covers ionic, covalent, ceramic, metallic, van der Waals and hydrogen bonding with some basic quantum mechanics and is written at a level that could be understood by any PhD physicist. The article contains a number of nice tables of experimental and theoretical values of bonding energies in elements, semiconductors and alkali halides. The four articles in volume 5 on electronic structure of condensed matter—"Electron States in Zero-, One- and Two-Dimensional Structures" by Frank Stern, "Electron States, Localized" by Constantinos M. Soukoulis and Eleftherios N. Economou, "Electron Structure of Liquids"