

Drawing Theories Apart

The Dispersion of Feynman Diagrams in Postwar Physics

David Kaiser

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Feynman diagrams have been with us for almost 60 years in a great variety of styles and renditions. A recent example of their continuing impact is an awesome quantum electrodynamics (QED) calculation involving 891 eighth-order Feynman diagrams by Toichiro Kinoshita and Makiko Nio (see *PHYSICS TODAY*, August 2006, page 15). The typical set of eight-vertex diagrams that illustrates the report in *Physical Review Letters* on 21 July 2006 of the remarkable precision measurement, better than one part per trillion, of the electron's magnetic moment by Gerald Gabrielse's group at Harvard University serves as a timely postscript to David Kaiser's *Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics*.

The book is a colorful and readable account of the earliest applications of the diagrammatic technique. The story of Julian Schwinger's, Freeman Dyson's, and Robert Karplus and Norman Kroll's second- and fourth-order calculations of the radiative corrections to the electron's magnetic moment is among the highlights in the tale Kaiser tells so well. In a congratulatory letter to Gabrielse after his group had announced its achievement, Dyson rightly marvels at how the diagrammatic method developed in the decade after World War II has proven to be so durable.

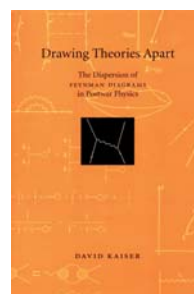
Kaiser is a faculty member in MIT's department of physics and its program in science, technology, and society. His book, a scholarly work based on his doctoral dissertation in the history of science, draws on ideas that are current in the sociology and philosophy of science. Physicists may find terms like "prosopography" or "postconstructivist science studies" unfamiliar, but such hurdles are neither too numerous nor too high. The book comes equipped with a formidable ancillary apparatus of footnotes and appendices and a massive bibliography that alone is worth the price of the paperback. Kaiser collected much of the material, none too soon, through personal contacts with the surviving physicists who conducted QED research in the decades following World War II.

At one level the book is a history of the genesis and evolution of Feynman and Feynmanesque diagrams. It is also a painstakingly assembled and thoroughly documented account of the informal diffusion—or dispersion, as Kaiser calls it—of the diagram method from one group of mostly young theorists and students to another, like an infectious virus. As the diagram technique spread, mutations of the method showed up as characteristic differences in the use of the graphs. Kaiser writes as a physicist who has a gift for summarizing technical, theoretical developments of QED in prose accessible to readers who took some quantum mechanics, even if that was a while ago.

Is Kaiser too ambitious, trying to cover too many fronts in one book? Perhaps so. But he has not intended to write a comprehensive history of Feynman diagrams in the manner of, say, Edmund Whittaker's two-volume *A History of the Theories of Aether and Electricity, from the Age of Descartes to the Close of the Nineteenth Century* (Longmans, Green and Co, 1910). Instead, he uses the story of Feynman diagrams as an exemplar to understand and explain the inner workings of modern theoretical physics as it is practiced. Although the popular perception of a theoretical physicist is that of a Maxwell-like or Einstein-like creator of a perfect and beautiful set of equations, Kaiser finds cues and clues to understanding progress in physics by examining the activities of physicists and the tools they use. The saying that "theoretical physics is what theoretical physicists do" does not sound so flippant in Kaiser's narrative.

In the spring of 1948, at a small invitational conference of experts, Feynman introduced his diagrams, or "stick figures," as spacetime depictions of the real and virtual processes in which charged particles (initially, electrons and positrons) interact with photons. He formulated the rules that made it possible to use the diagrams as tools for the isolation and consistent elimination of troublesome infinities in calculations of radiative corrections to energy-level shifts and scattering cross sections. Few of his listeners understood him, and Feynman was slow in publishing his new technique, which, like most skill-based knowledge, is easier to learn through face-to-face contact than through articles and books.

Kaiser is at his best when he describes how word about the diagrams



got around quickly from one physics department to the next, from teacher to student, and among the new postwar breed of postdocs. In particular, news of the diagrams was well received by many at the Institute for Advanced Study in Princeton, New Jersey, despite J. Robert Oppenheimer's

initial reservations. Dyson emerges as the central figure connecting Feynman's method with Schwinger's emphatically diagramless Lorentz-covariant renormalization techniques and Sin-Itiro Tomonaga's independently discovered methods. Dyson showed that the diagrams were indispensable for the systematic higher-order application of QED perturbation theory. Kaiser is fortunate that Dyson shared with him, and with readers, the charming letters to his parents, which are a gold mine of spontaneous and enlightening observations.

My own training after World War II was with Schwinger at Harvard; but like everyone else I was eager to get up to speed on Feynman diagrams after earning my PhD. Using Dyson's lecture notes on advanced quantum mechanics as a self-study guide, I and my colleagues at the University of North Carolina at Chapel Hill and Duke University taught each other the new techniques of perturbative QED. We thus became the link in a chain of informal diffusion of the diagram method. Kaiser calls this activity "dispersing the diagrams."

Kaiser's description of the role of Feynman diagrams in the more recent developments in particle physics and the standard model is perhaps inevitably sketchy and less satisfying. He devotes an inordinate amount of space to the charismatic theorist Geoffrey Chew of the University of California, Berkeley, and Chew's ambitious program to replace quantum field theory with the bootstrap methodology of "nuclear democracy" in the framework of the S-matrix dispersion formalism. Present-day particle theory has profited from those proposals, but they did not fulfill their creator's high hopes. The appeal of Kaiser's book would not have been lessened if the history of Chew's program and the speculations about its intellectual relationship to the political temper of the times had been published elsewhere.

Physicists who want to get to the bottom of *Drawing Theories Apart* quickly can read Kaiser's excellent article, "Physics and Feynman's Diagrams," in the 2005 March–April issue of the *American Scientist* (page 156). But

they will miss much fascinating historical detail that is eloquently presented in his book.

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