More Surprises in Theoretical Physics

Rudolf Peierls
Princeton U. P., Princeton, N. J., 1991. 106 pp. $9.95 pb
ISBN 0-691-02522-3

This is not a textbook or monograph, nor is it intended for the layman. It is instead a delightful little book meant as light reading for the professional physicist, graduate student or old-timer, theorist or experimenter. Although it is clearly written and easily read, it is not mainly philosophical or qualitative but contains surprisingly explicit theoretical physics, especially quantum mechanics and condensed matter theory (as well as statistical mechanics and nuclear theory). The topics covered are representative of Rudolf Peierls's distinguished career of almost 60 years and come mostly from the middle of that period (20 to 40 years ago). The treatment of the topics gives the reader an excellent view of Peierls's refreshingly direct and down-to-earth research style.

The book is about "surprises," but not at all in the sense of the unpredictable, as in gambling or sports or politics—or even experimental physics. Some aspects of modern theory, especially quantum mechanics, are still counterintuitive even for professionals, so that some results are not what one predicts at first glance, and certain methods turn out to be easier or harder than expected. It is Rudi's genius to show the reader in concrete terms how to do the predicting after some organized thinking.

The style of the book is quite similar to that of its predecessor, *Surprises in Theoretical Physics*, published in 1979 (Princeton U.P.), and access to both books will help the reader achieve a deeper understanding of modern physics. Like the first book, the sequel starts with general quantum mechanics and shows how to get concrete results in, for instance, the counting of states, the WKB method in three dimensions and perturbation theory. Most of the treatment may seem "lowbrow," but there are enough hints to allow the reader to supply the mathematical rigor as an afterthought. Later chapters bring out unifying themes for seemingly disparate subjects, such as pseudomomentum for crystals, fluids, sound and even light. Some chapters are less detailed and mainly give physical insight into questions such as, What really goes on when one applies an electric field to a piece of palladium that has hydrogen dissolved in it?

This is a refreshing book all the way through, and it is easy reading in the sense that you don't need a battery of reference books in front of you. But you do need to do some concentrated thinking if you want to get some of the book's subtleties.

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Innovation in Maxwell's Electromagnetic Theory: Molecular Vortices, Displacement Current, and Light

Daniel M. Siegel
Cambridge U. P., New York, 1991. 225 pp. $49.50
hc ISBN 0-521-35365-3

The late Richard Feynman once declared that "from a long view of the history of mankind . . . there can be little doubt that the most significant event of the 19th century will be judged as Maxwell's discovery of the laws of electrodynamics." The US Civil War, he said, would "pale into provincial insignificance" beside this other event of the 1860s. Feynman may have exaggerated a little, but the formulation of Maxwell's theory certainly ranks as one of the prime events of 19th-century physics, and it is little wonder that Maxwell's steps toward that theory, particularly his use of mechanical models, have attracted close historical scrutiny. The ambiguities and seeming contradictions in Maxwell's electromagnetic writings, especially when viewed from a 20th-century perspective, have helped make them a notorious source of confusion and academic controversy.

Daniel Siegel, in recent years one of the leading students of Maxwell's work, has set out to clear up some of this confusion. The core of his book is in effect a close reading of Maxwell's key 1861–62 paper, "On Physical Lines of Force," and some related documents. Making very effective use of a traditional "internalist" approach, Siegel shows how close attention to the details of Maxwell's writings—including the grouping of terms and the signs in his equations—can illuminate the inner structure of his thinking.

Siegel focuses on Maxwell's famous vortex and idle-wheel model of the ether and its close though complicated relationship to his electromagnetic equations. Maxwell presented himself, Siegel says, as "the mechanical engineer of the magnetoelectric medium," and in Siegel's reconstruction, the vortex model emerges not as a confused or inconsistent auxiliary to the mathematical theory but as a consistent working model of the electromagnetic medium and the basis of Maxwell's thinking on the subject. Siegel shows, for instance, how the displacement current and the "electromagnetic theory of light" emerged from Maxwell's exploration of the workings of his mechanical model and how greatly the original versions of these important ideas differed from their later, purely electromagnetic formulations. Although not all of his conclusions are new, the new level of detail and rigor that Siegel brings to his analysis enables him to settle, apparently conclusively, several long-debated points. There is perhaps still room for dissent on some points, such as his claim that Maxwell regarded electric charge as a real accumulation of idle-wheel particles and his dismissal of the idea that Maxwell ever seriously intended to treat the wheels as acting directly on each other by their mutual pressure. But it is clear that Siegel has greatly advanced our understanding of what Maxwell was up to.

More broadly, Siegel makes a convincing case that Maxwell was a far more committed mechanist than has often been depicted—in particular, that he believed strongly in the existence of ethereal vortices in the early 1860s and that he continued to retain some belief in their reality in later years, even while making a "measured retreat" from his more speculative idle-wheel mechanism. Moreover, Siegel shows how intelligently and productively Maxwell was able to use his model. As Siegel remarks, Maxwell was not a confused and groping 20th-century physicist, but a clear-thinking 19th-century one, for whom imaginary mechanical models were an effective research tool. Siegel has laid the groundwork for a new treatment of Maxwell's work, placing it firmly within the specific 19th-century context from which it grew.

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Quantum Electrodynamics

Edited by T. Kinoshita
World Scientific, River Edge, N. J., 1990. 997 pp. $48.00 pb
ISBN 981-02-0214-8

This collection of specially prepared articles on precision tests of quantum electrodynamics celebrates the triumphant success of the application of theoretical physics to the world of atoms and leptons. The subject itself, QED, is the core theory of atomic and particle physics and, by extension, chemistry and condensed matter physics.

No other physical theory has been evaluated and tested with such precision. Consider for example, the gyromagnetic moment of the electron: The ratio of its spin precession frequency to its Larmor frequency in a uniform magnetic field is predicted by the Dirac equation to have the value $g = 2$. However, due to the electron's self-interactions with the electromagnetic field, its gyromagnetic ratio is corrected by QED to the value $g = 2(1 + a_e)$, where

$$a_e^{QED} = 1\,159\,652\,140 \times(\pm 5.3)(\pm 4.1)(\pm 27.1)\times 10^{-12}$$

The first two uncertainties in a_e^{QED} indicate the level of the theoretical precision. The last uncertainty, $\pm 27.1 \times 10^{-12}$ corresponds to the experimental uncertainty in the determination of the fine structure constant α from the quantized Hall effect. This prediction for the electron's anomalous moment includes the contributions of order $(\alpha/\pi)^4$. These $(\alpha/\pi)^4$ QED corrections, obtained in a remarkable calculation by Toichiro Kinoshita and his coworkers, are eight orders in perturbation theory beyond the Born approximation. The nonlinear effects of light-by-light scattering begin to make an important contribution to the theoretical value at order $(\alpha/\pi)^6$.

Hans Dehmelt and his collaborators have measured with extraordinary precision the anomalous moment of a single electron confined to a Penning trap:

$$a_e^{exp} = 1\,159\,652\,188.4(\pm 4.3)\times 10^{-12}$$

Thus the gyromagnetic ratio of the electron is successfully predicted by QED to 11 significant figures. In the case of the heavier leptons, the anomalous magnetic moment is sensitive to quantum fluctuations resulting from virtual quark currents and the fields that carry the weak interactions. A new experiment to measure the muon magnetic moment to sufficient precision to check these effects is now being constructed at Brookhaven National Laboratory.

Quantum electrodynamics provides the rigorous theoretical foundations underlying atomic physics, allowing extraordinarily precise predictions of the spectra and properties of one- and two-electron atoms. The QED predictions for the Lamb shift, hyperfine splitting, fine structure and the decay rates of hydrogen, muonium, positronium and helium take into account not only radiative corrections due to quantum fluctuations of the electromagnetic field, but also subtle relativistic recoil and bound-state corrections. These high-order calculations not only verify the applicability and consistency of the perturbative renormalization procedure of gauge theory, but they are also the forerunners of calculations for the non-Abelian extensions of QED, which include the radiative corrections needed for precision tests of the unified theory of electroweak interactions and the gauge theory of the strong and nuclear interactions, quantum chromodynamics. Much of the physics of quarkonium—heavy quark pairs bound by gluonic interactions in quantum chromodynamics—has a direct counterpart in the physics of positronium in QED.

The Kinoshita volume provides a detailed account of the main theoretical and experimental advances in testing quantum electrodynamics during the last two decades. Each article is self-contained. The theoretical articles include a beautiful introduction to bound-state systems by Kinoshita and Peter Lepage; a comprehensive survey by Kinoshita and William Marciano of the physics of the muon magnetic moment (including new physics beyond the "standard model"); a detailed review of the theory of hydrogenic atoms by Jonathan Sapirstein and Donald Yennie; and two extensive surveys of perturbative methods for computing lepton magnetic moments: one by Kinoshita and the other by Ralph Roskies, Ettore Remiddi and Michael Levine. Francis Pichanick and Vernon Hughes review the theory of two-electron atoms.

At the level of precision required for testing QED, one needs a detailed understanding of the theory of the measurements themselves. In this category are chapters such as the one by Gerald Gabrielse, Joseph Tan and Lowell Brown on the theory of cavity shifts required for the measurement of the electron magnetic moments. The experimental articles are as authoritative as the others; they include a review by F. J. M. Farley and E. Picasso on the theory and development of the muon anomalous moment experiments; a review by Francis Pipkin on Lamb shift measurements; a review by Norman Ramsey on hyperfine structure experiments; a review by Allen P. Mills, Jr and Steven Chu on positronium studies; and a review by Hughes and Gisbert zu Putlitz on the physics of the muonium atom (μ^+e^-).

In the 1950s Dover's *Selected Papers on Quantum Electrodynamics*, edited by Julian Schwinger, and Academic's *Quantum Mechanics of One- and Two-Electron Atoms* by Hans Bethe and Edwin Salpeter became bibles for workers in particle and atomic physics. This new collection, beautifully edited and annotated by Kinoshita, is a worthy successor to the earlier volumes, providing a comprehensive technical and historical reference for the field.

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Chain Reaction: Expert Debate and Public Participation in American Commercial Nuclear Power, 1945–1975

Brian Balogh
Cambridge U. P., New York, 1991. 340 pp. $34.50 hc
ISBN 0-521-37296-8

Brian Balogh's *Chain Reaction* is both an account of the rise and fall of nuclear power in the US and an attempt to place this history in a broader theoretical political–scientific framework. Not being a political scientist, I can hardly judge the validity of Balogh's political theorizing, and I suspect most readers of PHYSICS TODAY would encounter similar difficulties in fathoming exactly what he means by "issue networks" and the "prominstrative state." But serious and scholarly is his account of how commercial nuclear power originated under Atomic Energy Commission Chairman Lewis Strauss in the 1950s, how it (or rather its prospects) reached a zenith under Glenn Seaborg in the 1960s and how it began its retreat as public interest scientists fanned public apprehensions in the 1970s.

Balogh's main point is that decisions as to how much risk a technology can impose on the public can no longer be decided as they were in the 1950s, by a small group of in-house governmental experts: Outside experts and the public itself are now integral parts of the process by which standards of risk are established. This is a fact of life that those involved with nuclear technology, as well as other technologies, now must accept.

Balogh, a professor of history at the University of Virginia, assumes that the public interest scientists, who intervened in pubic hearings on the licensing of specific reactors, were responsible for the fall of the first nuclear era and therefore, in his view,