

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

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

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:

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

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 Pa-*

pers 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 "proministrative 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 public hearings on the licensing of specific reactors, were responsible for the fall of the first nuclear era and therefore, in his view,

for ensuring the public's safety. But this is a somewhat distorted view of the past. After all, the most important safety device, the containment shell, was invented in 1948 to house a secret military reactor, the Submarine Intermediate Reactor. And the Advisory Committee on Reactor Safeguards (which itself was a creature of the in-house establishment) realized that containment shells would not ensure zero external release of radiation for very large commercial reactors. The fact that reactor safety then became probabilistic, not deterministic, was also recognized within the nuclear community, although I would agree that the acceptability of a technology whose safety is probabilistic was an issue largely raised by the intervenors.

Whether or not the current US hiatus in building nuclear plants adds to the public's safety, given the various risks imposed by other sources of energy, is still moot: In short, one can argue whether or not the interventions by public interest scientists have really added to our well-being.

This book is too detailed to be read easily by either reactor physicists or political scientists. But for those interested in the history of nuclear power, particularly old-timers like myself who are amused at becoming objects of historical scrutiny, Balogh's story is both revealing and frustrating.

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Physics: Imagination and Reality

P. R. Wallace

World Scientific, River Edge,
N. J., 1991. 567 pp. \$64.00 hc
ISBN 9971-50-929-6

The teaching of physics as a liberal art, usually the province of a few mavericks scattered throughout higher education, seems to be in vogue of late. Liberal arts physics courses present physics—especially its 20th-century achievements—as a part of the scientific worldview that is a defining feature of the civilization we call “Western.” This book is the product of one of the mavericks: Phillip Wallace is a respected senior theoretical physicist from Canada who long taught such a course at McGill University.

While the book clearly traces its origin to the author's course, it is not burdened with the usual textbook paraphernalia of exercises and study questions, and offers numerical examples only where there is an important

point to be made. Although it is generally written in lucid and readable prose, the book's pace is quite uneven, in places reverting to little more than extended lecture notes. While it assumes adeptness at no more mathematics than the usual high school algebra and geometry, the text occasionally demands that the reader make full use of these skills.

The author has committed himself to the rapid introduction of contemporary topics after giving the reader a minimal preparation in classical physics. Thus he completes classical mechanics and electromagnetism in the first 70 of 540 pages, while thermodynamics and statistical mechanics claim 50 more pages midway. Other classical concepts appear *en passant* as needed: For example standing waves on a string first appear as an introduction to Schrödinger's hydrogen solution.

The treatment of relativity is one of the book's stronger points. In discussing the special theory, Wallace takes pains to emphasize the distinction between what an observer sees and the picture reconstructed by correction for signal transit time. This distinction is not always fully appreciated by physics majors (or even, lamentably, by their teachers). The general theory is explained well, although the author omits some of the more up-to-date confirmations of its validity, such as the annual variation in the period of atomic clocks and transit-time delays revealed in studies of millisecond pulsars. This section concludes with an excellent treatment of stellar evolution and the compact objects that represent the endpoint of this evolution.

The introduction to quantum theory is fairly conventional, but it takes the curious approach of introducing indeterminacy through Heisenberg's relations without explicitly mentioning the probability interpretation of the wavefunction.

On the most current topics, Wallace wisely tailors his emphasis to what is likely to interest the student rather than the teacher. Thus cosmology is covered in considerable detail, while particle physics as well as the author's current specialty of condensed matter theory get shorter shrift.

A careful attention to history is the hallmark of the most successful books of this type, and Wallace clearly understands this. But it is also possible to be a slave to history: For the lay reader, the Gell-Mann-Nishijima scheme and the SU(3) particle classification schemes described in Wallace's book shed little light on the far simpler quark model that followed

from them.

The author's style has one feature that seriously mars his treatment of several topics. He seems addicted to the unexplained forward reference. Thus he derives the gravitational red shift from the quantization of light long before he introduces light quanta, and he makes similar use of the uncertainty relations and the Planck length. For most readers, a simple note that a particular topic will be treated in detail later suffices to alleviate any confusion but Wallace does not always take the trouble to do this.

All in all, this book is a modest but worthy addition to the growing selection of texts in this area. An instructor who contemplates teaching a course on liberal arts physics to a superior group of students, and who shares the author's preferred list of topics, would do well to consider it.

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Weak Chaos and Quasi-Regular Patterns

G. M. Zaslavsky,

R. Z. Sagdeev, D. A. Usikov
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Cambridge U. P., New York,
1991. 253 pp. \$75.00 hc
ISBN 0-521-37317-4

With the growth of interest in and understanding of dynamical systems has come a rise in the number of books devoted to the subject. The present volume is one more addition to this swelling throng. It devotes its attention primarily to Hamiltonian systems and, within the general framework of Hamiltonian systems, to questions of the origin of chaos in such models.

Hamiltonian dynamical systems can be well understood in two limiting regimes. At one extreme lie the “hyperbolic” dynamical systems. These systems are completely chaotic; but due to the presence of certain well-understood geometrical structures in the phase space of the problem, one can make predictions about the decay of correlations and the insensitivity of the motion to perturbation of either the initial conditions or parameters of the model. At the opposite extreme lie the integrable systems. In these systems, the motion is completely regular, and by introducing action-angle variables, one can solve the equations of motion explicitly.

Between these two extremes the situation is far less understood. One major advance occurred in the 1950s and 1960s through the work of Andrei