Das, *J. Vac. Sci. Technol.* **b9**, 95, 1991).

I believe that the book will appeal to the two distinct audiences the author set out to reach: graduate students and industry researchers who wish to become (or remain) familiar with the methods used in the modern semiconductor industry. I was impressed with the number (more than 1300) and currentness (through 1988) of the references, the clarity of the illustrations and the completeness of the index. Above all, I was impressed with the author's writing style and his not overly pedagogical approach.

From someone who remembers with nostalgia his first encounter with the Haynes–Shockley experiment in 1952—seeing on an oscilloscope screen the passage of holes from one contact on a Ge sample to another—I highly recommend this book to those who were there then, as well as to those who have come along since.

LAWRENCE G. RUBIN
Francis Bitter National Magnet Laboratory
Massachusetts Institute of Technology

Pions to Quarks: Particle Physics in the 1950s

Edited by Laurie M. Brown, Max Dresden and Lillian Hoddeson
Cambridge U. P., New York, 1989. 734 pp. $59.50 hc
ISBN 0-521-30984-0

Pions to Quarks is a collection of 47 essays based on lectures presented at a 1985 symposium at Fermilab. It is the second in a series, of which the first volume, *The Birth of Particle Physics*, covers the 1930s and 1940s. Unlike the first volume, *Pions to Quarks* includes some contributions by historians of science, though most are by physicist protagonists of the 1950s. While the volume will be a valuable source for historians, it is also fascinating reading for physicists wishing to understand the origins of today's "standard model" of the elementary particles and their interactions. Like most successful theories, the standard model is often portrayed as if it had sprung full-blown from the head of Zeus. It is marvelous to be reminded of the real story: a struggle toward a coherent theory using incomplete and confusing information, plagued occasionally by false or misleading clues.

The ample volume contains a foreword by Leon Lederman and an introductory essay by the editors—Laurie Brown, Max Dresden and Lillian Hoddeson—that are alone worth the price of admission. Lederman explains what the symposium participants have in common with a keen-sighted golf caddy named Pete (of this I can say no more). The introductory essay by the editors is a succinct overview of the period, encompassing scientific, technological, political and socioeconomic aspects of the story.

That story is very relevant to the situation of particle physics today. While the subtle interplay of theory and experiment was at work during the 1950s, as it always is, the leading role was played by experiment—as Murray Gell-Mann writes in the closing essay, there was "a close partnership of experiment and theory in a period . . . [of] sensational experiments." By the end of the 1940s the notion of separate weak and strong

nuclear forces had begun to emerge (though less sharply drawn than this reader had imagined), a point discussed in the contributions of Bruno Pontecorvo, Abraham Pais and Robert Marshak. A short, tidy list of elementary particles had been enumerated. But parity violation and the full complexity of the particle spectrum were unimagined. Not enough of the map of reality was known to have allowed any chance of formulating the unified electroweak theory or quantum chromodynamics, the two monuments of the standard model.

Making use of the new technology of particle accelerators and detectors, the important elements of the map were drawn from experiments of the 1950s and 1960s, so that by the early 1970s theorists were able to formulate the standard model. Today its success enables us to formulate deeper questions, concerning for instance the nature of the unknown fifth force that the standard model requires to give the particles mass. Again, too little of the map is drawn, and progress now depends on constructing the essential cartographic instruments, the Superconducting Super Collider being among them.

The τ–θ puzzle is a paradigm for the decade of the1950s. Its central role is exhibited in a bibliographic analysis contributed by D. Hywell White and Daniel Sullivan. θ and τ denoted particles decaying to two and three pions, respectively. When precise mass and lifetime measurements strongly suggested that they were in fact the same particle (today's K meson), a detailed analysis of the decays by Richard Dalitz (which he describes in this volume) led to the suggestion by T. D. Lee and C. N. Yang to search for parity violation in the weak interaction.

This much of the story is fairly well known. Less familiar is the work that brought the problem to the point of Dalitz's analysis. In this story Bohr's necessary condition for progress was fully satisfied: All possible mistakes were made! In the initial cloud-chamber experiments (described in this book by George Rochester and Donald Perkins), K and Λ particles were regarded as a single particle, but a little later five observed K-decay modes were regarded (provisionally, it must be said) as five different particles (described by Yang, Gerson Goldhaber, Val Fitch and William Chinowsky).

Clarification followed from crucial technical developments, especially higher-energy accelerators and improved particle detectors. Jack Steinberger recounts an amusing vignette from the 1952 Rochester Conference in which a young, unflappable experimenter, Robert W. Thompson, overcomes an impatient J. Robert Oppenheimer to describe the "nonconvective" cloud chamber that allowed him to distinguish K from Λ decays. New accelerators (described by Matthew Sands, John Blewett, Ernest Courant, Lawrence Jones and Donald Kerst) were needed to produce large numbers of the new particles, which previously could only be studied in relatively small numbers in cosmic-ray experiments. Development of electronic counters (described by Peter Galison and Shuji Fukui) was essential for the precise measurements that suggested that τ and θ were the same particle, preparing the way for Dalitz, Lee and Yang.

The τ–θ puzzle is only one of several major episodes described in *Pions to Quarks*. Besides being entertaining reading for today's practicing physicists, the book also provides a useful perspective on how great physics is done. In particular, it is clear that the standard model could not have been formulated without the progress in accelerators and detectors described in this volume. It is equally clear that future dramatic developments in accelerators and detectors will be needed to explore the new force(s) and particles that the success of the standard model enables us to contemplate.

MICHAEL CHANOWITZ
Lawrence Berkeley Laboratory

Energy and Empire: A Biographical Study of Lord Kelvin

Crosbie Smith and M. Norton Wise
Cambridge U. P., New York, 1989. 866 pp. $89.50 hc
ISBN 521-26173-2

Lord Kelvin deserved a big book and this certainly is one. In more than 800 pages Crosbie Smith and M. Norton Wise provide a major scholarly work on the man who shaped physics and engineering more than anyone else in Victorian Britain. Smith and Wise had separately published important articles on Kelvin before combining forces in 1980 to work on this book. While explaining who is chiefly responsible for which portions of the book, they emphasize that they have integrated their respective contributions and arrived jointly at their overall interpretation.

Smith and Wise divide their story into four parts. Part I on "the making