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

of the natural philosopher" discusses the influences on the young William Thomson of his father (professor of mathematics at Glasgow University) and of his undergraduate studies at Glasgow and Cambridge Universities. Part II, by far the longest and most original of the four, analyzes Kelvin's physics–field theory, thermodynamics, dynamics, electromagnetism and theories of matter. Part III concerns the application of thermodynamics to the "irreversible cosmos," discussing controversies surrounding Kelvin's views of such matters as the cause and duration of the Sun's heat and the age and habitability of the Earth. Part IV explores Kelvin's engineering science—his role in the laying of the Atlantic Telegraph Cable and his inventions improving electrical and navigational technologies.

Smith and Wise's title, *Energy and Empire*, seems to convey their basic view of Kelvin. Formulated at mid-century, the physics of energy embodied Kelvin's most far-reaching ideas, embracing all areas of physics. The dissipation of energy entailed the "irreversible cosmos," drawing Kelvin into his well-known debates with geologists and biologists. Kelvin's physics obviously did not reside in a vacuum, and one of this book's many strengths is its constant attention to the historical context of Kelvin's ideas. But the one context that encompassed all others was the British Empire, or more specifically its economical and technological foundations. That workhorse of the Industrial Revolution, the steam engine, helped give rise to and was explained by energy theory. Kelvin's science-based electrical patents found ready homes in the British electrical industry, and his navigational inventions held obvious importance for a seafaring empire. Smith and Wise thus see Kelvin's physics as above all "practical," motivated by and grounded in industrial, imperial concerns.

The development of telegraph technology illustrates their thesis. On the one hand, Kelvin's scientific understanding made the Atlantic cable possible. Smith and Wise nicely bring out the contrast—and conflict—between Kelvin's views and those of an older, less sophisticated approach, responsible for an earlier, expensive failure of the Cable. On the other hand, in Kelvin's view, practical telegraphic successes supported his overall electromagnetic theory in opposition to that of James Clerk Maxwell, which physicists generally accepted by the 1890s. Smith and Wise contrast the practical Kelvin with the gentrified Maxwell and conclude that Kelvin's "was a methodology that grounded mathematical physics in steam-engines, vortex turbines, and telegraph lines; a methodology of industrialization and Empire."

Kelvin's physics also contrasted with Maxwell's, Smith and Wise say, in being "non-hypothetical." This aspect of Kelvin's physics was part of a system of values that his father had imposed on the Thomson family, calling for moderation in all things, including a latitudinarian religion, Whiggish politics and non-hypothetical physics. Just as his father advised him to avoid controversy in religion and politics, so also Kelvin developed in the 1840s a physics that emphasized the common ground of competing theories, avoiding what necessarily would have been controversial claims about unobservable causes of observed phenomena. Hence, Maxwell's electromagnetic theory was un-

acceptably hypothetical to Kelvin because the crucial concept of an unobservable displacement current was not properly related to experience.

Though impressive, the book is not without weaknesses, especially in its more general interpretations. Smith and Wise ask for a degree of elasticity in their terms describing Kelvin's moderate views, but one wonders if the terms really apply much beyond the 1840s. In 1849, Kelvin's brother, also a member of the Thomson family after all, openly declared his radical unitarianism. The intense controversies of the last half-century of Kelvin's life involved both hypotheses in science and differences in theology. Indeed, guided by his father, Kelvin even began his career with controversy, with a paper that showed up the professor of mathematics at the University of Edinburgh. Describing Kelvin's science as "non-hypothetical," especially with the connotation of noncontroversial given the word by Smith and Wise, seems off the mark.

Nevertheless, this long-anticipated volume by two well-respected historians of science provides a thorough and illuminating treatment of a principal founder of both modern science and modern engineering science.

DAVID B. WILSON
Iowa State University

NEW BOOKS

Atomic and Molecular Physics

Advances in Chemical Physics LXXVII. I. Prigogine, S. A. Rice, eds. Wiley, New York, 1990. 645 pp. $105.00 *hc* ISBN 0-471-51609-0

Atomic Photoeffect. *Physics of Atoms and Molecules.* M. Ya. Amusia. Plenum, New York, 1990. 317 pp. *hc* $89.50 ISBN 0-306-43548-9

Atomic Spectroscopy. J. W. Robinson. Marcel Dekker, New York, 1990. 299 pp. $99.75 *hc* ISBN 0-8247-8311-5

Crystallographic and Modeling Methods in Molecular Design. Proc. Symp., Gulf Shores, Alabama, April–May 1989. C. E. Bugg, S. E. Ealick, eds. Springer-Verlag, New York, 1990. 268 pp. $65.00 *hc* ISBN 0-387-97210-2

The Physics of Electronic and Atomic Collisions. *AIP Conference Proceedings 205.* Conf. Proc., New York, 1989. A. Dalgarno, R. S. Freund, P. M. Koch, M. S. Lubell, T. B. Lucatorto, eds. AIP, New York, 1990. 678 pp. $90.00 ($72.00 AIP members) *hc* ISBN 0-88318-390-0

Tunneling Phenomena in Chemical Physics. V. I. Gol'danskii, L. I. Trakhtenberg, V. N. Fleurov. Gordon and Breach, New York, 1989. 334 pp. $198.00 *hc* ISBN 2-88124-655-9