ment-sponsored antimonopoly policies despite his heartfelt aversion to corporate monopolies and his faith in small inventors. On the other hand, Zachary's decision not to address these and other issues at greater length was arguably a legitimate one: Had he done so, he would have produced a much longer book for a much narrower readership of academic specialists.

As the book's subtitle indicates, Zachary believes Bush epitomized the growing stature of the engineer in 20th-century America. His own narrative, however, opens the possibility that Bush was less a modern engineer than an old-style inventor and tinkerer. Throughout his life, Bush constantly designed new gadgets and machines, both workable and unworkable. Profit was not his motive; once he had achieved economic security in the 1920s, after new radio tubes and other devices earned him valuable shares in Raytheon and Spencer Thermostat, he no longer patented his inventions (including the differential analyzer), because he wanted the world to benefit freely from them. Rather, his psyche demanded that he create, and he produced a dizzying array of devices in his home workshop. The offspring of his fertile imagination included a spring-loaded birdfeeder that dumped off heavy pigeons while allowing his favorite songbirds to feed; a new type of fuel-efficient car engine that the technologically stagnant American auto industry of the 1960s refused to test; and heart valves that were ultimately unusable because Bush possessed too little medical knowledge. From Zachary's account, Bush appears not to have worked from theory; he was a gadgeteer who operated from a purely mechanical sensibility. Is it any wonder, then, that he proved incapable of embracing the digital age?

Master of Modern Physics: The Scientific Contributions of H. A. Kramers

Dirk ter Haar
*Princeton U. P., Princeton, N.J. 1998. 288 pp. $39.50 hc
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Hendrik A. Kramers stood at the center of physics in the first half of the 20th century. A 1987 biography by Max Dresden deals with his life and work and includes an in-depth discussion of early work on dispersion theory and his contributions to quantum electrodynamics. As a substantial part of the oeuvre could not be included there, this new book—*Master of Modern Physics* by Dirk ter Haar—is a welcome addition.

Ter Haar, who studied with Kramers, has a unique approach to scientific biography: He makes us read the original papers; the second part of his book consists of 12 of them, in English, while the first part contains a discussion of the published work and an elucidation of these papers. This format makes the more difficult of Kramers's articles easier to follow. Particularly helpful are ter Haar's comments regarding the pioneering extensions of the old quantum theory, culminating in the Kramers–Heisenberg paper on dispersion and in the Kramers–Kronig relations.

For the important 1923 paper (Phil. Mag. *46*, 836) on absorption and dispersion of x rays, ter Haar has no room, to his expressed regret. He does give the translation of a 1925 paper on Werner Heisenberg's matrix mechanics, to show both how closely it relates to the Kramers–Heisenberg paper and how much they differ conceptually: From a theory of which the results can be expressed in terms of observables, Heisenberg created a theory that deals exclusively with these observables.

Kramers's research on statistical mechanics and on the quantum theory and its applications to solids forms a substantial part of this book. I enjoyed the introduction to "Brownian motion in a field of force" with quotes from Nicolaas van Kampen's analysis. It reads like a detective story, a genre that Kramers treasured for relaxation. (I once heard him converse for a full hour about Erskine Childers's novel *The Riddle of the Sands*).

The theory of flow of polymers, which Kramers began as a consultant at Shell, is reviewed next. The book discusses several papers on equilibrium statistical mechanics, including "Statistics of a Two-Dimensional Ferromagnet," written in collaboration with Gregory Wannier. This paper teaches us much about the Ising model, including the value of the transition temperature—if it exists—but the abstract ends with the statement "the information thus gathered by rigorous methods remains incomplete." When Lars Onsager later solved the problem, Kramers was impressed by the difficulty of the proof, undoubtedly because abstract algebra, which Onsager employed, was not a tool Kramers readily used. When Kramers's student Raymond Houtappel suggested a generalization to hexagonal lattices as a thesis project, Kramers tried in vain to dissuade him, because "it was too difficult." It pleased him, though, that Houtappel succeeded without using abstract algebra.

Of the papers on quantum theory of solids, the best known contains the so-called Kramers degeneracy. Ter Haar discusses the proof, but it is hard to improve on Kramers's simple and lucid derivation unless one prefers Eugene Wigner's proof based on space inversion and time reversal symmetry. I was pleased that ter Haar included the paper on the eigenvalue problem in a one-dimensional periodic potential, which forms the basis of the thesis of one of my students. It excels in elegance and generality and, ter Haar tells us, was "one of Kramers' own favorites."

A prime example of Kramers's inimitable style is found in the derivation of formulas equivalent to the Dirac equation. This is reprinted as paper F and can also be found in Kramers's book *Quantum Mechanics* (translated by ter Haar, North-Holland, 1957). Ter Haar also discusses a contribution Kramers made to Heisenberg's S-matrix theory. It consists of a single but important remark: that the S-matrix should be extended to imaginary values of its argument and that its poles in the complex plane correspond to the bound states of the "scattered" particles. Kramers said this during a lecture that Heisenberg gave during a wartime visit to Leiden. Kramers could not reveal at that time that this discovery was made by his student, Siegfried A. Wouthuysen, who, being Jewish, was in hiding. A footnote in Heisenberg's third paper on the subject, put in at Kramers's request, rectified the omission.

No book on Kramers is complete without mentioning his work on quantum electrodynamics. Ter Haar devotes chapter 4 to this subject, giving a good characterization and adding a few interesting points. On this and the other subjects on which he touches, he has written a stimulating book that brings Kramers's history-making work more into focus, even for those, I among them, who were his students.

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Cats' Paws and Catapults: Mechanical Worlds of Nature and People

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Steven Vogel is in the department of zoology at Duke University. He is a biologist who has thought about biomechanics for 40 years. His emphasis, and that of his colleagues, is on engineering practice rather than physi-