value of the critical mass; at one point he even stated that no attempt had been made in Germany to calculate the number. Nowhere, however, did Heisenberg acknowledge his enormously consequential error in estimating the value at tons rather than kilograms, leaving the carefully crafted impression that only precision had been lacking. Maintaining this convenient ambiguity after the war, Heisenberg could insist disingenuously to the *New York Times* (12 December 1948) that "our reasoning was just like that of your physicists," and continue to avow that his wartime fission work had been occupied exclusively with "technical developments, with a peacetime application."

In Heisenberg's facility at rationalizing uncomfortable truths, and in his unresisting posture toward the Nazi ascendancy, Rose discerns a sense of responsibility that is strange in its detachment from the horror that was unfolding around him. To comprehend Heisenberg's moral view of the world, with its peculiarly German emphasis on the virtues of "inner freedom" and unquestioning obedience to established authority, is the ultimate purpose of the book and the ten years of fact-gathering that went into it: "Heisenberg," Rose writes, "seems to have believed that all power was amoral—a common prejudice in German culture. But this politically immature attitude was dangerous in that it promoted moral and political cowardice. For if all power was amoral, then no political cause was good, and hence the Allied cause was hardly superior to that of Hitler. In the end, the only thing that mattered politically for Heisenberg was the German nation."

Maxwell's Demon: Why Warmth Disperses and Time Passes

Hans Christian von Baeyer
Random House, New York, 1998.
207 pp. $25.00 hc
ISBN 0-679-43342-2

Modern physics is haunted by the specters of two celebrated mythical creatures—Schrödinger's cat and Maxwell's demon. Each embodies one aspect of the logical pitfalls that arose when randomness entered the foundations of our science.

Most physicists, and much of the general public, are aware that the cat, after a run of more than 60 years, is still there to torment us. But we sometimes need to be reminded that neither has the demon, after more than 130 years, yet been fully exorcised. In *Maxwell's Demon*, Hans Christian von Baeyer examines the underpinnings of the second law of thermodynamics and its role in fixing the direction of time's arrow.

Some of the finest literature in the English language has been penned by authors for whom it was not a mother tongue—Joseph Conrad and Vladimir Nabokov come readily to mind. German-born theorist von Baeyer, although perhaps not quite in that league, is a prime candidate for best wordsmith among popularizers of physics, composing prose that is elegant, economical and, above all, civilized.

Although his *Maxwell's Demon* is targeted to the broadest possible lay audience, with nary an equation in 174 pages of narrative, it can also be read with profit by physicists, for whom it will provide a historical perspective as well as an outline of some of the current thinking on the topic. It also boasts extensive notes and a remarkably complete index.

The story of the second law begins in 1823 with Sadi Carnot. His insight—that a hypothetical reversible heat engine would be the most efficient possible, but still could never achieve 100% efficiency—was a remarkable exercise in abstract reasoning. But trapped within the caloric theory on which his analysis was based, and lacking an absolute temperature scale, he could not clothe this logical skeleton in quantitative flesh. Three decades later, Rudolf Clausius, armed with a mechanical model for heat and Kelvin's absolute scale, gave Carnot's ideas substance through the concept of entropy.

James Clerk Maxwell built his kinetic model of gases on these foundations. Though unable fully to incorporate entropy, he recognized its statistical underpinnings, and thus was the demon born—able to violate the second law by manipulating matter on the atomic scale. Ludwig Boltzmann completed the theory with his inspired interpretation of entropy as the logarithm of the combinatorial probability of the state of a system.

Over the years, there have been attempts to exorcise the pesky sprite by developing mechanical demons and showing why they fail. These attempts range from Marian von Smoluchowski's simple flap door in 1912 to Richard Feynman's ratchet and pawl in 1964. But all modern work on this topic is enlightened by the 1950s work of Claude Shannon and Léon Brillouin, who established the connection between entropy and "missing" information.

In the last part of his *Maxwell's Demon,* von Baeyer outlines some contemporary approaches to the problem. Wojciech Zurek, noted for his efforts to exorcise Schrödinger's cat through the mechanism of decoherence, has an audacious proposal for dealing with the demon: Redefine entropy by adding a term based on something called "algorithmic complexity," which is nearly vanishing in all practical cases. It is designed to replace probability theory with the still-developing complexity theory as the logical basis for the second law.

The story ends with accounts of attempts to exploit thermal noise as an energy source without actually violating the second law. Biochemist R. Dean Astumian has proposed that a variant of Feynman's ratchet could well be the engine that drives molecular transport in living cells, while physicist Albert Libchaber's optical thermal ratchet is a working physical model of just such a device.

In short, von Baeyer serves up some nourishing food for thought for the lay reader and the professional alike. For a fuller meal, the latter may also wish to consult some of the references cited by the author.

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Tracks to Innovation: Nuclear Tracks in Science and Technology

Robert L. Fleischer
Springer-Verlag, New York 1998.
193 pp. $49.95 hc
ISBN 0-387-98342-2

A moving charged particle can produce ionization that, in certain materials, results in permanent radiation damage. When these materials are etched, the resulting conical pit reveals the particle's trajectory by the cone axis orientation, its energy by the cone depth and its charge by the cone half-angle. P. Buford Price and Robert M. Walker, along with Robert L. Fleischer, developed the art and technology of nuclear track etching and then adapted this process to a surprising variety of applications. The three documented their work in *Nuclear Tracks in Solids: Principles and Applications* (U. California P., 1975). The reprise presented in Fleischer's *Tracks to Innovation* was motivated by his desire to illuminate what he calls "the interplay between science and technology." Since the experimental technique was refined at the General Electric Research Laboratory, where Fleischer worked for many years, he is in a particularly good po-