books

The Devil is in the details

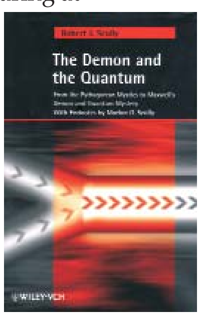
The Demon and the Quantum

From the Pythagorean Mystics to Maxwell's Demon and Quantum Mystery

Robert J. Scully, with endnotes by Marlan O. Scully
Wiley-VCH, Weinheim, Germany, 2007. $45.00 (271 pp.). ISBN 978-3-527-40688-3

Reviewed by Gian Paolo Beretta

Notable physicist Marlan Scully has contributed to the discovery, design, and interpretation of many quantum effects, devices, and puzzles. In *The Demon and the Quantum: From the Pythagorean Mystics to Maxwell's Demon and Quantum Mystery*, he contributes endnotes to a book principally penned by his son, Robert. Written with the goal of explaining the secrets of the quantum in layman's terms, the book ends up painting a lively, readable portrait of the genesis of modern physics. A diesel mechanic, Robert Scully gains readers' sympathy and attention by declaring at the outset that he is not a physicist. He also disarmingly explains the fortuitous reasons for his unusual familiarity with many famous physicists, including several Nobel laureates, who attended barbecues at his father's ranch during his childhood.



In the first half of the book, the reader is guided step by step along a wonderful journey across the highest physical concepts. Before each step, Scully gives a thoughtful, brief introduction not only to the physics that motivates the theories but also to the human sides of the ancient mathematicians, philosophers, and modern pioneers of classical or quantum theory who contributed to shaping the next concept he will introduce. The smart introductory epistemological essays set a novel-like rhythm, dilute the difficult concepts, and stimulate the reader's curiosity.

The second half, with its extensive set of endnotes, can be disregarded by the nontechnical reader. But those who have some mathematical background will find well-written, concise mini-lectures that translate the descriptions, ideas, and inferences of the first part into the proper technical language of mathematical physics. The consistency of the main chapters with the rigorous material of the endnotes allows for discussions in the first part that are never oversimplified and makes *The Demon and the Quantum* satisfying also to readers who have a strong physics background.

The Scullys successfully explain counterintuitive quantum effects, such as wave–particle complementarity and delayed-choice and which-path information erasure in two-slit interference experiments. Less clearly outlined and convincing are the discussions of Maxwell-demon aspects of Stern–Gerlach experiments and quantum heat engines. Yet that flaw is not the authors' fault: It is a fair representation of the status quo. The role of thermodynamic concepts in quantum theory is still far from fully understood. No definitive word has been written about which exorcism prevents the demon from threatening the validity of the second law of thermodynamics. It is actually very exciting to see the strong revival of thermodynamics in today's scientific literature. About three decades ago, almost every physicist was convinced that thermodynamics was a dead subject and that the final word about it had been said by statistical mechanics. Pioneers who dared to reveal the demons of statistical mechanics and who worked at more consistent theories aimed at unifying quantum mechanics and thermodynamics lost their jobs.

Today, perhaps because of the impressive recent advances in single-particle experimental techniques, one might say that the quantum is finally becoming thermal. After having been kicked out of the front door 30 years ago, thermodynamics has now reentered through the back window and is once again permeating the physics literature as a source of inspiration. Scully's book shows how historic contributions in physics are not made by those who publish papers by the hundreds or who get funding by the millions, but by the few thinkers and independent minds who have the strength to step out of the race, and quietly identify and address the big questions.

Perhaps in the next edition, Scully could complete the picture with a selection of the physicists, chemists, and engineers who long ago broached the key questions being addressed today by those who study quantum demons and heat engines. Some of those issues are covered in, for example, *Meeting the Entropy Challenge: An International Thermodynamics Symposium in Honor and Memory of Professor Joseph H. Keenan* (AIP, 2008), which I coedited with Ahmed Ghoniem and George Hatsopoulos. Overall, *The Demon and the Quantum* is accessible to a large spectrum of readers of PHYSICS TODAY; it is worthwhile reading even though, in the end, the book turns out to be more convincing in explaining the quantum effects than in clarifying the demon conundrum.

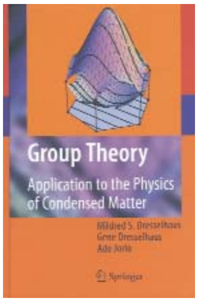
Gian Paolo Beretta is a professor of thermal sciences and mechanical engineering at the University of Brescia in Brescia, Italy. He specialized in axiomatic foundations of thermodynamics and was among the first to develop a fully quantum theory of irreversibility.

Group Theory

Application to the Physics of Condensed Matter

Mildred S. Dresselhaus, Gene Dresselhaus, and Ado Jorio
Springer, New York, 2008. $89.95 (582 pp.). ISBN 978-3-540-32897-1

In my experience, there is no ideal way to teach the application of group theory to the quantum mechanics of atoms, molecules, and solids; the reason is the inherent nature of the subject. Students have to invest a large amount of intellectual capital before they reap the benefits in applications that often fall out almost trivially. Moreover, the mathematics of group representations is quite sophisticated and unfamiliar to most physics and electrical engineering graduate students, and that is rather off-putting for many if they do not already have some idea of the physical applications.



Group Theory: Application to the Physics of Condensed Matter, by Mildred S. Dresselhaus, Gene Dresselhaus, and Ado Jorio, has had enormous consumer testing in the way it steers around those obstacles: It was developed for a graduate course taught mostly by Millie Dresselhaus at MIT for more than 30 years, with many revisions of lecture notes. Very much a graduate text or specialist monograph, the book covers a wealth of applications across solid-state physics. In fact, the only two topics I could not find covered in its pages were selection rules for Raman transitions in solids and lines of accidental degeneracy when electron energy bands cross, both somewhat esoteric.

Following a four-chapter introduction to the mathematics—with more math promised for later—and another two chapters on its applications to quantum systems, two chapters on electronic states and vibrations in molecules (including Raman activity) introduce the basics of group theory in molecular systems. The authors use crystal-field effects to show how to treat the perturbative splitting of degenerate energy levels. Nearly half the book is taken up with the space-group symmetry of solids, its application to phonons and electron energy bands, and the use of double groups to account for spin. The authors give detailed discussions of effective-mass tensors, *g*-factors in a magnetic field, and other topics. Three more chapters cover time-reversal symmetry, tensors in elasticity and nonlinear optics, and the permutation group. The point of including the last subject is not clear. The authors use the permutation group to derive the spectroscopic terms (which denote the total angular momentum L and total spin S) in various orbital configurations such as p^5 or d^5, but that can be done much more simply with John Slater's scheme, which originally introduced Slater determinants. That approach is not mentioned, perhaps because it is assumed known from atomic theory.

The book takes a how-to approach throughout. For example, the authors introduce irreducible representations of the full rotation group from spherical harmonics, assumed to be familiar, and they write the extension to spin representations by analogy. Even so, the background mathematics covers the first 70 pages, though the authors provide examples from physics to illustrate concepts. A novice would be advised to have a guide through that early material, because, of course, not all the mathematics is needed for many simple applications.

In one or two places, where the ideas are a matter of physics and not of mathematics, the authors' how-to approach left me a bit dissatisfied. The most basic points of the subject are that quantum energy levels have associated group representations and that those representations are "normally" irreducible, as stated on page 58. But why should they be irreducible? The fact is that they are irreducible only if the group includes all the symmetries of the system and if neither quirky mathematical symmetries such as those inherent in the hydrogen atom's simple $1/r$ potential nor "accidental" degeneracies such as the band crossings mentioned above are present, while keeping in mind that time-reversal symmetry treated afterward as an add-on can also produce degeneracy. The authors include those ideas, of course, but in a conversational way without a crisp formulation of where the irreducibility comes from. I noticed only one small typo, and found the index satisfyingly complete.

The book can be warmly recommended to students and researchers in solid-state physics, either to serve as a text for an advanced lecture course or for individual study, preferably with an instructor to help select mathematical background and applications of interest. But even if one is never going to use the detailed machinery of group theory, the concepts give a precise way of thinking about symmetry and degeneracy in physics.

Volker Heine
University of Cambridge
Cambridge, UK

Panofsky on Physics, Politics, and Peace

Pief Remembers

Wolfgang K. H. Panofsky
Springer, New York, 2007. $69.95 (191 pp.). ISBN 978-0-387-69731-4

Wolfgang Kurt Hermann Panofsky (1919–2007), nicknamed "Pief," was a man of small physical stature but one of the intellectual giants of 20th-century experimental physics. His memoir, *Panofsky on Physics, Politics, and Peace: Pief Remembers*, is not an autobiography in the usual sense. It contains little about his family life; instead, it is a personal account of his professional activities—his outstanding scientific research in the early part of his career, his founding and leadership of a great national laboratory, and his extensive work throughout his career advising the government at various levels. The book also has numerous photographs, mostly showing Pief involved in his various activities but also including his wife, Adele, and their five children.

Born in Berlin, Germany, Pief was the son of distinguished art historians. In the early chapters of the book, he discusses his childhood; his family's move to Princeton, New Jersey, in 1934; and his university studies from his days as a 15-year-old freshman at Princeton University to the completion of his PhD in physics at Caltech in 1942. After his work for the war effort at Caltech and the Los Alamos laboratory, he joined the University of California Radiation Laboratory (UCRL) at Berkeley, also known as the Rad Lab, and pursued outstanding particle-physics research. Pief's recollections provide an excellent glimpse into the atmosphere and research directions in the Rad Lab under the leadership of Ernest Lawrence and Luis Alvarez after World War II. They also indicate that Pief, in a short time at Berkeley, became a particle-accelerator expert. As he notes, "at UCRL there was no distinction between particle physicists and accelerator physicists" (page 26). In 1951, the "loyalty oath" imposed by the University of California system prompted Pief to leave Berkeley for Stanford University. Faculty were expected to take an oath of allegiance to the US and California constitutions and disavow membership in the Communist Party. Unfortunately, Pief gives only a brief account of the feelings and considerations that led him to that momentous decision.

The next part of the book is devoted to Pief's work at Stanford prior to his drafting the SLAC proposal. He covers the development of electron linear accelerators (linacs) and their application to a high-quality program of exploratory high-energy physics, with energies on the order of 1 GeV and the beams comprising electrons or photons.

In his fascinating discussion of the development of the SLAC proposal, Pief details many of the scientific, technical, and administrative issues that he encountered before its approval. He describes interacting with the Stanford administration, the physics department, the Atomic Energy Commission, and the outside physics community while, at the same time, working to satisfy the technical requirements of the