

tation, although there have always been mutterings of discontent. But as the formalism won acceptance, it brought along for the ride the "Copenhagen interpretation," a worldview that belongs more to metaphysics than to physics.

One of the postulates of Copenhagen dogma—apparently backed up by John von Neumann's no-hidden-variables theorem—is that no deterministic theory allowing for actual particles moving in well-defined trajectories can be consistent with the formalism. This dictum has been repeatedly challenged, most successfully by David Bohm's work of the early 1950s. This work and its subsequent amplification by others have created a (nonrelativistic) Schrödinger-equation-plus-dynamical-system model, wherein particles and their trajectories are quite "real." True determinism reigns. Amazingly, the Hilbert space formalism is a corollary.

Quantum Mechanics: Historical Contingency and the Copenhagen Hegemony, James T. Cushing's wonderful book, explores this curious situation from a number of viewpoints: physics, philosophy and history. Cushing tells three main stories, one of them fictitious. He recounts the rise of the Copenhagen hegemony, even in the teeth of Albert Einstein's opposition, and of promising beginnings toward deterministic models. He summarizes Bohm's work and the story of its unfair neglect—which is still the general rule. Finally he contrives a quite plausible "alternative history" showing that something very like Bohmian mechanics could have been developed around the time of the celebrated 1927 Solvay Congress. The germinal ideas—and the brains—were all there.

Cushing accomplishes this not through loose narrative but through a marvelously concise exposition that takes full account of the technicalities. Nearly one-fourth of this text consists of appendices that present fully mathematical accounts of the chief points at issue. Cushing is relentless and bracing. He touches on virtually all the issues with pinpoint accuracy and no waste of words.

For the record, Cushing states his lack of partisanship for either the Copenhagen or the deterministic interpretation. The alert reader will note, however, that this is rather like Marc Antony's neutrality with respect to Caesar and Brutus. Clearly Cushing sees in the Copenhagen orthodoxy a substantial amount of wrongheadedness, frequently backed up by hot air. He gives the game away when he notes that, had Bohmian dynamics been available before the Copenhagen doctrine hard-

ened, any subsequent formulation of a Bohr-like *weltanschauung* would have been regarded by the physics community as a contrarian philosophical fidget of no real importance. That things fell out otherwise is Cushing's "historical contingency."

I do have some quibbles. For the sake of his meditations on underdetermination and theory choice, Cushing minimizes important distinctions between the Copenhagen doctrine and Bohm's work. The Copenhagen interpretation is a philosophical gloss on a predictive formalism; Bohmian mechanics, by contrast, is a rigorous mathematical model that entails that formalism. Bohm is to the formalism as Newton is to Kepler's laws, a point that Cushing should have made clear. This is not merely a philosophical point; it has important implications for future work on the foundations of physics, work that, in my view, must take up the problems that were largely sidetracked decades ago as a consequence of Copenhagen *hauteur*. In this context the Copenhagen view is unlikely to lead anywhere. By contrast, Bohm's work and related efforts—they are hard-edged mathematical physics, after all—may very well prove extremely fruitful.

In trying to account for the Copenhagen interpretation, many suggestions have been made. However, some note might have been taken of the role of sheer ambition. It may well be that the Copenhagen School's condemnation-in-advance of any attempt to restore realism and determinism to microphysics is best explained by an insight of Francis Bacon (*The New Organon*, Book I, Aphorism 88): They did it "all for the miserable vainglory of having it believed that whatever has not yet been discovered and comprehended can never be discovered and comprehended hereafter."

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Atoms in Electromagnetic Fields

Claude Cohen-Tannoudji
*World Scientific, River Edge, N.J.,
1994. 670 pp. \$53.00 pb ISBN
981-02-1243-7*

Claude Cohen-Tannoudji has led in the theory of optics as applied to atomic physics over the last 30-odd years. A student of Alfred Kastler—the Nobelist inventor of optical pumping—and of Jean Brossel, his doctoral thesis spelled out the theory relevant to their school. It opened the path

for Cohen-Tannoudji's "dressed atom" approach to diverse applications, culminating recently in the cooling of atomic assemblies to the micro-Kelvin range. The appearance of the present rich collection of his work constitutes an important event.

The book's format, reprints of original papers with appropriate introductions, was selected by the author—eventually—as he recalled how helpful its analogs had been to him. It implies, however, a target audience composed principally of specialists in quantum optics. The book's importance suggests that it might prove useful to a wider audience, a prospect somewhat clouded by various circumstances: Three of the book's 39 papers, originally lectures, occupy about one third of its space. Notably, over one tenth of the book remains in the original French.

Distinguishing features of the author's approach are illustrated by their contrast with Fermi's famous introduction to the quantum theory of radiation (*Rev. Mod. Phys.* **4**, 87, 1932). Whereas Fermi's writings and conversations reflected his assessment of the recipient's readiness to absorb his material—being thus labelled "demagogic" by a common friend—Cohen-Tannoudji's concern appears instead centered on the precision and completeness of his own material and perspective.

The development of intense laser sources through the 1960s required the initial theory of optical pumping to progress beyond its earlier, mainly perturbative, approach to that of Cohen-Tannoudji's own concept of "dressed atoms." This concept, viewing target atoms or molecules as strongly coupled to incident radiation beams, first dealt quite properly with radio-frequencies (section 2), whose intensity minimizes quantum-mechanical aspects, and later with the optical frequencies of laser beams (section 3). Consideration of multiphoton emission and of radiative corrections followed.

Later sections turn to detailed procedures designed to achieve an array of other effects: High-power lasers are used to steer the motion of atoms, whether singly or in whole ensembles. Typically, the dielectric action of a standing-wave field distorts each atom or molecule more strongly at its antinodes than at its nodes. Stimulated emission by resonant light may add to this action, thus trapping atoms or molecules. Viewing this light-atom interaction more simply in terms of conservation of momentum, as an atom absorbs photons from a traveling wave and re-emits them in random directions, one can readily un-

derstand the most familiar approach to the cooling of matter in gas phase.

Macroscopically, such cooling actions amount to quenching the thermal motions along translational degrees of freedom. Attaining lower and lower temperatures implies analogous quenching of smaller energy transfers characteristic of optical spectra and of their fine-and-hyperfine-structures.

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Nuclear and Particle Physics

W. E. Burcham and M. Jobes
Wiley, New York, 1995. 752 pp.
\$59.95 pb ISBN 0-582-45088-8

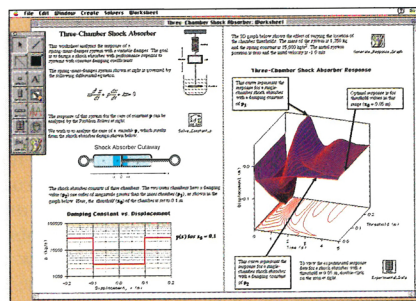
William E. Burcham and M. Jobes, two well-known British physicists, have produced a massive, 752-page treatise on nuclear and particle physics. Both fields are constantly developing as a consequence of new facilities, discoveries and insights. Thus an up-to-date book is always welcome. *Nuclear and Particle Physics* is no exception, even though it has some shortcomings in its nuclear physics coverage. The authors state that the book is written "at two levels." Part I (220 pages) is a "brief summary of the main topics normally appearing in an undergraduate course in nuclear structure physics." Part II, on particle physics, should be useful for graduate students and researchers interested in this field.

The problem with Part I is that there are too many inaccuracies and too few explanations. For instance, the authors state that central forces do not mix states of different angular momenta. But noncentral forces do not do so either; the authors undoubtedly meant to restrict this statement to orbital angular momenta. Further, the basis given for the shell model makes little sense. And is it really true that "direct evidence for the existence of shell structure has come from nuclear reactions"? They are certainly not the source of the best evidence. Also in Part I, formulas appear without bases—for example, the formulas for form factor (3.11), the nuclear g factor (3.21) and total cross section (6.9). The Mössbauer effect is described but not explained. Perhaps the reader is supposed to have seen all this material (with appropriate explanations) earlier, but I believe it does not help the reader to present facts without clues to their origins. Also, there is little differentiation between older and newer physics. There

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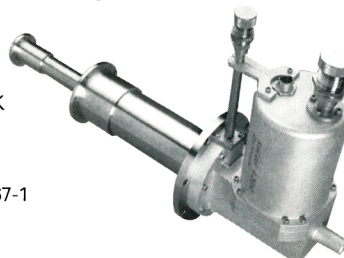
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