

gle section on biogenic particles; otherwise excellent treatments of wet and dry deposition do not mention the ways in which these mechanisms may influence interpretation of ice cores in climate analysis. This urban emphasis is not particularly surprising, given that Seinfeld is chairman of the division of engineering and applied science at Caltech and Pandis is a senior faculty member in the department of chemical engineering at Carnegie Mellon University. Nonetheless, the book

presents a much more balanced, broad and yet still detailed view of atmospheric chemistry and physics than any of its predecessors.

The authors' aim is to provide a rigorous, comprehensive reference on atmospheric chemistry and physics as well as a textbook for use in the atmospheric sciences. They succeed on both accounts. As a reference, the book contains extremely useful updated tables of concentrations and fluxes for sulphur, nitrogen, carbon and halogen

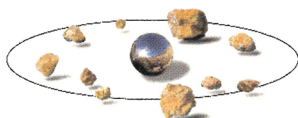
compounds. Extensive reference lists at the end of each chapter provide a roadmap to relevant new literature. The amount of material alone makes it nearly an encyclopedia in its field.

The book is also very well written from a pedagogical point of view. Despite the level of detail, the chapters are surprisingly easy to read. Derivations are done without skipping over dozens of "obvious" intermediate steps, and the resulting final relationships and equations are highlighted with boxes. Problems at the end of the chapters are coded with their level of difficulty. Stimulating and topical examples are interspersed throughout. The major difficulties in using the book as the basis for a single course would be selecting material to omit and getting students over their initial consternation at being confronted with a textbook weighing 2.5 kg.

Like Seurat's masterpiece, *Atmospheric Chemistry and Physics* is a tremendous achievement. It will undoubtedly soon be considered an essential element in the library of students and professionals in the atmospheric sciences.

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Quantum Optics

▶ Marlan O. Scully
and M. Suhail Zubairy
Cambridge U. P., New York, 1997.
630 pp. \$110.00 hc (\$47.95 pb)
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(0-521-43595-1 pb)

When Paul Dirac showed how the quantum theory of radiation accounts for the creation and annihilation of particles (photons) while still describing the wavelike aspects of fields, the theoretical foundations of quantum optics were essentially put in place. The discipline as presently practiced was created by the development of lasers in the 1960s. Efforts to understand the properties of laser radiation vis-à-vis all previously known kinds of light culminated in the quantum theory of optical coherence. Laser theory was formulated both semiclassically and in quantized field theory. New effects such as photon echoes, self-induced transparency and superradiance were discovered, and entire new fields such as nonlinear optics and high-precision spectroscopies were born.

In recent years, concepts of quantum optics have been used in a wide range of fundamentally important experiments. These include tests of Bell's theorem, routes to chaos in lasers and other optical systems, soliton propaga-

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tion, cavity quantum electrodynamics, novel quantum states of light, measurement theory, quantum cryptography and quantum computers, laser cooling and trapping of atoms, and, most recently, the observations of Bose-Einstein condensation made possible by atom cooling and trapping. Many of these developments might have technological implications in addition to their basic scientific value, and the experiments are relatively inexpensive—often of the tabletop variety. Were I asked by a funding agency to suggest a great area to invest in, I would definitely rate quantum optics a “strong buy.”

Good books on the subject exist, but they are relatively few in number. Rodney Loudon's *Quantum Theory of Light* (Oxford U. P., second edition, 1983) immediately comes to mind as a masterpiece of clarity and scholarship. Another notable contribution is, of course, *Optical Coherence and Quantum Optics* by Leonard Mandel and Emil Wolf (Cambridge U. P., 1995), which in over 1100 pages covers just about the entire field and includes chapters on mathematical tools and many hundreds of references to the research literature.

Marlan O. Scully and M. Suhail Zubairy's *Quantum Optics* meets the high standards set by these earlier books and deserves to be ranked with them as best in the field. Scully, the senior author, has been a major figure in quantum optics since the late 1960s, when, with Willis Lamb, he developed a quantum theory of the laser. His recent interests and Zubairy's are clearly reflected here.

The first four chapters develop the theory of the quantized electromagnetic field, coherent states, squeezed states and various distribution functions and include familiar (to quantum optics) examples of the use of first- and second-order field coherence functions. These are followed by 13 chapters on the theory and application of the interaction of light with bound electrons, including the quantum theory of damping and of the laser in both the density-operator and Heisenberg-picture approaches, resonance fluorescence, micromasers, correlated-emission lasing, squeezing in nonlinear optical processes and atom optics. The final four chapters deal with applications of quantum optics to foundational aspects of quantum theory—Bell's theorem, quantum nondemolition measurements and Francon-Chiao interferometry, among other things.

The book is fairly hefty, but mastery of only the first 300 pages or so should enable the graduate student to follow much of the modern research literature

on quantum optics. The problems following each chapter should be valuable in that respect; they are not always simple variants or extensions of the text, and many come with a reference to the research literature to guide or assist the reader.

The presentation is physically motivated and generally clear, although occasionally the syntax might not win the approval of a certain Mrs. Burns (my high school English teacher). Of less interest to Mrs. Burns, but of fundamental importance to quantum optics, is the form of the interaction between an atom and the electromagnetic field. The electric dipole ($\mathbf{r} \cdot \mathbf{E}$) form of the interaction can be obtained by transformation of the minimal coupling ($\mathbf{A} \cdot \mathbf{p}$) form, but is it also necessary to transform wavefunctions? Scully and Zubairy warn the reader that “*wrong* results are obtained for physically measurable quantities . . . if only one of these two transformations is carried out.” Mandel and Wolf, by contrast, do not indicate any need to transform wavefunctions along with operators. The point is that one can express the untransformed Hamiltonian in terms of new canonical variables; in that case it is not necessary to transform wavefunctions, or write a transformed Hamiltonian in terms of the old canonical variables, in which case the wavefunctions must also be transformed. Slightly expanded discussions in either book might have helped to end some of the confusion surrounding this most basic of points. I prefer the treatment of the interaction Hamiltonian by Mandel and Wolf, partly because their list of references is more comprehensive.

Quibbles aside, *Quantum Optics* is very impressive and arguably the best book available for the reader who wants to get to the leading edges of the field in the least amount of time.

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