

Understanding macroscopic motion from a microscopic basis

Statistical Physics and the Atomic Theory of Matter

Stephen G. Brush

356 pp. Princeton U. P., Princeton, N. J., 1983. \$45.00

Reviewed by William K. Wootters

How does one understand the macroscopic properties of matter in terms of its microscopic constituents? This question has been a central one in science since its beginnings and the focus of some very beautiful scientific work. In *Statistical Physics and the Atomic Theory of Matter*, Stephen Brush leads us through three centuries of the effort to answer this question, beginning with Newton's mechanics (because it opened the door to kinetic theory) and Torricelli's experiments on suction, and continuing through Lev Landau's ideas on superfluid helium and Kenneth Wilson's analysis of critical phenomena. What most distinguishes the book from other historical studies of this branch of physics is its scope. Previous books, including an excellent two-volume work by Brush himself, *The Kind of Motion We Call Heat*, take us as far as the advent of quantum mechanics. I am not aware of any book other than this one that goes on to trace the development of the theories of superconductivity and superfluidity, or follows the theory of phase transitions from the work of van der Waals through the relatively recent successes of the lattice gas approach. As we read through this story, we cannot help being reminded how impressive the progress in statistical physics has been since Daniel Bernoulli first used a particle model of a gas to explain why pressure is inversely proportional to volume.

Of course, along with this progress has come a great deal of mathematical sophistication. For better or for worse, Brush has allowed this change in sophistication to cause an inconstancy in the level of the physics in his book. For

example, the chapter on the early development of kinetic theory can be read by anyone who has had two years or so of college physics—the reader even being reminded what it means to say that the momentum vector of one particle is the negative of another. On the other hand, the 30-page section on superfluid helium would be difficult to follow in detail for anyone who was not already familiar with the concept of a collective excitation, or who had not already been introduced to the Feynman path-integral approach to statistical mechanics. It appears that Brush has written the book for a wide range of possible audiences, with the idea that some readers will get more out of it than others. The reader who profits from being told in the earlier chapters what a complex number is, or why pressure, volume and work are related as they are, will have to skip over much in the later chapters on phase transitions and quantum mechanical properties of matter. The book will probably be of most benefit to the physicist who has worked on some aspect of statistical mechanics and would like to learn more about the broader history of the subject or to the graduate student who is just entering the field and would like to have a "map" for finding his way around. Such a reader will find the last chapter useful: It is a collection of opinions from various physicists concerning the likely direction of future research in the field.

Unfortunately there are other reasons why it is helpful to be well versed in physics when reading this book. Typographical errors appear in a number of important equations, and in other places symbols are introduced without being defined. These are only a minor irritation to the reader who knows the physics already, but they create impassable barriers for one who does not.

The book is at least as much about the flow of history as about the physics itself, and one does find many interesting historical connections here. For example, the author discusses at length the thesis, which he endorses, that the

probabilistic assumptions used by James Clerk Maxwell, Ludwig Boltzmann and others paved the way for the acceptance of indeterminism by many of the founders of quantum mechanics. Elements of this argument appeared in *The Kind of Motion We Call Heat*, but the connection with quantum mechanics is now spelled out more explicitly. In the section on superfluidity, Brush focuses on the competition in the 1940s between Landau's theory and the London-Tisza approach, and shows how various subsequent developments, such as the discovery of quantized vortex lines, have derived from or shed light on this competition. Finally let me mention a passage in which a certain historical link takes the reader by surprise. Newton's mechanics allowed one to adopt any force law that worked (say, between two atoms), without having to explain it. Yet some researchers still insisted on following the old Cartesian program of reducing all forces to contact actions. According to Brush, this effort "resulted in curiosities such as the kinetic theory of gravity, the vortex atom, and the virtual-photon-exchange concept of modern quantum electrodynamics."

Other subjects treated in the book include theories of the chemical bond, philosophical aspects of statistical physics, and astronomical applications. There is an extensive bibliography.

One should not read this book expecting to learn statistical mechanics, but for the reader who knows the physics, it is an opportunity to learn some fascinating history. For the researcher in particular, it may be a chance to gain insight into present-day problems by reflecting on the successes and failures of the past.

Quantum Statistics of Linear and Nonlinear Optical Phenomena

Jan Perina

310 pp. Reidel, Boston, 1984. \$71.50

What's new in coherence and quantum optics has been best defined every five

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or six years by the Rochester conferences organized by Leonard Mandel and Emil Wolf. Over the last three conferences, the focus has moved from the pioneering work of R. Hanbury Brown and R. Q. Twiss, Tito Arecchi, Roy Glauber, Mandel and Wolf on photon statistics and coherence of optical sources toward applications of photoelectron counting distributions, neosemiclassical radiation theories, resonance fluorescence, photon antibunching, optical bistability, optical nonlinear dynamics and squeezed states in turn.

Active researchers and graduate students in this field will no longer need to cull background material on statistics in quantum optics from a variety of texts and conference proceedings. Jan Perina's new text offers this resource, while expanding upon his earlier *Coherence of Light* to include the treatment of nonlinear field-matter interactions.

One gains the sense in reading *Quantum Statistics of Linear and Nonlinear Optical Phenomena* that a diligent student of the field and contributor in many branches has shared his private working compendium of facts and figures—complete with details, applications and references. For the informed reader, the book is a delightful guided tour; for the interested and disciplined student, it provides both detail and the best entry into the research literature. Apart from a few texts on photoelectron counting and detection, this represents the first major monograph in the 1980s to deal with the revolutions in quantum optics in this decade. No longer is the field defined by quantum coherence functions, a quantized radiation field, coherent states and the statistics of laser radiation. Detailed modern treatments must include nonclassical states of the radiation field that are referred to as photon antibunching and squeezed states.

The book contains a marvelous collection of background material, careful derivations of the conventional and modern formalisms, and such a wondrous wealth of references to previous work that one may generally disregard the author's apologies for an incomplete bibliography. The dense packing of material makes this monograph best suited as a reference for experts or the basis for a guided tutorial for graduate students. The reader is escorted through conventional topics such as quantized fields, optical correlation, coherent states, photocounting, master equations, turbulent media and quantum statistics in nonlinear interactions. Historical pitfalls such as the definition of an uncertainty principle between the variances of the photon number and phase operators are ad-

ressed directly and the foundation is carefully laid for the recent exciting developments in the creation of squeezed states.

The book reaches early 1983 in its references, and while it anticipates the discoveries of the last four years with discussions and references to theoretical work on squeezed states, it does not cover the more recent and exciting experiments. Nevertheless, it lays the groundwork solidly and, unlike the chapters or texts of the 1970s, this text presents a thoroughly modern view of the field and provides a basis for searching the current literature and conference proceedings to find the latest details. To build on this background one would have to turn to the proceedings of the 1983 Rochester conference and then turn to *Laser Physics III* of the New Zealand summer school series, the Glauber festschrift of 1986 and the proceedings volume of the next Rochester conference, which is but a few short years away.

The comprehensive detail of the text will make it difficult for the general reader to use, but it is the best reference to back such popular introductions as Les Allen and Peter Knight's *Concepts in Quantum Optics*. I recommend the book highly for research libraries and the shelves of quantum optics experts. It will gain a greater following if a second edition incorporating the more recent work on squeezed states, the quantum statistics of optical nonlinear dynamics and other developments is issued within a few years.

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Atoms in Strong Light Fields

N. B. Delone and V. P. Krainov

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 \$49.00

This book constitutes a guided tour through a number of topics in the interaction of strong lasers with atoms. N. S. Delone is a pioneer of experimental multiphoton physics of atoms while V. P. Krainov, a well-known theorist, has made a number of contributions to the theory of intense-field phenomena. The strong fields considered in the book are due to laser beams with intensities up to 10^{14} W/cm² at near-infrared to ultraviolet frequencies. But as the authors aptly point out, radiation that couples two atomic or molecular levels resonantly is already strong at 100 W/cm². Thus the feature that runs through all topics in this book is the nonlinear dependence on the field intensity whatever the precise range of that intensity may be. Strong-field