

resolved problems of interpretation. Moreover Heisenberg holds that no matter how successful the theory has been we must try to go beyond it. He himself has taken a leap by building a unified field theory of elementary "particles." He is still at it: The blackboard in his office is covered with formulas from that theory, which he feels calls for an even greater mathematical ability than his own. This kind of theory, rather than a mere predicting device, is what Heisenberg cherishes.

One of the most intriguing facets of Heisenberg's philosophy is that, like Bertrand Russell's, it is double stranded. Indeed, Heisenberg now leans towards positivism (although he dislikes it), now towards Platonism (in which he takes pleasure). He read Plato as a young man and is probably the only modern scientist to take the *Timaeus* seriously. Thus in connection with his new theory he writes, "The thesis 'In the beginning was symmetry' is surely truer than Democritus's thesis 'In the beginning was the particle.' The elementary particles embody the symmetries, they constitute their simplest representations, but they are a consequence of the symmetries," and, further on, "The elementary particles may be compared to the regular solids in Plato's *Timaeus*. They are the primaeva models [*Urbilder*], the Ideas of matter" (page 326).

A philosopher is likely to take issue with this and other philosophical views aired by Heisenberg here and elsewhere. On the other hand, the historian of science will record (impartially or not) the heuristic stepping stones leading to a scientific theory. And the psychologist of science may study what kinds of heuristic clues trigger certain brains while failing to activate others. The scientist's attitude is again different: What counts for him is not the philosophical pedigree of a scientific theory but the theory itself and its performance in accounting for experience and spurring it. The philosopher is entitled to get annoyed only if an heuristic clue, or crutch, even a fertile one, is counted as evidence for the soundness of the philosophy it may be associated with, or as evidence for the thesis that the given theory confirms that philosophy.

He will be entitled to his discomfort, as one and the same heuristic charmer is apt to trigger different ideas in different minds. In particular the result may backfire. One example, as Einstein told the young Heisenberg, is relativity. Mach's operationalism may have played an heuristic role in the genesis of the theory even though the outcome defeats Mach's philosophy, by focusing on observer-invariant formulas containing transobservational concepts. Another example is Heisenberg's unified field theory of elementary particles. This theory, despite its Platonic inspiration,

might not have displeased Democritus, for its ambition is to account for the basic units that compound matter. Moreover, it might have pleased Einstein.

Whatever your philosophy may be, you must read this book if you are interested not only in net results but also in research programs and in styles of conducting research. This is one of the rare occasions where a genius talks freely, in simple (misleadingly simple) words—without any formulas—with some of his peers and with his readers on some of the trickiest problems of theoretical physics. The book is also a challenge to the young scientists who handle so deftly some of the tools wrought by Heisenberg. He insists that computation is not everything and that calculating should be a means for understanding the deeper patterns beneath the apparent details and beyond the bookkeeping apparatus.

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The reviewer, a professor of philosophy at McGill University, was formerly a professor of theoretical physics. He has worked on relativistic quantum mechanics, nuclear theory, the axiomatic foundations of physics and the philosophy of science.

Quantum Mechanics With Applications

By D. B. Beard, G. B. Beard

333 pp. Allyn and Bacon, Boston, 1969. \$11.50

This book is a revised version of a text on introductory quantum mechanics written by David B. Beard and published several years ago. It is intended for students who have taken courses on intermediate classical mechanics and electromagnetism and who possess more than a casual knowledge of physical optics and the phenomenology of quantum physics.

Indeed, the first four chapters are devoted to a persuasive (if not rigorous) dialectic on the properties of light waves and matter waves wherein the reader is asked constantly to draw upon his previous experience with modulated waves, diffraction and interference. The authors' approach has the merit of emulating the historical development of wave quantum mechanics and distinguishes itself by a very believable presentation of the Schrödinger equation in the context of Feynman path integrals. A credibility gap is opened, however, when we are told in the second chapter that "Heisenberg originally derived quantum mechanics by postulating [the uncertainty relations] as fundamental to all physical measurement," and, in the third, that Robert A. Millikan "quickly confirmed" Albert Einstein's equation for the photoelectric effect. Lapses such as these are probably more

annoying than they are consequential, but, in this fifth decade of quantum mechanics, it is trifles that make perfection.

The middle chapters are the expected ones on one-dimensional motion, the WKB approximation, elementary perturbation theory, and central-field motion. The discussion here is adequate and not a little influenced by the well known text by Linus Pauling and E. Bright Wilson. But once again there are the lapses, this time centering about the authors' somewhat cavalier attitude toward the uncertainty relations. Of most significance in this regard are the incorrectly calculated transmission coefficient for a particle incident upon a potential step with energy less than the step height and the statement that " $\langle xp_x \rangle$ " is a meaningless symbol anyway, because x and p_x cannot be measured simultaneously with infinite precision, which stands in defiance of the quantum-mechanical virial theorem.

The last six chapters of the book are concerned with applications, atomic and molecular structure, metals, scattering phenomena and nuclei, and contain much useful information to complement the primarily theoretical sections. These chapters are done with care and are eclectic enough to satisfy the needs of a variety of possible one-term courses on quantum mechanics. The same can be said of the book itself, if one is inclined to regard the blemishes noted above only as moles in a generally lucid introduction.

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Solenoid Magnet Design: The Magnetic and Mechanical Aspects of Resistive and Superconducting Systems

By D. Bruce Montgomery

312 pp. Interscience, New York, 1969. \$13.95

Many readers may doubt that enough useful information is available about solenoids to fill 312 pages. They will be agreeably surprised to find that *Solenoid Magnet Design* is packed with cogent analysis and design instruction. Although it is written as a handbook for solenoid designers, its author has managed to make his material interesting, and one reads this book with pleasure.

D. Bruce Montgomery was one of the founders of the National Magnet Laboratory in Cambridge, Mass. There, more than 20 solenoid magnets produce high magnetic-flux densities, in some cases reaching over 200 kilogauss. The power supplies available add up to 10 megawatts; the adjacent Charles River

provides the coolant. Descriptions of the laboratory are included in Montgomery's book.

This is indeed a handbook for the designer. It tells the reader how to design for the most field per watt, for the highest possible field and for the most uniform field. Problems of design, of mechanical construction and of cooling are treated in some detail. There is a chapter on superconducting solenoids and a little discussion of "noncircular" coils. The mathematical sections are presented simply and clearly and need not frighten a beginning graduate student. The author follows admirably his stated philosophy that "it is unwise to complicate (unnecessarily) the analysis of a given problem."

The early chapters treat, in sequence, solenoids of uniform and nonuniform current density. Many elegant little theorems are derived. For example, it is shown that the solenoid that gives the highest field per watt of power consumption has an outer diameter three times its inner diameter and a length twice its inner diameter. The discussion of nonuniform current distributions leads into presentation of the disk solenoids evolved by Francis Bitter and now in routine use at the National Magnet Laboratory. Montgomery devotes appropriate attention to materials of construction and to methods for restraining the magnetic forces from destroying the magnet coil.

The chapter on superconducting solenoids was written just before an impor-

tant development took place and so is not up to date. It includes a clear discussion of the conventional methods for stabilization of type II superconductors. But, as the book went to press, work was beginning on inherently stable superconductors that consist of many fine transposed strands of superconductor imbedded in a copper matrix. The success of this approach can be expected to revolutionize the superconducting-magnet art. Nevertheless the author's treatment of superconducting-coil design will be useful for some time.

The book concludes with a chapter on "field analysis," treating the distribution of field in and around solenoids and describing methods for producing fields of any desired homogeneity over any required volume. The chapter includes 25 pages of computer printout, for a variety of solenoid geometries, of several parameters that characterize field patterns.

I was slightly disappointed to find no discussion of the effects of iron shields. An intriguing theorem, attributed to someone at the National Magnet Laboratory, says that iron is best used for increasing solenoid fields when it is all completely saturated, and one might have hoped that Montgomery would enlarge upon this. But, in general, this is a satisfying and definitive work. If the reader has occasion to build solenoid magnets, this book should be on his shelves.

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Electronic and Ionic Impact Phenomena, Vols. 1 and 2: Collision of Electrons with Atoms

By H. S. W. Massey, E. H. S. Burhop
1335 pp. Oxford U. P., Oxford, 1969.
\$32.00

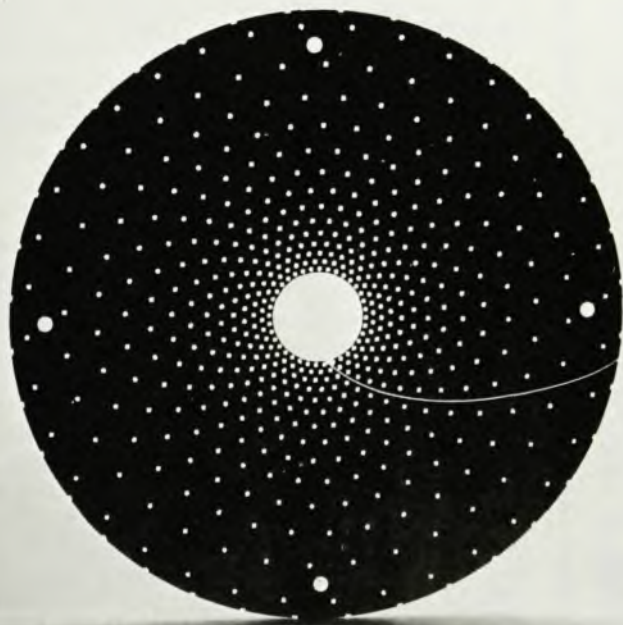
These two volumes by Sir Harrie Massey and E. H. S. Burhop will undoubtedly become an asset for a wide range of scientists. Theoreticians and experimentalists engaged in continuously refining our knowledge of electron impact cross sections, plasma physicists, atmospheric scientists and astrophysicists who urgently need these cross sections will all find this book a treasure house in which to look for very authoritative information.

This reliability comes from the authors' many pioneering works in electron collisions. Under Massey's leadership, University College London has remained one of the finest centers of research in atomic and molecular physics. In fact, no one else is better qualified to write this book.

Volume 1 is devoted to the collisions of electrons with atoms. The first part (chapters 1-5, covering 372 pages) contains descriptions of the various experimental methods used for determining the electron-impact cross sections. A chapter for each of the collision processes (namely, momentum transfer or ionization), starts with a very lucid and up-to-date discussion of the various laboratory techniques available for their measurement. Naturally, such recent developments as techniques for measuring the cross sections for the excited or ionized atoms have received their fair share of discussion.

Nowhere is the description of the experimental methods made boring by the excessive enumeration of details. The emphasis is on clearly explaining the principles of measurements. To this end, detailed and explanatory block diagrams of the experimental setup are used frequently. The observational method is followed by detailed review of the results obtained, with a stress on the interpretation of the data rather than on their cataloging.

The latter half of the first volume (chapters 6-9, covering 291 pages) deals with theoretical models for describing cross sections. The authors have prefaced their discussion by a very illuminating description of the systematics of the theoretical problem, which will considerably help the readers to digest easily the succeeding material. The semi-empirical "optical-model" approach to elastic scattering is treated at full length as is the scattering problem in terms of the detailed atomic structure, which includes the existence of the atomic states. This latter



"Bitter plate," that is, a single-turn coil, for a 1.88 MW magnet, which generates 123 kOe; plate has a 2.54 cm internal diameter. The slit is curved to avoid intersecting any cooling holes. (From *Solenoid Magnet Design*.)