

Nuclear physics, conveyed enthusiastically

Theoretical Nuclear Physics Vol. 1: Nuclear Structure

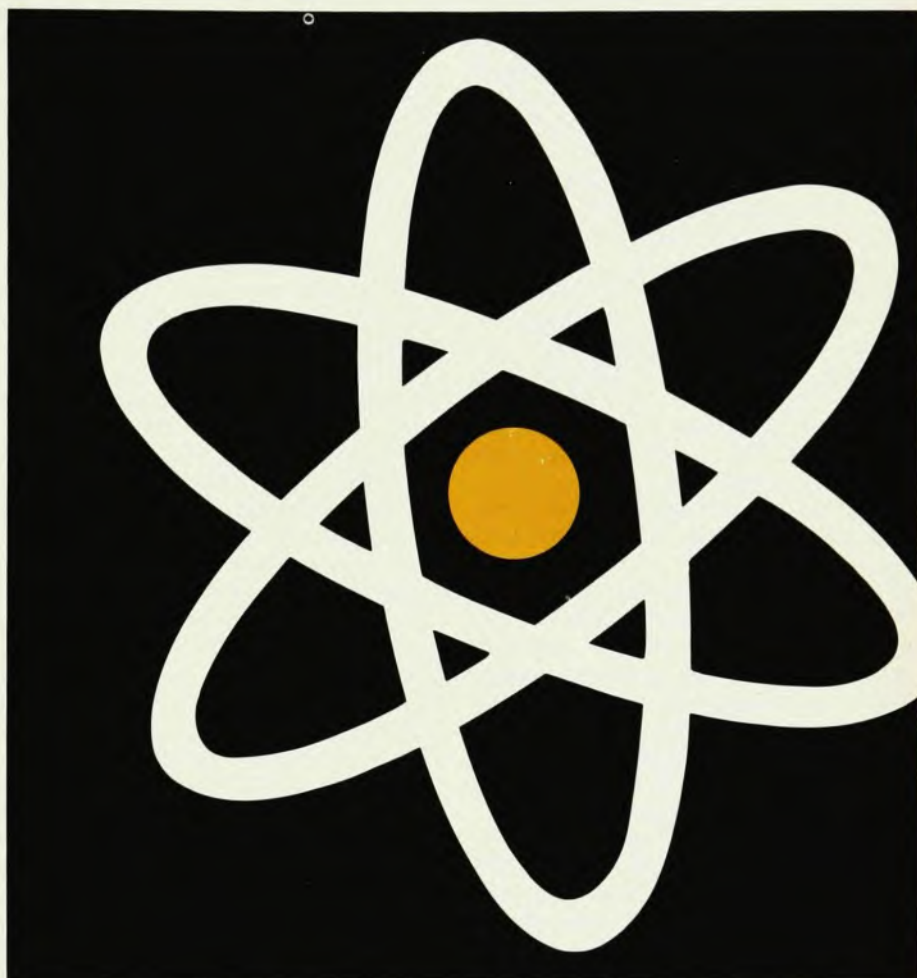
Amos deShalit, Herman Feshbach
979 pp. Wiley, New York,
1974. \$27.50

Reviewed by Eric Sheldon

"It's beautiful! I'm so glad you told me this. You made me understand the problem much better."—words of a typical conversation by Amos deShalit, as recalled by Victor Weisskopf and as applied frequently to so much of theoretical nuclear physics, might very aptly be applied again to his last work, *Theoretical Nuclear Physics*, written jointly with Herman Feshbach and now published, nearly five years after deShalit's untimely death at the age of 42.

This book will serve as an enduring tribute and legacy. It was first conceived in 1960, but due to the pressure of other commitments its authors could not begin the actual writing until 1965. By the time of deShalit's death most of the manuscript for the first volume, which now runs to almost 1000 printed pages, had been compiled. The task of completing the text and steering it through publication devolved to Feshbach. Of the second volume, only a small preliminary portion had been started; Feshbach has meanwhile completed about one-third, with publication scheduled for 1976. The joint volumes will together constitute a remarkably comprehensive survey of theoretical nuclear physics by two of its leading practitioners.

Each author had already collaborated in the writing of widely used and highly regarded textbooks: In 1963 Amos deShalit co-authored *Nuclear Shell Theory* with Igal Talmi; Herman Feshbach and Philip M. Morse wrote the two-volume treatise, *Methods of Theoretical Physics* which appeared in 1953. Both enjoyed a prominent and distinguished international reputation in nuclear physics: deShalit as an experimentalist and theoretician with a particular zest for the shell-model and unified-model interpretation of nuclear structure characteristics, while Feshbach as a multi-faceted theoretician has been particularly closely involved with the elucidation of nuclear reaction and interaction processes. Their respective



fields of specialization thus admirably span the purview of the two volumes in the present work.

The first volume, after an introductory chapter to establish the foundation via a general overview of such nuclear characteristics as size, mass, force, energy and interaction properties leading to basic concepts of structure and reactions, proceeds to build up the towering edifice of nuclear configuration and structure in a sequence of progressive complexity (and, fittingly, devotes its two concluding chapters to a detailed examination of decay!). The development is pedagogically persuasive: first the nucleus is presented as a statistical ensemble of nucleons making up a Fermi fluid; then the generalization to nuclear matter makes plausible the validity of the independent-particle approximation.

Thus, thanks to a generous quirk of

nature, it becomes possible to describe finite nuclei in terms of the independent motion of particles in a central "average" potential, dominated by the influence of the Pauli exclusion principle. An appropriate and simple choice of potential is one intermediate between an harmonic oscillator (applicable to light nuclei) and a rectangular well (applicable to heavy nuclei), having a judicious admixture of a fairly strong spin-orbit attraction to provide a basis for a shell-model treatment of the principal nuclear characteristics, and in particular to account for the "magic number" of nucleons associated with striking discontinuities in the properties of nuclei. The obvious, if complicated, next step is to extend this treatment to the generalized shell model, in which a deformed potential is used to represent the nonspherical (axially symmetric and nonsymmetric) nuclei, and then via a

consideration of collective rotational and vibrational modes of motion to arrive at the unified model, in which single-particle shell aspects are combined with multiparticle cooperative aspects of aggregate nucleon behavior.

The link between descriptions of shell-model and collective motion with the underlying nuclear forces furnishes the substance of the next presentation, in which the authors undertake an exhaustive survey of the recent advances in the handling of multinucleon systems. From second quantization, through the time-dependent Hartree-Fock method, the Tamm-Dancoff and random-phase approximations and the Bogoliubov-Valatin transformation, the superfluid model and Bardeen-Cooper-Schrieffer superconductivity theory, the linked-cluster expansion, Bethe-Goldstone equation, the self-consistent Hartree-Fock approach and Brueckner theory, the presentation leads to a microscopic examination of effective interactions. How nuclear structure relates to nuclear transitions is explored in the two final chapters of this volume, which respectively deal with electromagnetic (radiative) transitions and weak-interaction (beta-decay transition) processes. The study of weak interactions is carried through to include not only beta-decay and electron capture, together with the attendant considerations of interaction modes and parity non-conservation, but also to embrace muon decay and other elementary-particle transition processes. In a commendably up-to-date exposition, the treatment includes considerations of the conserved-vector-current theory and the partially-conserved-axial-vector-current theory, second-class currents, PC-violation and time-reversal invariance. An appendix presents the mathematical and formal adjuncts to some of the material utilized throughout the book. There is also an extensive bibliography, listing general and specific references ranging up through 1973.

The second volume will aim to elucidate the nature of nuclear dynamics as revealed by nuclear binding and reaction characteristics. It will in the first place deal with nuclear forces, their origins, effects, manifestations and attributes in three-body and four-body bound systems; in the second place, it will examine the entire gamut of nuclear reactions, from weak interactions to heavy-ion processes. If the treatment is as detailed and comprehensive as in this substantial first volume, a very complete account of the present status of theoretical nuclear physics and its trends will have been rendered.

The coverage in this first volume is intermediate between that of other recent major texts, such as *Nuclear Structure, Vol. 1: Single-Particle Mo-*

tion by Aage Bohr and Ben R. Mottelson (1969), and the very thorough three-volume *Nuclear Theory* by Judah M. Eisenberg and Walter Greiner (1970-72). It is doubtful whether, despite the publisher's claim, it will ever altogether replace the elegant, time-honored (if dated) work, *Theoretical Nuclear Physics* by John M. Blatt and Victor F. Weisskopf (1953), but it will certainly supplement it admirably, and worthily take up an adjoining space on the bookshelves of practically very active or aspiring nuclear theoretician. It should lend itself rather well to discerning use as an authoritative reference text and a stimulating, instructive, if perhaps somewhat massive, teaching text in advanced graduate courses for theoretical nuclear physics and nuclear-engineering students.

My highly favorable impression of this scholarly work was dimmed slightly by the occurrence of many minor printing blemishes, which have persisted despite the evident care lavished by the authors and publisher on the production of this book. It is to be hoped that they will be rectified in subsequent printings and that some un-English mannerisms in deShalit's style in certain passages will be revised (to say nothing of Feshbach's recurrent use of the term "nonparity conservation," which might perhaps be dismissed as "nonarrant sense"). A few important topics have been omitted, among them a discussion of level densities in the statistical model, and the seniority scheme and SU(3) group-theoretical classification system in the shell model. Greater emphasis in the collective-model development might have been placed on the variable moment-of-inertia (VMI) approach, and perhaps on the precursors to the 1953 formulation by Bohr and Mottelson of nuclear rotational/vibrational theory (such as the 1938 Teller-Wheeler discussion of nuclear rotation, the 1941 consideration of surface vibrations and rotations in nuclei by Flüge, the 1943 Guggenheimer investigation of rotational levels and the 1949 survey by Preiswerk of nuclear levels that lent themselves to interpretation in terms of a rotational nuclear model). For pedagogic use, it is regrettable that there are no numerical problems at the ends of chapters.

On the other hand, the well-chosen selection of illustrative examples and challenging problems interspersed within the text is illuminating in the extreme. The authors place their insight at the service of the reader and succeed not only in clarifying the obscure, justifying the assumed, and interrelating the fragmented, but in conveying their contagious enthusiasm for the subject to the responsive student. There is an enchantment to theoretical nuclear physics that transcends the anguish of trying

to master its complexities, and this book most ably underlines this affirmation.

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Thermoelectricity in Metals and Alloys

R. D. Barnard

259 pp. Halsted, New York, 1973.
\$21.00

Of all the electronic and thermal transport properties in metals and alloys, the thermoelectric power is perhaps the most difficult to understand and interpret because it is so sensitive to such a broad range of perturbing phenomena. Even very slight changes in the Fermi surface or the character of the electron-scattering processes can drastically alter the sign, magnitude and temperature dependence of the experimentally measured thermopower. It is not surprising, therefore, that, to date, only two authors have attempted to treat this problem in a general systematic way that is accessible to graduate students and others who are learning the field. *Thermoelectricity in Metals and Alloys* by R. D. Barnard is the recent contribution to the field; the first was *Thermoelectricity, An Introduction to the Principles* by D. K. C. MacDonald (Wiley, 1962).

The structure of Barnard's book is quite similar to the earlier work and includes brief introductory chapters on the phenomenology and some experimental techniques of thermopower measurement. In the chapters on theory, however, Barnard has far surpassed the MacDonald work by fleshing out the basic electron transport, electron scattering and phonon-scattering theory with a delightfully consistent approach to the mathematics, roughly on the level of John Ziman's *Theory of Metals*. His treatment of theory stresses physical insight rather than formalism and very seldom sends the reader to advanced texts on solid-state theory. These central chapters treat the basic theory of the processes involved in the thermoelectric power of solid and liquid metals and alloys. Barnard's chapter on diffusion thermoelectricity is a sort of interfacing transition that eases the reader into the intricate maze of experimentally