

notation. The important point is that, in presenting the mathematical development of subsequent chapters, he omits no important step "for the reader to work out by himself." The meaning and the significance of the mathematical conclusions are always discussed, often with examples.

The technical matter is so advanced throughout most of the text that one cannot read through once and comprehend completely—but it is clear that the author has done everything he could to guide the reader carefully through his arguments. There are surprising and delightful insights that clarify things you thought you already knew. For this reason, the book is very useful as a review for people who once were familiar with the material but who have become rusty. In addition it would serve as an excellent textbook at the graduate level, provided the lecturer supplies problems and review questions.

The first part of the book deals with the purely physical aspects of how sound behaves in rooms. Starting with a chapter on sound propagating freely in gases, the author introduces next the concept of reflection(s) at a single wall; he then goes on to consider multiple reflections within an enclosure: first in terms of wave theory and then in terms of geometrical acoustics. The first half of the book ends with an ingenious discussion of reverberation in diffuse sound fields, and a description of the nature of sound absorption and absorbers.

The last part of the book introduces the subjective aspects of the perception of sound fields: the perceptibility of single reflections, either as desired early reflections or undesired echoes, the perception of time-sequences of reflections, the perception of "subjective" reverberation time, and the "spaciousness" of the sound field. The book concludes with chapters on design considerations and procedures (how the subjective demands of the listener can be reconciled with the physical laws governing sound in rooms), and the related use of electroacoustical installations, either to enhance speech intelligibility or (on more treacherous ground!) to modify the "musical acoustics" of an auditorium.

Both in his sensibly written introduction and throughout the text where the physics of room acoustics confronts the esthetics of room acoustics, Kuttruff draws a nice balance, giving each its due; he also makes it clear why the design of rooms for hearing is usually a series of compromises among requirements that are often compelling and conflicting.

Having said so much, however, I found myself wishing for one more step in the account of the design process. While our laboratory and computer studies may give us tentative answers to

such questions, for example, as to whether lateral reflections are preferable to overhead reflections in a concert hall, they do not really tell us *how much* preferable! In spite of our recent gains in room acoustics, the acoustical consultant often finds himself "designing by the seat of the pants" when the recommendation that he knows is safe turns out to conflict with a firm desire on the part of the architect. The essential flavor of contemporary consulting in room acoustics is missing from the book. In all fairness, however, this flavor is not readily brought out in the technical literature, and few authors have tried to do it justice. This aspect of room acoustics remains an important, but probably indescribable, part of the state of the art.

As for the production of the book, it is well made, and there are very few misprints. The table-of-contents and index are clear and useful—all contributing to a most satisfying and valuable volume.

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Principles and Applications of Magnetic Cooling

R. P. Hudson

230 pp. Elsevier, New York, 1972. \$20.75

By 1968, four years after P. Das *et al.* [*Low Temperature Physics LT9* (Plenum Press, New York 1965)] had demonstrated that a closed-cycle refrigerator could be operated with a dilute solution of $\text{He}^3\text{-He}^4$, the minimum temperature had been pushed to 10 mK and the dilution refrigerator had supplanted adiabatic demagnetization as a refrigeration technique. Almost a decade lower in temperature was obtained shortly thereafter by coupling a Pomeranchuk cell to a dilution refrigerator, and it was with such an apparatus that D. D. Osheroff *et al.* [*Phys. Rev. Letters* **29**, 920 (1972)] discovered the A and B transitions in liquid He^3 . The prospect of experimental riches that this work uncovered made the convenient access to temperatures from 10 mK to the submillikelvin region a *desideratum*. The Pomeranchuk cell has serious limitations as a refrigerator, and the old standby CMN (cerous magnesium nitrate) covers the same temperature range $T^* = 2$ or 2.5

mK—depending on whose temperature scale you choose—which is not quite low enough. Physicists at several institutions are either developing adiabatic nuclear demagnetization or are searching for electronic paramagnets more dilute than CMN. This concise book by Ralph Hudson appears on the scene at a most opportune time because of the renewed interest in magnetic cooling.

Principles and Applications of Magnetic Cooling is intended to serve, according to the author, "as a shop manual for the uninitiated" or "would be of most use to the physics undergraduate as he embarks on specialized studies or to a research student who has chosen to enter the field of cryogenics." The author devotes a chapter to the standard thermodynamic introduction, and then proceeds to give a good introduction to electronic paramagnetism. An elaboration of some of the ideas in the main text are made in several appendices. There is a short chapter on experimental procedures, followed by one on the properties of several paramagnetic salts. The final chapter, dealing with nuclear magnetism, presents an introduction to nuclear orientation and its application to the thermometry, then proceeds to a discussion of nuclear cooling with illustrations of two cryostats in which the technique has been used successfully. A description of the nuclear magnetic resonance thermometer in the text and last appendix complete the 216 pages of text. A list of references follows with one as current as the year of publication, 1972. As with all of Hudson's writing, this too is well styled; there is, however, a slight impression of *déjà vu*.

Hudson, chief of the heat division of the National Bureau of Standards, has made the study of paramagnetic salts his métier and has been a principal contributor to the thermodynamic temperature scale based on the susceptibility of CMN. I am somewhat astonished, then, at the short shrift given the Casimir-du Pré technique for determining the zero-field heat capacity, particularly as Hudson and colleagues have used the method. It is doubtful that the uninitiated would detect in the short sentence on page 11 the basis for an extremely powerful technique. Perplexing also is the decision to devote more than two pages to a description of the vibrating magnetometer but no mention is made of the superconducting fluxmeter. H. B. G. Casimir's classic monograph served as the model for this book. It and the several review articles that have appeared on paramagnetic salts and adiabatic demagnetization have been written by physicists who have been primarily interested in the properties of the salts, not in the salt as a refrigeration device.

There has yet to appear an article or a book that shows how to calculate a demagnetization schedule when equilibrium between the salt (or nuclear stage) is long compared to the rate at which the field is reduced. Although simple and straightforward, a calculation on the devastating effect of irreversibility would have been of value. As an experimentalist who has been fighting the battle of irreversibility for years, I may be overly sensitive to these omissions. Had the material been included, it would certainly have enhanced greatly the value of the book to the initiated as well as the tyro. Nonetheless, graduate students will find much of value in the book; at the price, I doubt that many will find it essential for their bookshelf.

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A Survey of Hidden-Variables Theories

F. J. Belinfante

354 pp. Pergamon, New York,
1973. \$24.00

Within the literature on the foundations of quantum mechanics there is a subset, known as "hidden-variable" theory, which attempts a more detailed description of physical processes than the statistical description given by quantum mechanics (QM). Fredrick J. Belinfante has provided a unified critical review of that loosely structured body of literature, complemented in part by original contributions.

At the outset he clarifies the motivations for such investigations, thereby helping to dispel the misconception that so-called hidden-variable (HV) theories are opposed to standard quantum theory. Firstly, there arises the conjecture that if similarly prepared systems characterized by identical

quantum states nevertheless yield different measurement results, then the systems might differ in some respects that QM does not describe. There is the question of whether or not QM is compatible with deterministic laws at a deeper level. There is the hope that these studies may lead to advances in fundamental physics, but even if this hope is not realized they have already led to a clearer understanding of some subtle aspects of QM. Finally there is a polemic reason—to refute those who dogmatically maintained HV theories to be impossible.

Belinfante divides the book into three parts: theories of the *first kind*, in which an equilibrium distribution of the hidden variables leads to the statistical predictions of QM; theories of the *second kind*, in which additional physically reasonable conditions are imposed that may lead to differences from QM, and theories of the *zeroth kind*, which are defined by a self-contradictory set of postulates and so are impossible. First among theories of the *zeroth kind* was the work of von Neumann, and the inadequacy of his argument against HV is made embarrassingly obvious.

Belinfante also does a good job of exposing the physical content of the difficult mathematical theorems by A. M. Gleason and by S. Kochen and E. P. Specker. Suppose we measure a dynamical variable A , with corresponding eigenvalues $|a_i|$ and eigenvectors $|\phi_i|$. QM does not predict which particular result will occur in a single measurement. However we may suppose that the result $A = a_n$ is determined, in principle, by a function $n = n(\psi, \xi, |\phi_i|)$, which may depend in the most general case on the state vector ψ , the hidden-variables ξ , and the set of possible states $|\phi_i|$ among which the measurement is capable of distinguishing unambiguously. Now if there are degenerate eigenvalues, the set $|\phi_i|$ is not uniquely specified, and one would like the theory to be invariant under any linear transformation among degenerate eigenvec-

tors. However that is not always possible, according to the above mentioned theorems. Physically, this implies that the result obtained in a measurement of A may depend upon the detailed nature of the measuring apparatus, that is, upon how it resolves the degeneracy. In the words of Belinfante, HV cannot predict what "is" but only what "would be found" in a specific experiment. The extent to which quantum phenomena are dependent on the measuring apparatus has been debated inconclusively since the beginning of QM, and is now being partially clarified through the study of HV.

Complementary to the discussion of general theorems is the study of particular models. The original theory of the *first kind* was developed by David Bohm in 1951. In it the particles are governed by classical mechanics but with an additional quantum potential

$$U = -\hbar^2/2m \nabla^2 R/R$$

where $R = |\psi|$ is the modulus of the wave function. Other models are based upon the "polychotomic algorithm" of N. Wiener and A. Siegel. In addition to the usual state vector ψ , there is assumed to be a HV vector Ξ in the same Hilbert space. These can be expanded in terms of the eigenvectors of the observable being measured: $\psi = \sum c_i \phi_i$, $\Xi = \sum \xi_i \phi_i$; and the result of the measurement will be eigenvalue a_n , where n is the index of the largest ratio $|c_i/\xi_i|$. A "canonical" distribution of Ξ leads to the usual probability distribution for a_n , $|\langle \phi_n | \psi \rangle|^2$. Belinfante presents some previously unpublished calculations of measurable differences between QM and the polychotomic algorithm in certain experiments with polarized light for which a non-equilibrium distribution of Ξ (if it exists) is to be expected.

In any interpretation of QM that assumes the state vector to be a complete description of an individual system, one must postulate that a measurement yielding the eigenvalue a_n also "reduces" the state vector from ψ to the eigen-

