Book Reviews

Experimental Neutron Thermalization. By P. A. Egelstaff and M. J. Poole. Pergamon Press (1969). 339 pp. $17.50.

This excellent book presents an account of coordinated theoretical and experimental work on slow neutron scattering and neutron thermalization. The necessity for the close interweaving of theory and experiment stems, as the preface states, from the impracticability of measuring thermal neutron cross sections over the ranges of energy and momentum transfer needed in reactor applications. Therefore, reactor physics quantities such as energy transfer cross sections for thermal neutrons must be calculated. To do this correctly requires models which express how the scattering depends on the dynamics of the motions of thermally excited atoms bound in the moderators.

Egelstaff and his collaborators have used the exact Van Hove formalism for slow neutron scattering[1] to guide the construction of their models. The Van Hove method is particularly useful for condensed matter where detailed knowledge of atom dynamics is lacking. In it the scattering cross section is expressed as a space-time Fourier transform of functions which show how atom positions, or atom velocities, are correlated over times of the order of those required by a slow neutron to traverse a scattering center. This book describes two methods for obtaining realistic approximations to these correlation functions. One method employs approximate forms for the velocity-time correlation and the other shows how the correlation function can be deduced directly from measured scattering data. An important part of the book is the chapters which evaluate the scattering models by comparing calculated results with deductions from scattering data.

The theoretical part begins with an excellent discussion of elementary scattering theory, followed by a very good treatment of the important features of the Van Hove theory. The physical principles are clearly expressed and the reader is given a good basis for understanding how the scattering data are used to develop models. The chapters describing experimental techniques are clearly written with adequate detail for the purposes of this book. These cover first the measurement of neutron energies and differential scattering cross sections. The last four chapters deal with techniques for measuring scalar spectra, angular spectra, time-dependent spectra, and spectra in lattices. Included in these chapters are evaluations of scattering models in terms of the spectral measurements. The material will assist the reader to identify situations where it should be important to have a model which correctly calculates moderator scattering.

At the end of the book is a useful Appendix by Schofield which gives the transport theory and diffusion approximations which employ the scattering kernels which are the concern of the book.

Because this book focuses on methods developed by Egelstaff and his collaborators, there is, understandably, limited discussion of procedures emphasized by other workers in this field. In particular, this book gives rather little attention to the formalism of Zemach and Glauber[2] which is particularly useful when the Hamiltonian for a system is known well enough to permit a detailed calculation of the dynamics of the atom motions. It is true, also, that the experimental part emphasizes the methods and equipment which these writers have found to be most useful. This concentration on the Egelstaff method is reflected, also, in the references. They cover the literature associated with his approach but do not everywhere reflect the full scope of work in the field. In this regard the book by Parks et al.[3] is more complete, although less digestible. However, as the preface states, a comprehensive treatment was not intended. The book does stand as an impressive account of the expert application of basic physics to the problem of calculating the behavior of thermal neutrons in reactors.

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June 12, 1972

About the Reviewer: Since 1970, H. L. McMurry has been Supervisor of the Reactor Analysis Section of Aerojet Nuclear Company. From 1958-70, he was concerned with the theoretical analysis of slow neutron scattering measurements being carried out using neutron beams from the MTR. Prior to 1958, he worked on reactor physics problems important to the operation of the Materials Testing Reactor.

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[1] L. VAN HOVE, *Phys. Rev.*, **95**, 249 (1954).

[2] A. C. ZEMACH and R. J. GLAUBER, *Phys. Rev.*, **101**, 118 (1956).

[3] D. E. PARKS, M. S. NELKIN, J. R. BEYSTER, and N. F. WIKNER, *Slow Neutron Scattering and Thermalization*, W. A. Benjamin Company, New York (1970).

A First Course in Turbulence. By H. Tennekes and J. L. Lumley. The MIT Press, Cambridge, Massachusetts (1972). 300 pp. $12.50.

This book attacks a very real "closure" problem in turbulence theory faced by all newcomers to the field: the gap in coverage of turbulence theory between introductory texts in fluid dynamics and the sophisticated treatment found in advanced texts, monographs, and the literature. Turbulence has been studied for somewhat longer than a century and yet it is still one of the major unsolved problems of classical physics. Consequently, the literature on turbulence extends from purely empirical correlations of data to complicated mathematical analyses. Even though empirical correlations are often entirely adequate for design purposes (provided some care is used in their application), it is clear that a more fundamental approach is required in many situations. For instance, the friction factor for long, smooth pipes, far from the entrance region, is known to better than ±5% but the heat-transfer coefficient under similar conditions is only known to ±40%. At the other extreme the most extensive body of theoretical results is for homogeneous, isotropic turbulence for which there is neither mean strain nor production of turbulence energy, two factors of great importance in most engineering applications. Often decades elapse between the initial publications of a theoretical result and the realization that there is a fundamental deficiency in the analysis. An attempt to prepare an introductory text which addresses itself to the turbulence problem, presents a balanced view of the whole and omits outdated theories is indeed a formidable task.

In developing the material in this book, the authors chose to emphasize ideas and concepts concerning the physics of turbulence because in so many instances the successful solution to a problem "depends on the inspiration involved in making the crucial assumption." In order to arrive at a situation where physical concepts can be introduced, the authors make extensive use of dimensional analysis and similarity laws, which, after introduction of appropriate length and velocity scales, often reduce the equations of motion to be tractable form. Although Cartesian tensor notation is used, mathematical details are kept to a minimum and often a solution is given without derivation. Reference to experimental studies is minimal, being largely restricted to mentioning values for numerical coefficients which give reasonably good representation of the experimental data.

The first chapter begins with a definition of the turbulence syndrome: turbulence is associated with large Reynolds numbers, is diffusive, rotational, three dimensional, and dissipative. This is followed by brief discussions of dimensional analysis, asymptotic invariance and local invariance, techniques used to obtain specific results under appropriate circumstances. The chapter concludes with the introduction of various scales (length, time, and velocity), which characterize turbulent flows.

The second chapter is concerned with the turbulent transport of momentum and heat. Of particular merit is the thorough discussion of mixing length theories, the reasons why they work so well in some cases and most importantly the limitations of such theories.

Dynamics of turbulence is treated in the third chapter starting with an analysis of the kinetic energy of the mean and turbulent motion in which it is shown that the energy exchange between the mean flow and the turbulence is governed by the dynamics of large eddies; since dissipation occurs mainly at small scales, this leads to the implication that energy must be transferred from large scales to small scales of motion. Finally, vorticity dynamics is discussed in some detail since fluctuating vorticity is the principal feature that distinguishes turbulence from other random fluid motions.

Chapters 4 and 5 discuss boundary-free shear flows (jets, wakes, and mixing layers) and wall-bounded shear flows (pipe and channel flows, planetary boundary layers, and turbulent boundary layers). These flows offer ample opportunity to expand on the notions of dimensional analysis, asymptotic invariance and self-preservation (local invariance) introduced in Chap. 1. The treatment is very well balanced with discussion of the physics of what is occurring intermixed with analysis in a most effective manner.

Chapter 6 is an introduction to mathematical tools required in the statistical description of turbulence. Although brief, topics considered include the probability density, Fourier transforms and characteristic functions, correlation functions and spectra, and the central limit theorem. The treatment is largely expository with suitable drawings illustrating the different concepts.

In Chapter 7, turbulent transport is introduced by considering the case of homogeneous, stationary turbulence. Although this is a rather unrealistic case (because turbulence cannot be maintained without mean shear), it does permit a simplified discussion of the problems involved in determination of the probability density of the Lagrangian velocity and the Lagrangian integral scale when only their Eulerian counterparts are readily accessible to experimental measurement. This analysis leads naturally to brief discussions of transport in uniform shear flows and longitudinal dispersion in channel flow. Chapter 7 then turns to the problem of the dispersion of contaminants (smoke, salinity, heat), including the interaction of molecular and turbulent transport. Flows considered include both those characterized by pure steady strain as well as self-preserving, inhomogeneous statistically steady flows such as grid generated turbulence. Application of these techniques to other self-preserving flows such as jets, wakes, plumes, and boundary layers is briefly discussed.

Finally, Chap. 8 examines the spectral dynamics of turbulent flows with particular emphasis on the way "eddies" of different size exchange energy with each other. After discussing one- and three-dimensional spectra, isotropic relations are introduced. The energy cascade discussion is particularly well done and leads easily into the concepts of local isotropy, the equilibrium range, the inertial subrange, and Kolmogorov's hypotheses. The chapter concludes with a brief discussion of the spectra of passive scalar contaminants having both large and small Prandtl numbers.

The authors have succeeded remarkably well in providing an introduction to modern turbulence theory which is balanced, avoids complex mathematical formulations and is addressed to the wide range of disciplines which encounter turbulence. Particularly notable is the authors' concern with developing physical concepts underlying turbulence phenomena. This together with their presentation of dimensional analysis and scaling arguments should make the book especially attractive to those in research and development who are concerned with studying turbulent flow in complex situations.

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June 16, 1972

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