REVIEWS

A Textbook of Magnetohydrodynamics. By J. A. SHERCLIFF. Pergamon Press, 1965. 265 pp. 21*s*.

Over the past five years or so many authors have recognized the confusion resulting from the boom psychology in magnetohydrodynamics (or 'MHD') and have attempted to chart a course for the field by means of a suitable text. Not all have been successful. Prof. Shercliff's book, however, has succeeded in characterizing the subject and at the same time in making evident why it is an exciting one and why it offers to its inventive participants a rich area of unexplored technology.

The book is addressed to both the engineer and physicist whose backgrounds are either in fluid mechanics or electrical science. It is essentially a theoretical text in which, as the author points out, the main aim is physical comprehension and not mathematical sophistication. Its pages are filled with the sense of possibility and not necessarily with 'the most appetizing morsels for the mathematician' which are 'rarely the most physically realistic or practically important cases'.

Prof. Shercliff has stated that he has written a text for advanced undergraduate and postgraduate research students but not a research monograph. Though it is certainly true that the book fulfills its claim as a text, it also fulfills many of the requirements of a research monograph in its penetrating interpretations so appreciated by the research worker.

From the very outset a central idea which pervades the text is that of the 'kinematic' aspect of MHD whereby the fluid motion affects the magnetic field, and the 'dynamical' aspect whereby the magnetic field affects the motion. With this 'pre-Maxwellian' aspect of electromagnetic theory clarified the reader is then treated to a delightful historical survey of the field which makes clear the technological motivations for the subject but even more important, its inherent limitations.

MHD deals with the dynamics of conducting fluids in magnetic fields and in the second chapter the conditions underlying the MHD approximation and the resulting equations are presented. Though the fluids may be gaseous plasmas or conducting liquids, within the framework of the book the medium is treated as a continuum obeying classical equilibrium relations, with no net charge, and with relativistic effects neglected. The low-frequency approximation and the justification for the neglect of the charge distribution is made clear. It is heartening to see emphasis placed on the fact that although Gauss's law for electricity is not used, $\nabla . \mathbf{E}$ may not be taken equal to zero. The generalized Ohm's law for moving conductors with a scalar electrical conductivity is introduced and although the Hall effect is discussed it is ignored in the book, a fact which might prove to be a deficiency to those who must deal with real plasmas and not just conducting liquids. Most of the text, with the exception of the final chapter, considers the fluid to be one of constant density with constant properties, and all the basic electromagnetic and fluid dynamic equations given are based on these approximations, a discussion of the energy equation being reserved for the chapter dealing with magnetogasdynamics.

In the third chapter the kinematic problem based on the linear electromagnetic equations and Ohm's law is treated. Here is introduced the well-known analogy between the transport and diffusion of magnetic induction with that of vorticity in a constant density fluid. For the case of infinite electrical conductivity the magnetic analogues of the Kelvin–Helmholtz theorems on vorticity and circulation are presented in relation to Alfvén's concept of 'freezing' of the field lines in the fluid. Recognizing the confusion which has existed in some of the MHD literature concerning moving fields, the author has given an excellent discussion of this subject which should clarify for the fluid dynamicist the invariance of a magnetic field to a Galilean transformation and on the other hand the relative nature of the electric field. The concept of magnetic Reynolds number is then introduced in terms of whether convection (high R_m) or diffusion (low R_m) of the magnetic field is the dominant process. The chapter concludes with a number of interesting kinematic problems including those for which the geometry is such that the velocity field is decoupled as, for example, in the electromagnetic flowmeter.

The next chapter is concerned with the dynamical aspects of how the $\mathbf{j} \times \mathbf{B}$ force affects the fluid motion. The analogy between inertial forces in steady flow and magnetic forces is given and it is shown how the principal Maxwell stresses may be thought of in terms of tension along the field lines and a transverse compression. Here again, Prof. Shercliff lays emphasis on the long-range character of these stresses in order to suggest how in MHD, in contrast to ordinary fluid mechanics, a momentum transfer in the fluid system is possible without a large-scale exchange of fluid elements. The author then turns to the simplest dynamical case in which the fluid has no bulk fluid motion, that of magnetohydrostatics. Examples of pressure-balanced pinch configurations and force-free fields along with their technological applications are given, though the question of the stability of such configurations is touched upon only briefly and then only in a qualitative way. The remainder of the chapter deals with the second central idea which pervades the text, that of the relationship between the rotationality of the magnetic body force and the vorticity in the fluid. As the author points out in his introduction, 'The idea that a magnetic force can *push* a fluid is so easily grasped that one can rapidly move on to the more searching question of whether it tends to *spin* the fluid elements as well'. By various examples the $\mathbf{j} \times \mathbf{B}$ force (density is constant) is shown to create or suppress vorticity in low R_m situations depending on the geometry, while for high R_m it is shown how vorticity can be propagated by the Alfvén mechanism. The author illustrates vorticity propagation by MHD waves through the case of the vortex/current filament, which has a direct analogue in aerodynamic lift and which shows clearly the nature of the mechanism unobscured by mathematical detail. Consideration of aligned fields and the attendant fluid-mechanical analogies complete this chapter. Here is presented a clear picture of the nature of the upstream MHD wake interpreted on the simplest physical grounds and containing a stern warning on the care with which appropriate upstream boundary conditions must be specified in highly-conducting flows.

One might wonder why Chapter 5 which treats various external, boundary, and initial conditions might not have come earlier, for it is here that the requirement on the completion of the external paths for the current and magnetic field is emphasized, a fact all too often overlooked by the fluid dynamicist in his quest for local solutions. Though clear in its presentation, a freer use of the concepts of surface vectors might possibly have made the discussion of the boundary conditions more closely related to the analysis of the preceding chapters. Particularly helpful to the fluid dynamicist is the treatment of contact resistance effects. The manner in which the idea of a Hartmann layer is introduced through consideration of the boundary conditions for a viscous fluid in contact with a solid with a normal component of magnetic field is also instructive.

In Chapter 6 on linear (but not linearized) constant density problems the author arrives at the point where many previous texts have begun. Prof. Shercliff considers the general class of problems in which (**v**.grad) or (**B**.grad) of **v** or **B** are linear in terms of the unknown components of **v** and **B**, thereby allowing the presentation of a wide variety of relatively simple mathematic solutions, while at the same time retaining the essential physics of the interaction between the velocity and magnetic fields. Given as examples are the technologically important cases of steady Hartmann flows, linear Alfvén waves, the oscillating wall (with and without electrical excitation at the wall), the Rayleigh problem, and various two-dimensional problems including the flowmeter problem of steady laminar motion in a pipe. The relations between the various solutions are always brought together in a clear physical manner as, for example, in the discussion of the presence of both a Hartmann layer and Alfvén mechanism in the Rayleigh problem.

The final chapter deals with magnetogasdynamics and is introduced by a detailed discussion of the energy and entropy equations. In reading this chapter it is clear that the same sense of cohesiveness which pervades the other parts of the book is to some extent missing and that the material has been added to fill out the subject but without the same continuity present elsewhere. However, the author has himself made fundamental contributions to many of the subjects which are discussed, and they are as interestingly interpreted as the other material in the book. Among other things, the chapter includes steady one-dimensional channel flows under transverse magnetic fields, the analogy between ordinary one, and two-dimensional gasdynamics and magnetogasdynamic flows under transverse magnetic fields, magnetoacoustic waves, shock waves, and two-dimensional infinitely conducting flows with aligned fields. Particularly useful for a student of the subject are the author's interpretations of one-dimensional processes in diagrams of density versus magnetic induction.

The book is intended as a text and, as such, problems play an important role. In this respect alone it is most outstanding for at the end of each chapter there is a wide variety of problems, all of which when worked out serve to extend the students' knowledge of the subject beyond the immediate material of the text. The summaries at the end of most of the chapters very nicely tie together for the reader the essential points covered. Although detailed references are not supplied, an adequate bibliography is given at the end of the book for the student desirous of delving further into the subject.

To introduce caveats at this point would be unfair to a book which has in every respect met the aims set forth by the author. It is a text which most others in the field will undoubtedly pattern themselves after for some time to come. The author has succeeded in writing a book which, in the best tradition of English University lectures, contains the heart of each topic presented in sufficient detail to be followed but unencumbered by redundant examples and with a minimum of mathematical complication. After reading the book, not only will the student have a grasp of the subject as a whole but also a better appreciation of Prof. Shercliff's cautions note in his introduction, where he warns the inventive MHD enthusiast, when considering a fluid conductor, to ponder the question 'Wouldn't copper be better?'.

RONALD F. PROBSTEIN

Fundamentals of Gas Dynamics. By A. OWCZAREK. International Text Book Company, 1964. 589 pp. $11.50.

This is a very long book presenting a first course in continuum gas dynamics. The student reader is assumed to have had one semester of introductory fluid dynamics and one of classical thermodynamics; in mathematics, ordinary differential equations, partial differentiation and vector analysis are supposed to be understood. Facility in the use of vectors is essential and there is an appendix of 50 pages written in the form of a chapter on vector algebra and calculus for those who need it. The book deals with the fundamentals of flow of non-viscous, non-heat conducting gases, but there is a final chapter of about 70 pages denoted to the derivation and discussion of the equations of flow when viscosity and heat conduction are included.

The text begins with basic ideas and definitions. All descriptions are well related to physical concepts and engineering applications, and are accompanied by good explanatory drawings and photographs that add point. Then follow the chief kinematical theorems—transport, circulation and vortex theorems—and the dynamics of compressible perfect fluids. There is a long chapter devoted to topics from classical thermodynamics and statistical mechanics, containing many useful tables and graphs, in particular of the thermodynamic properties of air, and a discussion of the dissociation and ionization processes. Maxwell's thermodynamical equations are derived in the second appendix to the book.

The common properties of stationary shock waves are given, and there is a short account of real gas effects. Next comes a chapter on one-dimensional flow in ducts, including flows with viscosity and with heat addition and subtraction, followed by a chapter extending over more than 100 pages on continuous, unsteady flows. This starts with simple waves in the (x, t)-plane and continues with quasi-one-dimensional flows, characteristics and their use by numerical procedures, the relations between characteristics in the physical and hodograph planes, and wave interactions of engineering significance.

The development of the Rankine–Hugoniot shock equations for unsteady flows is somewhat confused by the author's differentiation between flows from right to left and flows from left to right relative to the shock. After a few pages he allows that 'the equations relating the flow functions ahead of and behind shock waves whose speed is...$u_1 - U$ can be obtained from those...whose speed is...$u_1 + U$ by introducing $-U$ in place of U'! This chapter goes on to deal in an interesting way with flow in shock tubes and chemical reactions leading to combustion and detonation. The calculation of the Hugoniot curve for the mixture $H_2 + 2O_2$ is given for the sake of example, with and without dissociation of the molecules. The chapter concludes with a few remarks on real-gas effects in unsteady flows involving shock waves, with particular reference to the limitations of the shock tube for hypersonic research.

The standard two-dimensional steady flows are given, and some numerical examples, including the interaction of two simple waves. Applications to the design of supersonic nozzles and to the study of flow in a free jet are illustrated. Flows with axial symmetry are also discussed.

The last chapter, on viscous and heat-conducting fluids and laminar boundary layers, has already been mentioned. It begins with the algebra of dyadics, necessary for the introduction of the usual tensor quantities.

There are three appendices in addition to the two already described, including tables of the variation of quantities with Mach number for an ideal gas with constant specific heats.

The author has written his book very much with engineering students in mind. He has taken great trouble to furnish his text profusely with pen diagrams and photographs, and to provide examples of a practical or illustrative character at the ends of the chapters, where there are long lists of useful references.

D. C. Pack

SHORTER NOTICES

Proceedings of the 1965 Heat Transfer and Fluid Mechanics Institute. Edited by A. F. Charwat. Stanford University Press, 1965. 372 pp. 80*s*.

This latest volume in a familiar series records the 18th meeting of the Institute, and consists mainly of nineteen contributed papers on a wide range of topics. The format has been improved a little by retyping of all papers in a uniform style before photographic reproduction. The editor claims in the preface that 'the Proceedings of the Institute have become an internationally recognized archive record'; one may doubt that, while believing that the meetings themselves are valuable.

Proceedings of the Summer Seminar in Magnetohydrodynamics. Edited by P. L. Bhatnager. G.S. Press, Madras, 1965. 376 pp.

This paperback collection of review talks and contributed papers presented at a Seminar at the Indian Institute of Science, Bangalore, in May 1963 contains 26 papers which fall roughly into the following categories: plasma physics (7); plasma stability and fusion problems (4); engineering MHD (7); astrophysical MHD (3); general topics (5). The volume provides evidence of the range and depth of interest in the subject of MHD in India, at any rate as it was three years ago.

Rarefied Gas Dynamics, Vols. 1 and 2. Edited by J. H. LEEUW. Academic Press. Vol. 1, 1965, 700 pp., 156*s*. Vol. 2, 1966, 608 pp., 148*s*.

These two volumes record the proceedings of the fourth of a series of international symposia on rarefied gas dynamics held at Toronto in 1964, and contain 73 contributed papers. The papers are grouped under headings which include kinetic theory, shock structure, transition flow, free molecule flow, rarefied plasmas, molecular beams, and surface interactions.

Proceedings of the Second Australasian Conference on Hydraulics and Fluid Mechanics. Printed by University of Auckland, 1966. 899 pp.

The sixty-one papers presented at this wide-ranging meeting in Auckland in December 1965 have been copied photographically from type-script and bound together to make the inevitable volume of proceedings. Aside from their technical content, the papers have some interest as a cross-section of current research in one of the less well-known parts of the world.

Single and Multi-component Flow Processes. Edited by R. A. PERKIN and C. F. CHEN. Rutgers University, 1965. 127 pp. $3.00.

The curious title has been chosen to embrace the subjects of four 'state of the art' papers, originally presented at a one-day symposium at Rutgers in 1964. The titles and authors are: Gas-solid flow, by S. L. Soo; Some aspects of gas-liquid flows, by S. G. Bankoff; Dynamics and Thermodynamics of Separated Flows, by H. H. Horst; Recent trends in rarefied gas dynamics, by L. Talbot.

Directory of Fire Research in the United States. National Academy of Sciences–National Research Council, 1966. 320 pp. $4.00.

This is a catalogue of the military, university and industrial laboratories in U.S.A. in which investigations of combustion and fire prevention and control are being carried out. Hardly interesting reading, but potentially useful to someone who wishes to obtain authoritative information about some aspect of fluid dynamics involved in fires.

Handbook of Physical Constants. Edited by S. P. CLARK. The Geological Society of America, 1966. 587 pp. $8.75.

This revised and enlarged edition of a handbook first published in 1942 is concerned, despite its general title, with the physical constants needed for geological and geophysical calculations relating to the part of the earth below the solid surface.

Magnetohydrodynamic Stability and Thermonuclear Containment. Edited by A. JEFFREY and T. TANIUTI. Academic Press, 1966. 222 pp. 60*s*.

This is a collection of reprints of twelve well-known papers on MHD and plasma stability (published between 1954 and 1963) together with an introductory review by the editors. The papers have been well selected; they are almost all 'prescribed reading' for anyone working in this field. The volume costs less than it would cost to photocopy the articles direct from the originals, and for the specialist it may therefore be a good buy.