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REVIEWS

Theory and Application of the Boltzmann Equation. By CARLO CERCIGNANI. Elsevier, 1975. 415 pp. $35.00.

It is just over 100 years since Boltzmann produced the famous integro-differential equation, the fundamental equation of the kinetic theory of gases, that bears his name. Mathematical work on this equation has made many advances in recent decades, prompted by the great interest in non-equilibrium flows deriving from new applications in, for example, rarefied gasdynamics and shock structure. At the same time, new technologies relying on generalizations of the Boltzmann equation have also initiated intensive study wherein analytical, numerical and Monte Carlo methods of finding solutions have all been strongly developed. Like the kinetic theory, the newer studies are concerned basically with transport phenomena, and include neutron transport in nuclear reactors, photon transport in superfluids, plasma dynamics and radiative transfer.

This is, then, a good time for the appearance of a mathematician's book on the theory of the Boltzmann equation: to show the essential unity of approach across the physical disciplines, but also to point out the differences in formulation of the problems induced by differences in the physics; to illustrate the ways in which the Boltzmann equation has been replaced by model equations, and to discuss the solution of these and their validity as representations of the original. Professor Cercignani has himself contributed very significantly to the development of mathematical ideas in this field and here he makes it his aim 'to provide an introduction to the mathematical techniques and concepts related to the Boltzmann equation, and in particular, to the boundary value problems which arise in connection with such an equation'.

The first chapter deals with the basic principles of the kinetic theory. The Boltzmann equation is then derived (chapter 2) from the Liouville equation for a gas of rigid spheres without the assumption of 'molecular chaos'. The results are generalized to other representations of gaseous interaction and to related disciplines. Model equations are introduced at this stage. Chapter 3 is an important feature of the book, being an account of gas–surface interactions, in which Professor Cercignani has interested himself deeply and which is a vital and still controversial subject. Work on the scattering kernel is unified to show how to construct models that satisfy the fundamental physical requirements. The approaches adopted have achieved considerable success in closely reproducing certain experimentally determined patterns of scattering of a molecular beam. In chapter 4 various general methods are given for dealing with the linearized as well as the exactly linear Boltzmann equation, which is of particular importance in the study of neutron transport in a gas moderator. A discussion at some length of the Hilbert and Chapman–Enskog expansions comes next (chapter 5), with the adaptations required to meet the difficulties of the 'connection problems' associated with initial, boundary and shock layers. There are some sections on free and near-free molecular flows. On turning to the analytical solution of model equations (chapter 6), the general methods of chapter 4 are applied to some simple problems. The complexity of this work suggests that more straightforward

procedures yielding approximate but sufficiently accurate results are likely to be best for the treatment of the transition regime between near-continuum and nearly free-molecular flows (chapter 7). Moment and discrete ordinate methods, the variational method and Monte Carlo methods are considered. There follow brief descriptions of some well-known problems, such as shock wave structure and expansion of gas into a vacuum. The book ends with a short chapter on the present state of knowledge on the existence and uniqueness of solutions of the linearized and nonlinear equations.

The reader requires a sound background in mathematics. Each chapter is accompanied by an extensive bibliography, and the book will provide an important source of references for the research worker.

D. C. PACK

SHORTER NOTICES

Annual Review of Fluid Mechanics. Volume 9. Edited by M. VAN DYKE, J. V. WEHAUSEN and J. L. LUMLEY. Annual Reviews Inc., 1977. 509 pp. $15.00.

Rather longer than former volumes, this year's review retains the interesting diversity established previously. The articles contained in the work are as follows.

Recollections from an earlier period in American aeronautics, R. T. Jones.
Steady non-viscometric flows of viscoelastic liquids, A. C. Pipkin & R. I. Tanner.
Compressible turbulent shear layers, P. Bradshaw.
On the liquidlike behavior of fluidized beds, J. F. Davidson, D. Harrison & J. R. F. Guedes de Carvalho.
History of boundary-layer theory, I. Tani.
Incompressible boundary-layer separation, J. C. Williams, III.
Bubble dynamics and cavitation, M. S. Plesset & A. Prosperetti.
Underwater explosions, M. Holt.
Hydrodynamics of the universe, Ya. B. Zel'dovich.
Pulmonary fluid dynamics, T. J. Pedley.
Flow and transport in plants, M. J. Canny.
Particle capture from low-speed laminar flows, L. A. Spielman.
Electrokinetic effects with small particles, D. A. Saville.
Fluid mechanics of propulsion by cilia and flagella, C. Brennen & H. Winet.
Optimum wind-energy conversion systems, U. Hutter.
Finite-element methods in fluid mechanics, S.-F. Shen.
Aeroacoustics, J. E. Ffowcs Williams.
Study of the unsteady aerodynamics of lifting surfaces using the computer, S. M. Belotserkovskii.

Progress in Numerical Fluid Dynamics. Lecture Notes in Physics, no. 41. Edited by H. J. WIRZ. Springer, 1975. 471 pp. DM 37 or $15.20.

The nine articles contained here vary greatly in length and in standard but, although there is a heavy bias towards aerodynamic applications, the whole volume constitutes an extremely valuable survey of the state of the art in finite-difference calculations, undisturbed by any consideration of finite-element methods. Cheng's review of

methods for the Navier–Stokes equations is the longest and most introductory: it makes some useful points though some of the numerical analysis interpretations are a bit misleading. It is the authoritative accounts of transonic computations by Bailey, of inviscid supersonic flows by Kutler, of viscous separated flows by Mueller and of boundary-layer calculations – both steady (Krause) and unsteady (Wirz) – each with close comparison of computation with experiment, that make this essential reading for anyone interested in the field.

Applications of Global Analysis in Mathematical Physics. By J. MARSDEN. Publish or Perish Inc., Boston, 1974. 273 pp. $10.00.

This is a set of lecture notes applying the geometry of infinite-dimensional manifolds to nonlinear functional analysis and partial differential equations. The first quarter of the book is concerned with general theory, the second with hydrodynamics, and the remainder with quantum mechanics and relativity. The first main result is an existence (for sufficiently short times) and uniqueness theorem for solutions of the Euler equations, which is stronger than previous results. The second is a fundamental improvement on the time of existence (in three dimensions) for general initial data, using Chorin's approach. Basically Marsden proves the existence of smooth solutions to the Navier–Stokes equations for a finite time, which tend to solutions of the Euler equations as $R \to \infty$. Applications to turbulence theory are discussed in some detail. The book is rather heavy going, but the techniques are powerful.

Computational Methods and Problems in Aeronautical Fluid Dynamics. Edited by B. L. HEWITT, C. R. ILLINGWORTH, R. C. LOCK, K. W. MANGLER, J. H. MCDONNELL, CATHERINE RICHARDS and F. WALKDEN. Academic Press, 1976. 525 pp. £12.

This is the proceedings of a conference held at the University of Manchester in September 1974, organized by the Institute of Mathematics and its Applications. To quote from the preface by Sir James Lighthill, 'The aircraft industry today is one of the most lively areas of application of computational methods on a big scale, whether in fluid dynamics, structural analysis, power-plant analysis or systems analysis. The conclusion that their effectiveness in the first of these fields is still growing very rapidly indeed can be readily derived from a study of this book.' The topics include practical requirements in industry, finite-element methods, free vortex sheets, unsteady transonic flow, and fluid-dynamical applications of the Illiac IV computer.

Technische Thermodynamik. Grundlagen und Anwendungen. Volume 1. Einstoffsysteme. By E. SCHMIDT. 11th edition. Springer-Verlag, 1975. 428 pp. DM 64 or $26.30.

This is the eleventh edition of a standard textbook on technical thermodynamics by the undisputed doyen of German thermodynamics for many years. The field of thermo- and fluid-dynamics has grown so much during the last forty years that it now requires two volumes rather than one to set out what we should know. The first volume is concerned with single fluid systems, as opposed to multiple fluids, which are

to be dealt with in a forthcoming second volume. The term fluid is understood here to include ideal and real gases, liquids, and steam, as well as two-phase flows. The reader will find a very careful and detailed exposition of the concepts and laws of thermodynamics and of gasdynamics in this book. Especially useful are the extended and very lucid discussions of all kinds of practical thermodynamic processes and flow cycles, from chemical and mechanical engineering to aeronautical propulsion. Particularly interesting are the use of parameters which describe relations between a system and its surroundings in the derivation of the fundamental laws; and the introduction of the concept of the maximum work done when a system is brought into equilibrium with its surroundings by reversible changes of state, called the exergy (from ex ergon = work which can be extracted from a system). Thus it may be assumed that recent advances in this field have been fully digested and have been clearly presented, even though there are not very many references for further reading.