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REVIEWS

Thermodynamics of Irreversible Processes: Applications to Diffusion and Rheology. By G. D. C. KUIKEN. Wiley, 1994. 425 pp. ISBN 04719 48446. £29.95.

The thermodynamics of systems close to equilibrium underwent a remarkable development in the middle third of this century following the seminal work of Onsager on thermal transport coefficients. There emerged a class of continuum theories suitable for discussing diffusion, heat conduction, fluid flow and chemical reactions in which the large number of phenomenological transport coefficients was constrained and ordered by the Onsager–Casimir reciprocal relations, which reflected the underlying mechanical time-reversibility of these systems. The work of Prigogine, Meixner, de Groot and Mazur clarified the structure of these theories. Gerard Kuiken has written a monograph which surveys these developments and, with respect to diffusion and rheology, extends the classic exposition of de Groot and Mazur.

Kuiken aims to be accessible to students as well as to research workers, so he includes a detailed treatment of equilibrium thermodynamics as well as a summary of Maxwell's electromagnetic theory of polarizable media. He sets up the structure of non-equilibrium thermodynamics in an axiomatic way, stressing the role of invariance and covariance with respect to Galilean transformations. Separate chapters are devoted to the balance equations for energy, momentum and entropy in multi-component simple fluids and to the Markoff theory of thermodynamic fluctuations and the derivation of the reciprocal relations in this context. Mostly this discussion is a straightforward account of standard theory, with the exception of the derivation of the reciprocal relations where he explores the degree to which the results depend on the Boltzmann hypothesis expressing the distribution of fluctuations in terms of entropy differences. All this material is clearly presented, and accompanied by a valuable list of references to the literature on which it is based. There are few misprints in either text or equations, although there is a confusing one occurring in a statement of microscopic time-reversibility in the text just before equation (5.57).

In the last two chapters he treats multicomponent diffusion and rheological phenomena. Three different descriptions of diffusion and diffusion coefficients are presented using the freedom both to choose a particular reference component and to interchange thermodynamic fluxes and forces. In the final chapter a survey of the phenomenological classification of linear viscoelastic materials is presented in terms of stress–strain relations which show memory or retardation effects. Simple spring and dashpot models are used to represent the different classes of materials.

While the first five chapters are quite accessible to a student, the last two chapters are characterized by a relentless complexity (there are nearly 500 numbered equations in the last chapter). These sections are not to be read as a textbook but will serve well as a reference work for those concerned with engineering applications of multi-component diffusion or visco-elasticity. For real systems such as polymeric fluids or colloidal dispersions, much modern research aims to derive the phenomenological coefficients from microscopic models studies analytically or by computer simulation. Irreversible thermodynamics still plays a role in such microscopic models by providing consistency checks on their predictions. This book is welcome both for its exposition of the principles of non-equilibrium thermodynamics and for its unified treatment of diffusion and of viscoelastic systems. It would be a valuable addition to all science and engineering libraries.

R. B. JONES

Mathematical Analysis in Engineering. By C. C. MEI. Cambridge University Press, 1995. 461 pp. ISBN 0 521 46053 0. £45 or $54.95.

The subtitle of this book is 'How to use the basic tools', and the author's intention is, as stated in the Preface, to present basic mathematical techniques in the context of applications to simple engineering – usually mechanical – systems. In the first chapter, indeed, the reader is introduced to the transverse vibration of a string, longitudinal vibration of a rod, traffic flow, flow through a porous medium, diffusion in a stationary medium and shallow-water waves, all in the space of nineteen pages. This chapter, entitled 'Formation of physical problems', is an introduction to the art of mathematical modelling. The choice of examples leads to the construction of the wave equation, Laplace's equation, the diffusion equation and a couple of nonlinear first-order equations. The style, here and throughout, is economical but very clear, with a careful explanation of orders of magnitude and 'negligible' terms. The chapter ends with the linearization procedure for small-amplitude water waves which is part of the author's emphasis on the need to understand how to approximate. This is taken up with some detail in chapter 13, 'Perturbation methods – the art of approximation', in which regular and singular perturbations are described along with a discussion of the methods of multiple scales and homogenization.

The differential equations introduced in the first chapter are classified according to the usual scheme of hyperbolic, elliptic and parabolic equations, and lead to the best account of characteristic curves I have ever read. This is followed in chapter 3 by a discussion of one-dimensional waves, mainly based on d'Alembert's solution and terminating with 'a taste of nonlinearity' – the traffic flow problem.

Next the author moves on to the solution of the diffusion and Laplace's equations in finite domains by means of separation of variables and expansion in eigenfunctions. This leads naturally to a discussion of Fourier series in chapter 5 and later to Bessel functions in chapter 8. Fourier series are extended to Fourier transforms for unbounded domains in chapter 7, but in between there is an introduction to Green's function and the δ-function in chapter 6. Green's function is introduced in the context of the Sturm–Liouville equation and the author, very sensibly, deals with the δ-function in terms of integral operations only.

Rather curiously, in view of the fact that complex exponentials have been turning up fairly frequently in earlier chapters, the book now turns to an introduction to complex variables in chapter 9. However, this section has two purposes. Firstly, it serves as an introduction to the use of complex functions to solve two-dimensional hydrodynamic problems. This is taken further in chapter 11 with a description of conformal mapping and in chapter 12 with the Reimann–Hilbert problem. Secondly, it provides a basis for the inversion of the Laplace transform, introduced in chapter 10, with an account of branch-cuts and Riemann sheets, Cauchy's theorem and Jordan's lemma. The book ends with a chapter on computer algebra which the author advocates for, and illustrates by, examples of perturbation schemes, which 'can be tedious'.

All-in-all, this is an excellent book with a readable style. The mathematical analysis is clear, although I was disappointed to notice two minor shortcomings, both on p. 101: the method of induction is applied sloppily, whereas it can easily be done properly, and in the derivation of the asymptotic form of Fourier coefficients the stated conditions call for piecewise continuity while piecewise differentiability is assumed in the proof. The examples and illustrations are well-chosen and as simple as can be without being trivial. They are also practical and very diverse. The book apparently grew out of a first-year course for graduate engineers but parts of it would probably suit third- or even second-year undergraduates as well.

J. A. HUDSON

Cavitation and Bubble Dynamics. By C. E. BRENNEN. Oxford University Press, 1995. 282 pp. ISBN 0 19 509409. £60

The objectives of this book on cavitation and bubble dynamics are twofold: firstly to provide a monograph for advanced students with interests in the basic problems of multiphase flows and secondly, as a reference book in cavitation and bubble dynamics; a difficult task. The monograph is an outgrowth of a lecture course to students at Caltech and draws very much on the research activities of the author and his distinguished colleagues. Multiphase flows are extremely complicated in that, typically, the phases are in relative motion. This book is primarily concerned with a gaseous phase embedded in a liquid phase, so complications may occur due to the rapid deformation of a bubble surface, and in the case of cavitation bubbles, this motion may be extremely destructive. In addition to the complicated flow patterns noted above, the flows are typically turbulent and may include shock waves.

The first chapter on 'Phase change, nucleation and cavitation' introduces the reader to the mechanisms of formation of the phase mixtures of vapour and liquid and the physical properties of the liquid state. It proceeds by discussing the various types of nucleation that are central to both cavitation and boiling. It then leads on to develop the key quantities with regard to the fluid mechanics involving the pressure coefficient C_p and cavitation number σ. The author discusses a number of the fluid mechanical phenomena such as vortex shedding, the effects of bubbles on increasing or decreasing turbulent flow, production of noise, discussion of cavitation inception data and also the role of scaling in cavitation inception. Chapter 2 is concerned with the classical studies on the Rayleigh–Plesset equation, which provides a useful insight into some of the phenomena that one would expect in a cavitating flow. Topics that are covered include the growth by mass diffusion, the role of thermal effects on growth, non-equilibrium effects and non-spherical perturbations to the equation. One of the possible weaknesses of this section is that it could refer more to later theory, particularly from the computational side.

'Cavitation bubble collapse' is discussed at considerable length in chapter 3. In any real flow field, cavitation bubble collapse is far from spherical, often characterized by the high-speed liquid jet that penetrates the bubble during the collapse phase which may manifest itself in a more complicated flow pattern in three dimensions. The author argues that departure from sphericity can diffuse the focus of the collapse and reduce maximum pressures. In some cases, the contrary is clearly true because in non-spherical collapse the high pressures and high velocities are more focused and can lead to potentially greater damage. Nevertheless, there is an excellent discussion of the mechanisms of cavitation damage which include complicated steady flow phenomena combined with the reaction of the material surface. Some of the phenomena that are observed include highly localized shock waves, micro-jets, local surface fatigue in harder materials while in softer materials there is clear evidence of jet damage. Possibly even more important is the remnant cloud of bubbles that is often observed in cavitating phenomena which again may generate shock waves and include the large collective volume changes that may have enormous loading effects on nearby surfaces. The author continues by discussing other important features of cavitating phenomena which include the generation of noise over a relatively wide spectrum. The overall impression of this chapter is that it is a good historical presentation of the developments in the field which could have been improved if further insight into the latest theoretical developments had been discussed.

In chapter 4 the 'dynamics of oscillating bubbles' is presented. A discussion of the natural frequencies, the use of an effective polytrophic constant, damping due to the effects of viscosity, thermal effects and acoustic radiation are discussed. Other items discussed include rectified mass diffusion, Bjerknes forces and the threshold for transient cavitation.

In chapter 5 the 'Translation of bubbles' in a multiphase flow is discussed. The presentation in section 5.3 on low Reynolds number flows is concerned with only a rigid spherical particle and a zero stress spherical bubble. The author discusses Maragoni effects, including surface tension gradients and thermo-capillary effects. The discussion of unsteady particle motion fails to refer to some of the classic work in the field by Taylor, Tollmien and Voinov, and the more recent work of Auton and Hunt. Reference to these works would certainly be useful for research workers wishing to follow some of the more recent developments in this field. Some of the work on growing or collapsing bubbles could be much better expressed in terms of Lagally's theorem or the Kelvin impulse. Chapter 6 discusses 'Homogeneous bubbly flows'. This assumes that the two phases are well mixed and the dispersed particle size is sufficiently small to eliminate relative motion between the two phases. The author proceeds by discussing the low sound speeds that can occur in multiphase systems and then goes on to discuss various applications in nozzle flows, flows with bubble dynamics, acoustics of bubbly mixtures and shock waves in bubbly flows. Chapter 7 considers 'Cavitating flows', including travelling bubble cavitation and bubble flow interactions. The minimum pressures are at or near the boundary, which implies strong interactions with the boundary and highlights the importance of the normal pressure gradients and the role of curvature. The boundary layers are typically thinner than the bubble diameter and so an inviscid potential flow model is a reasonable starting point. There is an excellent discussion of some recent experimental observations on transient cavitation, particularly from the author's areas of expertise, continuing with material on large-scale cavitation structures, vortex cavitation, cloud cavitation and attached and sheet cavitation. The author continues by discussing both partial and super cavitation. In the final chapter on 'Free streamline flows', the author bases his presentation on the work of Wu. There is a good discussion of the various cavity closure models including Riabouchinsky, open wake, re-entrant jet, and Tulin's spiral vortex models. Included in the presentation is the role of wall effects and choke flows, steady planar flows, nonlinear results and a discussion of the flat plate hydrofoil model.

So how does the volume meet the original objectives to provide both a text for advanced students in cavitating and multiphase flows and, as well, a reference book for research workers? With only a few reservations, I believe the book is an excellent graduate student textbook providing a good introduction to a wide range of phenomena in both cavitation and multiphase flows. The book covers the historical developments in the field and leads one through this work in a systematic way. The theory should be accessible to most students at this level and introduces most of the important physical concepts that one needs to be familiar with when studying these flows. However, the book probably does not meet the second objective as successfully as the first, as much of the modern material is very selective, centred mainly round the author's own research interests. It has deficiencies inasmuch as it refers to some of the latest theoretical developments which are at a much more advanced level than those presented in this book. On the other hand, the volume is primarily designed for a graduate student programme and is relatively compact in size compared with its major competitor volumes. In conclusion, I can recommend the book as an excellent graduate text, for use by lecturing staff in this area and also an excellent reference book for purchase by most institutions which have strong research interests in fluid mechanics.

J. R. BLAKE