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REVIEWS

Thermodynamics and Gas Dynamics of Internal Combustion Engines, Volume I. By R. S. BENSON, edited by J. H. HORLOCK and D. E. WINTERBONE. Oxford University Press, 1982. 573 pp. £55.00.

The late Rowland S. Benson was Professor of Mechanical Engineering at the University of Manchester Institute of Science and Technology from 1962 until his death in 1978. He pioneered the application of computational techniques to the solution of the equations that govern propagation and superposition of pressure waves in the inlet and exhaust systems of reciprocating internal combustion engines. The present volume begins with a very brief introduction, in chapter 1, to the basic principles, covering such aspects as properties of ideal gases and gas mixtures, the application of the conservation equations to non-reacting and reacting systems with inflow and outflow, and the gasdynamics of steady and unsteady flow. Thereafter the volume concentrates almost exclusively on the wave action aspect of the gasdynamics of the internal combustion engine.

This volume was completed in draft form by the author, although it still required extensive editing. Volume 2, for which only outline plans existed at the time of Benson's death, will consist of contributions by a number of specialists, and covers the complete field of mathematical modelling of engines, by a variety of techniques, both for steady-state and transient operation.

The mathematical basis for the solution of the hyperbolic partial differential equation governing finite-amplitude wave motion (as opposed to small-amplitude acoustic waves), the so-called method of characteristics, was established by Riemann in the late nineteenth century. However, the great practical importance of wave action, initially in connection with the scavenging of two-stroke Diesel engines, was recognized only towards the end of World War II. In particular, de Haller and Jenny, both associated with the Swiss company Brown Boveri, were responsible for developing the now standard graphical technique of solution. Benson fully acknowledges this; in fact, chapters 2–5 are concerned exclusively with applying the graphical technique. The application is first to simple isentropic pipe flows in chapter 2, followed by simple closed- and fully or partially open-end boundary conditions in chapter 3, more realistic valve or port boundary conditions (as found in engines) in chapter 4, and finally the very instructive chapter 5 deals with more complex non-isentropic flows including flows with entropy discontinuities and shocks.

A minor criticism applicable to all these chapters concerns the use of the term 'homentropic'. To the best of the reviewer's knowledge, this term was first employed by Benson himself to denote strictly one-dimensional, isentropic unsteady flows. Unfortunately the term is never explicitly defined, and its use in connection with the strictly irreversible flows associated with entropy discontinuities and shocks in chapter 5 would seem not to be justified. However, in general the presentation of the graphical techniques in chapter 2–5 is clear and logical and, apart from a small number of illustrations in which excessive reduction has led to virtual illegibility, the reader can follow the development of the argument step by step.

As the author himself comments repeatedly, the graphical method has the great advantage that the physical nature of wave phenomena is at once apparent even to the novice. In particular, the simultaneous development of wave propagation paths in the so-called position, or distance–time, plane and of changes in pressure and particle velocity in the so-called state plane, enables the user to follow the gradual unfolding of complex wave patterns from their origin at the 'upstream' boundary throughout the space–time field.

The next three chapters deal with numerical solutions, of homenotropic flows in chapter 6, of flows with simple boundary conditions in chapter 7, and of the very important cases of sudden enlargements, contractions and pipe junctions in chapter 8. Chapter 9, finally, deals with the many problems associated with the representation of the boundary conditions for turbines and compressors as used in turbocharged engines. Of necessity, these later chapters are likely to present the reader with very real difficulties. They arise primarily from the nature of the subject matter, in that these chapters deal with details of complex procedures, rather than with the formulation of a basic theoretical approach, as in chapter 2, or the development of conceptually clear solution procedures, as in the chapters concerning the graphical method. Nevertheless, these highly specialized chapters are essential reading for actual or potential users of the comprehensive computer programs now available for the analysis of wave action in the complex branched manifolds of multicylinder turbocharged engines, and especially so when changes in, or additions to, such programs are required.

The following paragraphs deal with specific points arising in the text, taken in the order in which they occur.

Much of the material in chapter 1 can be found in appropriate textbooks, though undoubtedly the summary of basic thermodynamic and gasdynamic relationships is useful. However, in the development of energy properties of gases and mixtures of gases, in section 1.3, the use of *molar* rather than unit mass values of these properties should have been emphasized more strongly than in an inconspicuous footnote on p. 27.

In chapter 2 the very important characteristic function $C = C(x, t)$ is introduced in a manner likely to cause considerable difficulty to the student. I feel it would have been better, in this introduction to characteristics, first to illustrate the general principle of transforming a set of partial differential equations to a set of ordinary differential equations holding along characteristics, and then to apply the transformation to the continuity and momentum equations in their original form. As it is the reasons for the operations leading to equations (2.18) and (2.19) remain obscure, the very important result expressed by equation (2.20), i.e. $(\mathrm{d}x/\mathrm{d}t)_{\mathrm{dw}} = c$ (the propagation velocity), is presented without any further comment and the impact of the final characteristic equations, (2.27) and (2.28), is correspondingly lessened.

In chapter 3 the solution of the problem of the sudden opening of a valve is obscured by an illegible diagram, figure 3.9, and by the absence of numbered equations in the text. Again for the novice, the by no means obvious distinction between subsonic and sonic boundary conditions, as represented by equations (3.36) and (3.39) on the one hand, and (3.45) and (3.46) on the other, could have been amplified somewhat in the text.

Chapter 5 undoubtedly contains material not hitherto found in the literature. Flows with entropy discontinuities, shocks and, especially, multipipe system flows are treated both comprehensively and clearly, though this reviewer found the notation adopted for pipe junctions unnecessarily complicated.

While inevitably the detailed nature of the subject matter detracts from the readability of the text, this volume must be required reading for all students of unsteady flows in pipe systems.

F. J. WALLACE

Geodynamics: Application of Continuum Physics to Geological Problems. By DONALD L. TURCOTTE and GERALD SCHUBERT. Wiley, 1982. 450 pp. £20.20.

Every so often new applications of fluid dynamics grow to a point where a separate sub-discipline emerges. Thus the field called 'Geophysical Fluid Dynamics', which developed in the middle of this century and is now flourishing, has grown to the point that a number of sub-disciplines exist, such as rotating fluid mechanics (oceans and atmospheres), convection, magnetohydrodynamics and geological fluid mechanics. Each specializes in significantly different parameter spaces, interacts with different communities of observational scientists, and has attained a self-sustaining critical mass. The last field, geological fluid mechanics, is probably the smallest and youngest of these. It is really just attaining sufficient size to be considered a significant sub-discipline. The book *Geodynamics* is one of the first serious attempts to provide an advanced undergraduate or beginning graduate level text in geological fluid (and solid) mechanics.

The title and subtitle will be misunderstood by some people. There has been a tendency in Earth science to link the word geodynamics with kinematics of the earth, the movement and deformations of the surface. Thus some browsers will be surprised to see the book progress beyond chapter 2 (Stress and strain in solids). The words continuum physics likewise involve solid-state physics and imply something broader than the present intent (with the exception of two sections which describe qualitatively diffusion and dislocation creep). It is not easy to know what to call the discipline involving mechanics and statics of the earth, but Geological Fluid and Solid Mechanics seems most descriptive. Fortunately, anyone who browses through this book for a short time, or knows the work of its authors, will quickly appreciate its scope. The authors are accomplished practitioners in this area and have generated a barrage of useful papers on fluid and solid mechanics of the earth; they are well qualified to write this text.

The book should be useful for the introduction of Geological Fluid and Solid Mechanics to undergraduate or graduate students. Although the primary users would probably be prospective earth scientists, it may serve also as a useful reference for the curious fluid dynamicist, as extensive geological examples and detailed explanations of terms are given.

In style the book can be described as an engineering textbook – that is, complicated exercises in applied mathematics are avoided by going to simple geometries. For instance, one-dimensional flow is often adopted, special similarity solutions are used, and in some cases restricted parameter spaces are investigated, all for the sake of avoiding more complicated mathematics. However, in the tradition of engineering texts, there are large numbers of worked-out examples and many problems for the student to solve. Within this scope the text is relatively complete for a one-year introductory course.

The book starts appropriately with a chapter on plate tectonics. Concepts are presented in a form comprehensible to a sophisticated novice – terms are clearly introduced and discussed. Plate tectonics and the associated concepts of the lithosphere, including plate margins and subduction zones, are described first. Next come some descriptions of transform faults and continents (the latter really being a description of isotope dating and geochronology). The theme of diagnostic tools thereby introduced continues with a description of paleomagnetism. This leads to a description of the past motion of plates, but not without interruption by a section on triple junctions. (Why not have triple junctions next to subduction zones and transform faults?) Aspects of continental collisions and volcanism are then related to mountain building. This leads into a description of seismically active zones, and finally a brief description of an extremely idealized driving mechanism which consists of a two-dimensional convection cell, heated from within, with a cold boundary layer descending into the interior. It is difficult to see what such a primitive model, so sketchily described, is supposed to suggest. The introduction ends with mention of the extremely gross structure of other planets and moons. Photographs and a description of the overall surface features of the planets are provided along with overall parameters such as mass and radius. It is not clear what relevance this section has to the chapter, except to point to situations which are novel compared to the earth. (These, however, are no more novel than the great polar glaciers, which are not described.)

The second and third chapters cover solid mechanics – stress, strain, elasticity, thin plates – but go on to include some descriptions of geological stress and strain measurement techniques. Tensor notation is not used, so there is some loss in generality, and although there is some detailed generalized discussion of two-dimensional strain in the deflection of elastic material, this is limited to deflection of beams, in spite of the fact that the words 'plate' and 'two-dimensional' are used. These chapters are at the level of many textbooks, although they are more compact. It would perhaps have been beneficial to include here a table of deflection formulae for beams and plates under various sorts of load, such as those included in mechanical engineering handbooks, or at least a reference to a source such as Marks' *Mechanical Engineering Handbook* at the end of chapter 3.

Chapter 4 switches to heat transfer in solids. The chapter leads off with a brief mention of the heat transfer in the Earth, Fourier's law of heat conduction, and heat flow and generation by radioactive decay in the Earth. The sections on the transient cooling of a semi-infinite solid and the steady conduction in two or three dimensions take the first steps into partial differential equations, presenting them slowly, in detail, and in a self-contained manner. There are then discussions of a few conduction problems in the Earth, such as the cooling of the plates near spreading centres and the heating of plates as they descend into the Earth, and many more. The thermodynamics of a material under pressure is covered rather simply in terms of motionless fluids.

Another switch follows at this point, to gravity. This section contains almost no dynamics, simply statics of the potential field, whose gradient is the force of gravity. This chapter covers a subject area which is dealt with elsewhere and the reasons for including this diagnostic tool, while others such as seismology and magnetism are left out, is unclear.

Chapter 6 covers fluid mechanics at a first-course level. At the expense of excluding vector calculus, a lot of algebra is presented (almost 40 equations). In defence of this style, students with less mathematical background can follow the logical progress of the exposition from beginning to end. However, they will not learn of the unique difficulties of fluid mechanics which are an inevitable result of the nonlinear terms, nor will they begin to develop the experience necessary to handle such problems. For flow at very small Reynolds number, or simple flows in one direction, this chapter is a useful preparation.

A number of problems are treated which are peculiar to geological fluid mechanisms, such as buckling and folding, diapirism (Rayleigh–Taylor instability), post-glacial rebound, and aquifer flow. (Why didn't this go into the later chapter on flows in porous media?)

The subject area of convection and convective cells, which is so central to the cooling of the Earth, is treated in two sections – one concerned with linear stability and one concerned with a boundary-layer model of a convection cell. The student will not be aware of many peculiarities of convection, for example that there can be more than one scale of convection rolls, or that boundary conditions, viscosity variation or phase changes will strongly affect convection cells. Some of these features are mentioned in some of the collateral reading but there is no reference to them in the text. There is also no mention of numerical simulations such as those by McKenzie, Roberts & Weiss (*J. Fluid Mech.* **62**, 465–538, 1974) which illuminate many features of convection. It is understandable that everything cannot be included, but possibly some of the many geological examples were included at the expense of more basic problems.

The next chapter, Rock Rheology, presents some more general flow-deformation behaviour. The subject of mechanisms of creep (diffusion and dislocation) is described with a simple estimate tying this movement of objects to macroscopic properties. The chapter goes on to describe temperature and stress-dependent rheologies. Possible rheology of mantle parameters follows, and some discussion of mantle convection is given. In most cases the flows in the examples given are reduced to those with variable viscosity. The chapter closes with some descriptions of viscoelasticity and elastic–plastic behaviour.

Chapter 8 covers faults, a specialized excursion into sliding friction, and its relation to geological faults, earthquakes and displacement. There is a solution to a model of elastic deformation in stick–slip faulting which could as well have been placed in the elasticity section, and a solution to thermally activated creeping solids which could have gone into the heat-transfer or rheology section. There is also some overlap with other sections. More than likely the authors felt that faults are so central to geomorphology that a separate section was warranted. This will probably please the geologist and educate the non-geologist.

The last chapter is on flows in porous media. One wonders whether it was added as an afterthought, since it could have been more logically placed near the fluid-mechanics chapter. Numerous examples are given, and the structure of the chapter closely parallels the fluid-mechanics section. The chapter starts with D'Arcy's law and flow in one direction. There is then a similarity solution to the spread of a plume of hot water. Convection and thermal plumes are then covered, and the chapter ends with examples of magma injection and two-phase convection.

The only possible drawback of using this text alone is its lack of discussion of uncertainty in some parameters, particularly viscosity. The typical student, who will have little experience with which to evaluate some statements in the book, might be misled into adopting numbers verbatim, even though some aspects are speculative. The discussion gives the impression that the numbers are established fact rather than the best currently available (with high uncertainty). Potential users of the book should be alerted to this.

In the fluid-mechanics sections, one serious omission is the lack of treatment of double diffusion. The recent, impressive work connecting double-diffusive dynamics to questions of the compositional evaluation of crystallizing materials is completely left out. This is unfortunate, and at best is a measure of how quickly aspects of geological fluid mechanics can evolve. Those who wish to inform their students on this subject might want to consult some recent articles such as 'Replenished magma chambers: effects of compositional zonation and input rates', by Huppert, Turner & Sparkes (*Earth Planet. Sci. Lett.* **57**, 345–357, 1982).

The book is provided with generous appendices discussing units, physical constants and properties of the Earth (although I am curious about the sources of some data, such as the temperature of the mantle to 2885 metres). SI units have been adopted instead of the more traditional c.g.s. units, but there is an adequate appendix showing the conversion.

As a textbook, this volume stands alone – there is no competing book at present. There are numerous illustrations and exercises, with answers to selected problems. Some of the exercises are of graduate level. For some reason no answers are given in chapters 8 and 9. There is a lot of algebra in places (over 1700 equations). Although one can understand the authors' desire to avoid making too many approximations or being too abstract, following the algebra will take up a good deal of the student's time. The large number of equations is also undoubtedly a factor in the price, which is relatively high for a textbook. The ideas behind the sequencing of the chapters are not apparent; one would have thought that grouping all the solid mechanics together and all the fluid mechanics elsewhere would have been more logical and avoided some repetition. Those who adopt this book for a course might want to group the subjects differently. In any event, in grouping the various problems in their geological contexts, in explaining geological terms in a mechanical context (and vice versa) and in collecting appropriate references and worked examples, the book will undoubtedly stimulate further research in the field of geological solid and fluid mechanics.

J. A. WHITEHEAD

The Cambridge Photographic Atlas of the Planets. By G. A. BRIGGS and F. W. TAYLOR. Cambridge University Press, 1982. 255 pp. £12.50.

Hundreds of millions of Earth dwellers are familiar with the names of the probes launched into space during the past two decades, as part of an expensive and highly publicized campaign of 'planetary exploration' carried out largely by the world's two 'superpowers'. Thanks to the television cameras on board some of these probes, particularly those involved in the 'Voyager' mission to the outer planets, tens of thousand of images of various objects in the solar system are now available for study and interpretation by geologists and atmospheric scientists. Dr Briggs and Dr Taylor have made a careful selection of about 250 of the best of these pictures and built around them readable non-technical summaries of what is known about planets Mercury, Venus, Earth, Mars, Jupiter and Saturn and their satellites, together with maps of these objects. The chapters are set out with the text in block first, followed by the figures, each of which is accompanied by a long caption describing the essential points.

Fluid dynamicists will be particularly interested in pictures of cloud patterns on many scales in the atmospheres of Venus, Earth, Mars, Jupiter and Saturn. The interpretation of these pictures presents a challenge to atmospheric scientists, and, when, as in the cases of Jupiter and Saturn, the cloud pictures are virtually the only observations available, there is the added problem of having to use the data to infer the vertical structure of the atmosphere. (How well, one wonders, could a dynamical oceanographer infer the mean depth of the oceans from satellite pictures of surface flow or temperature patterns?) As might be expected, controversies abound amongst the theoreticians. Can the super-rotaion of Venus's atmosphere at many times the speed of rotation of the underlying planet be accounted for in terms of the internal redistribution of angular momentum by convection, or is it necessary to invoke external gravitational torques? Is the centuries-old Great Red Spot on Jupiter a

Taylor column, a soliton, a modon, a hurricane or a barcoclinic eddy? Are the other long-lived anticyclonic eddies on Jupiter such as the three White Ovals (that were seen to form in 1939) dynamically similar to the Great Red Spot, and why are there no long-lived eddies in the Earth's atmosphere? What produces the sharply bounded equatorial jet stream in Jupiter's atmosphere and why is the corresponding feature on Saturn much wider and faster?

These are not idle questions; their investigation has already led to significant studies in basic geophysical fluid dynamics, many of which have been reported in the pages of the *Journal of Fluid Mechanics*.

R. Hide

Special Relativity: The Foundation of Macroscopic Physics. By W. G. Dixon. Cambridge University Press, 1st paperback edition, 1982. 261 pp. £9.95.

Relativistic effects do not feature in standard courses on fluid dynamics. In a gas of particles of mass m at temperature T these effects would be significant when $kT > mc^2$, i.e. $T > 10^{10}$ K for electrons. Small relativistic corrections may become necessary in plasma-fusion calculations, but otherwise relativity is apparently irrelevant for terrestial problems, although the interaction of fluids with radiation is an important astrophysical problem. Why then should hydrodynamicists read a fairly difficult textbook on special relativity?

One of the more unexpected products of the renaissance of relativity in the last 25 years has been the realization that macroscopic physics is conceptually simpler when couched in a space–time (4-dimensional) formalism. This is well known in electrodynamics, but also holds true for other fields such as thermodynamics. A fluid is described by a mass-flux 4-vector whose divergence vanishes, giving the usual continuity equation, and a symmetric, rank-two, energy–momentum tensor whose divergence also vanishes, expressing conservation of energy and of 3-momentum. Entropy appears too as a 4-vector $S^a = (S, \boldsymbol{q}/T)$, where S is the entropy density and $\boldsymbol{q}$ the heat flux. In this formalism the second law of thermodynamics becomes $\operatorname{div} S^a \equiv \nabla_a S^a \geqslant 0$.

Dixon's monograph is in fact a detailed review of macroscopic physics from a relativistic viewpoint. He assumes very little other than a degree of sophistication on the part of the reader. Axioms are introduced and justified carefully, so much so that the first half of the book is taken up with the mathematical framework and relativistic dynamics. The remainder consists of two chapters on the dynamics and thermodynamics of simple and polarizable fluids. Both equilibrium and non-equilibrium processes are treated in considerable detail in a most elegant and self-contained description. At the end of each chapter, Dixon shows how to recover the Newtonian theory as a limiting case.

My only regret is that Dixon failed to include a chapter on the kinetic theory of relativistic gases. In both the classical and relativistic theories the treatment of thermodynamics presented here was suggested by an analysis of the moment equations derived from the Boltzmann equation, and this could have been used to motivate the discussion. He could also have shown that the equations of thermo-hydrodynamics form a hyperbolic system, thus guaranteeing causality. This is, however, a minor point. Dixon presents many fundamental ideas with great care, elegance and economy of axioms. Inevitably this does not make for easy reading, but the reader who perseveres may expect to gain deep insights into the thermodynamics and electrodynamics of fluids.

J. M. Stewart

Theory of Laminar Flames. By J. D. BUCKMASTER and G. S. S. LUDFORD. Cambridge University Press, 1982. 266 pp. £25.00.

As the authors remark in their preface it would not have been possible to write this book a few years ago, notwithstanding the fact that combustion has been with us, as helpmate or handicap, for a very long time now. Attempts to theorize about it are of relatively recent origin. Until the establishment in the mid 1960s of the method of matched asymptotic expansions as an approximate analytical technique of much wider utility than in the treatment of viscous flows (for which purpose it owes its origins to Prandtl) the theory of gaseous combustion was a theory even more than usually bedevilled by nonlinearity. Specifically, great difficulty is provoked by the nonlinearity that is intrinsic to even the simplest conceivable chemical reaction. The expression for the rate of chemical energy release to a gas stream must usually contain at least the product of a pair of reactant concentrations, or the product of a single reactant concentration with a factor of the form $\exp(-\theta/T)$. Here T is the absolute temperature of the gas and θ is a fixed temperature, characteristic of the particular reaction, which is related to its required activation energy (Arrhenius, *Z. Phys. Chem.* **4** (1889), 226–248. Usually the expressions are more complicated than this. Various devices to circumvent the difficulties of nonlinear chemistry were proposed and used with varying degrees of success until quite recently.

In the case of diffusion flames, which arise when the reactant chemical species are initially separated from one another, so that these species therefore mix and react simultaneously, it was proposed by Burke & Schumann (*Ind. Engng Chem.* **20** (1928), 998–1004), with support from some ingenious *ad hoc* arguments, that one should consign the complicated chemical reactions to the vanishingly thin interior of a sheet or surface. The latter is then a sink for the reactants, which must be presumed to be totally consumed at the sheet. The problem is thus reduced to the much more tractable one of two contiguous, effectively chemically inert, domains of combined convection and diffusion. This model is remarkably effective in predicting many general properties of energetically burning diffusion flames. Today we recognize that the diffusion flame sheet appears as the logical consequence of the application of a parameter limit in a properly chosen coordinate system. The parameter in this case is a typical Damköhler number, namely the ratio of a time representative of diffusion and a time representative of the rate of progress of the chemical reactions themselves.

Many flames occur in initially cool reactants that are already pre-mixed, and therefore reacting, albeit extremely slowly. A traditional model of these premixed flames ignores the slow ambient reaction and treats the whole flame as a diabatic discontinuity whose properties can be determined by classical Hugoniot-curve and Rayleigh-line methods. Whilst useful for some purposes, this model of premixed flame behaviour is generally less successful than is the Burke–Schumann diffusion flame sheet. This is largely because it leaves the flame as a two-parameter discontinuity; to be specific one must choose both the strength of the flame (e.g. temperature rise) *and* its speed of propagation. One might expect to have to choose the strength, by selection of type and quantity of reactants for example, but observations of real flames long ago suggested that such a choice also fixes the speed of propagation of the flame within fairly narrow limits. The reason for this somewhat unsatisfactory old-fashioned discontinuity model of premixed flames is that their structure is *not* a consequence of a simple Damköhler-number limit. Indeed what typifies a premixed flame propagating into cold fresh reactants is not *a* Damköhler number but the fact that the *local* Damköhler number changes from very small values ahead of the flame to large values in the burnt flow behind it. When activation energy (or temperature, θ) is large the rate of change of local Damköhler number through the flame is dramatic and the possibility opens up for a rational approximate approach to its structure through the method of matched asymptotic expansions with θ as the large parameter.

The present book is an account of the rapid developments that have taken place in the theory of steady and unsteady combustion during the past decade or so as a particular result of this realization that θ can be used as a limitingly large parameter in a whole spectrum of laminar-flame problems and that, in more restricted sets of circumstances, a truly typical large Damköhler number value can be similarly exploited.

Almost the entire book is taken up with large activation energy asymptotics, and amply illustrates the extraordinary variety of physical situations that yield to this approach. For example, extinction, ignition, stability (that is to say, cellular flames, pulsating flames, and the appearance of quasi-periodic perturbations that strongly resemble evolving turbulence) are but a few of the key features of laminar combustible systems that can be described by this rational approximate technique. Moreover, its use produces a good measure of physical understanding, as well as frequently quite simple formulae to summarize the complex interacting roles played by the various parts of such systems.

The foundations of the analysis, namely conservation and other necessary equations, are described in a brief, perhaps rather sketchy, first chapter. The 'apprenticeship' that is required before one can derive the conservation equations from kinetic theory need not be 'long', as the authors suggest on page 1. The gain in clarity of exposition that comes from the adoption of the kinetic-theory approach is substantial; it avoids the concept of kinetic energy of diffusion of each separate species (see p. 3), for example, and hence the need subsequently to drop all further reference to it because it is '...non-linear in the (diffusion velocities)...' (see p. 4). This is a relatively minor point, but a second point of criticism of the introductory material is rather more important. A quantity, written as D, with the dimensions of mass flux per unit area squared, is called the Damköhler number. The authors admit that the name might '...be better applied to (a quantity written as) $\mathscr{D}$ which, as the ratio of a diffusion time to a reaction time ... measures the rapidity of the reaction.' I would go further and say that the name Damköhler number should *only* be used to describe a ratio of flow, or diffusion, time to chemical time. As indicated above, it is frequently important to distinguish between local, and therefore changing, values of this ratio and truly typical single constant ratio values. Of course the use, or misuse, of words does not lead to mathematical error, but it can lead to difficulty in the interpretation of mathematical results. Just to complicate matters the same symbol D is also used to denote a related dimensionless quantity (see pp. 14 and 15).

One senses in the first two chapters that the authors are rushing through some rather dull preliminaries in order to get at all the fascinating new material they they, and a rather small band of like-minded researchers on both sides of the Atlantic have constructed (asymptotics have apparently not found similar favour in the USSR yet). One sympathasizes readily with this wish, but newcomers to the topic, which is not easy to comprehend at the best of times, may themselves wish for a rather more easeful introduction to the riches that follow.

Developments and advances in the use of asymptotic methods in combustion theory continue. It is time, perhaps, to make haste a little more slowly, to consolidate the achievements made to date, and to investigate their limits of numerical accuracy by exploiting matched asymptotic expansion techniques to acquire higher approximations. The latter is especially desirable, in view of the fact that realistic dimensionless θ-parameter values are not often larger than about 10. Any advances that do take place from now on will do so in the light of this important monograph.

J. F. Clarke

Shorter Notices

Structure of Turbulence in Heat and Mass Transfer. Edited by Z. P. Zarić. Hemisphere, 1982, 585 pp. $75.00.

This book is a reproduction of typescripts of papers given at the IUTAM conference held at the International Centre for Heat and Mass Transfer in Dubrovnik in October 1980. The participants came from North America, Europe and Asia. The idea of the meeting was to bring together those interested in the 'physics' of turbulence (which is equated here with 'coherent' or large-scale structures) with those interested in heat and mass transfer and environmental flows, with the aim of improving the understanding of transport processes. There are interesting experimental and theoretical papers on the structure of turbulence in boundary layers, jets, channel flows with free surfaces, on heat and mass transfer, on laboratory models of environmental flows, and on two-phase flows.

The Role of Coherent Structures in Modeling Turbulence and Mixing. Edited by J. J. Jiminez. Lecture Notes in Physics, vol. 136. Springer 1981. 393 pp. DM47, $24.70.

This book contains papers presented at a conference held in Madrid in 1980. The papers are of reasonable length (up to 20 pages) so that the reader has a chance of being able to assess their measurements and analysis and judge the conclusions, which is usually not possible in short conference papers. The first section contains some new results from computer analysis, both predictions of flow structure from the equations and analysis of flow structure from visualization records, as well as some stimulating introductory comments by Saffman on coherent structures in turbulent flows.

In the second and third sections, experiments are described where techniques of flow visualization, 'conditional sampling' and pattern cognition are fully exploited to study the structure and the randomness of coherent structures in turbulent shear flows. The connection between these large-scale structures and small-scale 'turbulence' is alluded to in several papers and in various ways. Mathieu & Charney relate these findings to various mathematical models of turbulence such as large-eddy simulations to the 'eddy-damped quasi-normal Markovian' model. The papers in the third section show how the form and energy of coherent structures strongly affect combustion, mixing and noise production in turbulent flows. (They might also have included two-phase flows!) Hence their practical importance.

This is a stimulating volume which includes papers on most of the current topics of intensive interest and controversy; it should be of interest to the newcomer and those more familiar with the subject.

The Dynamic Environment of the Ocean Floor. By K. A. Franning and F. T. Manheim. Heath, 1982. 502 pp.

This book is about the whole range of physical biological phenomena and physical and chemical properties on and in the ocean floor. A few pages are devoted to fluid flow – in this case flow through porous sediments and diffusion in the turbulent benthic boundary layer.

Recent Contributions to Fluid Mechanics. Edited by W. Haase. Springer, 1982. 338 pp. DM58, $23.00.

This volume is dedicated to Professor Dr.-Ing. Alfred Walz in honour of his 75th birthday, and consists of 34 papers (by 56 authors). There is one short survey paper by Bradshaw on shear-layer studies and then very brief papers, largely accounts of recent research by the authors. It is a pity that there is no article on the life and achievements of Professor Walz or much reference to his work in the papers.

Three-Dimensional Turbulent Boundary Layers. Edited by H. H. Fernholz and E. Krause. Springer, 1982. 389 pp. DM88, $36.70.

This is a collection of papers given at the IUTAM symposium on specific experiments and computations on three-dimensional turbulent boundary layers on aerofoils, ships, in turbomachinery, over bluff bodies, and through shock waves. There is no review paper, although there is a summary of the interesting final discussion of the conference, which ought to be read by those doing research on this subject.

Hydrodynamics of Semi-Enclosed Seas. Edited by J. C. J. Nihoul. Elsevier, 1982. 555 pp.

This volume represents the proceedings of the 13th International Liège Colloquium on Ocean Hydrodynamics. As with its predecessors, it presents a wide range of papers from many countries (27 papers, at least 10 countries), and on many subjects, ranging from detailed observational work to numerical simulations. The photographic reproduction of typescript is of a high standard throughout.

CORRIGENDUM

An amplitude-evolution equation for linearly unstable modes in stratified shear flows

by L. Engevik

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Equation (2.7) should read $(U-c_s)\rho_1-\mathrm{i}\mu(\partial\rho_1/\partial\tau)=\bar{\rho}'\Phi_1$, which yields the same expression for ρ_s as before. However, $\rho_{12}=(\bar{\rho}'\phi_{12}+\mathrm{i}\rho_s)/(U-c_s)$, and therefore $\rho_{201}=(\bar{\rho}'\phi_s^2/(U-cs)^2)'$, where we have used the fact that ϕ_s is real – see appendix B. Also (2.8) should have a term $-\frac{1}{2}\mathrm{i}\mu\,\partial\rho_2/\partial\tau$ on its left-hand side, but this does not affect the expression for ρ_{21}. Since $\rho_{201}\neq 0$, there will be an additional contribution to both a_{22} in §3 and C_2 in §4. The contribution to a_{22} is found to be negative, but so small that it will have no effect on figure 3. In §4 it is found that $C_2\sim-\frac{8}{3}\alpha_s^3$ when $\alpha_s\rightarrow 0$, including this additional contribution. Therefore, in order to find the nonlinear term in (4.13), we have to carry through the calculation to order α_s^4. The nonlinear term in (4.13) is found to be $-2\epsilon^2\alpha_s^4A^2A^*$.