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REVIEWS

An Informal Introduction to Theoretical Fluid Mechanics. By JAMES LIGHTHILL. Clarendon Press, 1986. 260 pp. £25 hardback or £12.50 paperback.

Sir James Lighthill is one of the great post-war exponents of the science of fluid mechanics, particularly in relation to aerodynamics and to animal locomotion, and the publication of his introductory texbook on the subject is an event of great interest for teachers and students alike. Many admirable textbooks exist already covering the traditional fields of nearly inviscid flow, irrotational flow theory, elementary aerodynamics, and so on; and to find a mode of presentation that is better than existing texts and that is fresh and original in style, is a challenge indeed.

Sir James will not disappoint his readers on the latter score; his style of presentation is highly original, and even on the most elementary material his peculiar blend of profoundly physical reasoning combined with just sufficient mathematical structure provides a continuously provocative and stimulating diet even for the most seasoned pedagogue.

His objectives are set out in the preface: to show how mathematical reasoning can be combined with experimental observation to provide a coherent understanding of the gross features of fluid flow, whose full details may still be far beyond the power of present-day computers. His fluids are water and air, and, for the most part, they flow through conduits, or past bodies, whether animate or inanimate, and exert forces upon them. To calculate the force and infer the motion, whether of an aircraft or a blue shark or a humming-bird, provides both the challenge and the satisfaction of the subject as presented in this way.

Lighthill starts with 'lumps' of fluid, and carries integral arguments as far as they can decently be carried, in pre-Eulerian style, but with emphasis rightly on the concepts of mass flux and momentum flux in fluid flow. Viscosity is discussed in physical terms, and in Chapter 2 the inviscid 'Euler model' is developed, with stress upon the fact that it *is* a model, with inevitable imperfections. Opinions will vary as to whether this procedure is preferable to the alternative of deriving the Navier–Stokes equations at the outset; but there can be little doubt that the classical 'inviscid' approach, when suitably augmented at critical points with reference to the influence of viscosity, makes the subject more accessible and arguably more intelligible to a wide range of students of mathematics and engineering than the alternative that requires preliminary familiarity with the techniques of tensor analysis.

And yet the author cannot entirely avoid tensor territory; his analysis in Chapter 4 of vorticity and rate of strain requires familiarity with certain standard procedures of matrix algebra – e.g. the diagonalisation of a symmetric matrix – so that his eschewal of suffix notation and tensor terminology, and his insistence on writing things out in Cartesian component form at first encounter, may seem unnecessarily expansive – particularly for those students who *have* had the benefit of an introductory course on vector and tensor analysis. Students should be warned also that some statements (e.g. equation (63) defining the components of the material derivative of a vector as the material derivative of the components) are true *only* for a Cartesian system, and not for example in polar coordinates.

Chapter 5 starts with a proof of Kelvin's theorem and a discussion of its implications (but alas no mention of helicity here!), followed by a good discussion of the properties of line vortices and vortex sheets, and a (necessarily) qualitative discussion of boundary layers and boundary-layer separation, where the vortex sheet provides a most helpful idealization of what is going on. Brief allusion is made to instability and turbulence: '...all vortex sheets are found in practice to be extremely unstable: even at very moderate Reynolds numbers they readily break up into discrete line vortices...'. The discerning student may ponder how it is that a vortex sheet having finite energy density can convert itself in an energy-conserving process into a system of discrete-line vortices each of which has (logarithmically) infinite energy per unit length – well of course it can't, but the student will have to get to the frontiers of research before resolving *that* dilemma!

Having established the circumstances in which it is reasonable to treat flows as irrotational, the next four chapters (6–9) are focussed on this ideal situation, in which, magically, the essential nonlinearity of fluid flow is subsumed within Bernoulli's theorem or its various extensions. The author treats a range of problems (collapse of a cavity, flow past bluff bodies, flow past airfoils...), in each case extracting maximal insight from minimal complexity of argument – a style of writing in which the author is unsurpassed. Chapter 10 incorporates non-zero circulation in the analysis of flow past airfoils, and the final Chapter 11 treats three-dimensional aspects of wing theory, and culminates with a delightful exposition of the merits of different wing, tail and fin shapes for aerial and aquatic propulsion – a context in which Lighthill's own animations of the movement of birds and fish have delighted generations of students and their teachers in Cambridge and elsewhere.

The book concludes with a selection of about 50 problems designed to test and deepen understanding of the topics covered.

A number of topics receive scant treatment – for example the stream function is discussed only in the context of two-dimensional irrotational flow, although many would regard it as an indispensible tool for the treatment of rotational flow, either two-dimensional or axisymmetric; and other topics, which could well fit in an introductory treatment, receive no mention at all, e.g. the behaviour of vortex rings, which can so easily be visualized in laboratory or lecture room, and which so beautifully exemplify some of the basic principles of the subject. And just occasionally I found the discussion beguilingly simplistic: it is for example suggested on p. 23 that the differential equations

$$\frac{\mathrm{d}x}{u(x,y,z)}=\frac{\mathrm{d}y}{v(x,y,z)}=\frac{\mathrm{d}z}{w(x,y,z)}$$

can in general be solved to provide 'a doubly infinite assemblage of streamlines'; whereas, in fact, in this age of chaos, these equations are generically non-integrable and a streamline may wander chaotically, even for quite simple choices of (u,v,w), throughout a fluid domain; but that again brings us back to the frontiers of research!

It may be questioned also whether the author has really achieved his objectives, particularly as regards 'the world of experiment and observation' to which he pays lip-service in the Preface. There is in fact very little in the book about either experiment or observation, and no photographs of real fluid flows, nor indeed any reference to any other books or articles where such photographs may be found, nor to the various films of fluid flow that are now available to supplement any introductory course. The absence of references to primary material is understandable in a first introduction to the subject; but the total absence of any bibliography whatsoever in a field so well covered by more specialized texts, is rather strange.

No such niggle should detract from the refreshing impact of this treatment by such an authority in the subject. Scholars and students alike will be grateful to Sir James for distilling his thoughts on the basic principles of high-Reynolds-number fluid mechanics in such an accessible format; and will benefit from careful reading of a text which is the product of a profoundly original expositor.

H. K. MOFFATT

General Circulation of the Ocean. Edited by HENRY D. I. ABARBANEL and W. R. YOUNG. Springer, 1987. 291 pp. DM160.

The book consists of five well-prepared lectures, held at the Scripps Institution of Oceanography of the University of California in San Diego in the Spring of 1983. The editors of the book have chosen topics of genuine importance for the development of the problem of the general circulation of the ocean. The authors of the lectures are well-known scientists who have made substantial contributions to the discussed topics. All this has helped to compile a book that will be of great help to 'advanced students and active research workers in physical oceanography, meteorology, and geophysical fluid dynamics' interested in the problem. All the lectures are written very successfully from the pedagogical point of view so that for their study it is necessary to know only the basic concepts of fluid dynamics and physical oceanography; the necessary introductory material is given in the lectures themselves. Moreover, to a great extent each lecture is self-contained: it can be studied without reading the rest. At the same time, all the lectures complement each other and, taken together, present a very useful and coherent analysis of the general ocean circulation problem.

In the first lecture P. P. Niiler addresses the observational basis for the present pattern of general ocean circulation. At present we have a lot of data of different quality collected by means of various instruments, and very often unmatched. A real problem is to work out a critical approach to the state of the art: what is really already known about ocean circulation, both surface and abyssal, and what is still of controversial value? The lecture by P. P. Niiler is very interesting first of all in developing a critical discussion of available data.

In the second lecture J. Pedlosky gives a review of modern theories of the main oceanic thermocline. Starting from the derivation of the basic equations and a discussion of a class of their similarity solutions, the author goes on to the recent concept of a ventilated thermocline and the corresponding theoretical analysis. It is important to note that Pedlosky has himself played a leading role in developing this new approach.

The third lecture, by G. Veronis, is devoted to inverse methods for ocean circulation. The main question here concerns estimation of water transport from temperature–salinity data. Using geostrophic and hydrostatic relations, the whole problem is easily reduced to the determination of the reference level. There are several difficulties, mainly resulting from the noisy and gappy character of the oceanographic data, that one encounters in trying to develop an adequate procedure. The author discusses the problem in full and describes a method that has led to useful and reliable results for several sets of data.

The fourth lecture is presented by W. R. Young and deals with baroclinic theories of wind-driven circulation. The whole approach discussed is very new and has recently been developed by Young, together with P. Rhines. The author introduces the concept of a geostrophic contour. It used to be thought that the geometry of geostrophic contours (closed, blocked by eastern boundaries, and impinging on the base of the mixed layer) determines the different flow regimes completely. However, for the most interesting case of a closed contour it is shown that small dissipation is necessary for selecting a unique solution. It is argued that the dominant dissipation in the general circulation is due to mesoscale (synoptic) eddies, and the homogenization of potential vorticity inside the closed contour is proved. The approach developed suggests a possible mechanism explaining the deep penetration of motions generated by surface effects.

The concluding fifth lecture by M. C. Hendershott discusses single-layer models of the general circulation. Here we find more traditional material, well organized and presented. The author reviews the basic ideas of western boundary-layer theory, both stationary and non-stationary. It is of special interest that not only is midlatitude dynamics analysed but also the peculiar dynamics of the tropics.

In conclusion I would like to stress once again that the book gives first-hand information to the interested reader. That is why I recommend this book for a thorough study not only to advanced students but also to experts.

V. M. Kamenkovich