J. Fluid Mech. (1997), *vol.* 350, *pp.* 375–378. Printed in the United Kingdom

BOOK REVIEWS

Fluid Mechanics. By Sir James Lighthill. In **Twentieth Century Physics**, Vol. II, Chap. 10, pp. 795–912. Edited by L. M. Brown, A. Pais & Sir Brian Pippard. Institute of Physics and American Institute of Physics, 1995.

Twentieth Century Physics is a handsome (and, unfortunately, correspondingly expensive) 2000-page, three-volume set jointly published by the British Institute of Physics and the American Institute of Physics and intended as 'a first step' towards the writing of the history of physics in this century. Professor Lighthill has contributed to this work a brilliant and thoroughly absorbing overview of fluid mechanics covering both a history of key developments and an account of some essential ideas. Intended for a broad audience, the coverage of topics is selective, with 'those mentioned having been chosen for their general importance and interest to non-specialist readers'. But special pleasures await the professional here, with many absolute gems of physical insight that make delicious food for reading, meditating, and teaching.

Far from being neutral, Lighthill's tone is that of an enthusiast. The thesis that he eloquently develops is that, with its impact on flight, ocean engineering, and the climate (among others), fluid mechanics has contributed to the shaping and understanding of our world on a par with the other great advances of 20th century physics. The chapter is divided into five sections that, in their arrangement and title, make the intentions of the author clear: 'Yet another great success for twentieth century physics', 'Boundary layers and wakes; instability and turbulence; heat and mass transfer', 'Non-linear effects on the generation and propagation of waves', 'Transforming the human condition through aeronautics and ocean engineering', and 'Dynamics of the Earth's fluid envelope, and its forecasting applications'.

The first section opens with a brief illustration of the idea of singular perturbations as a prelude to the explanation of Prandtl's 1904 conception of the boundary layer, a 'development by which D'Alembert's Paradox became D'Alembert's theorem'. It also gives a brief account of the early history of shock waves, with Rayleigh's and G. I. Taylor's contributions and, once again, Prandtl's work on supersonic flow in shaped nozzles, also carried out in 1904, the '*annus mirabilis* that transformed fluid mechanics'.

With 34 pages, the second section, 'Boundary layers and wakes; instability and turbulence; heat and mass transfer' is the longest one in the chapter. It describes Prandtl's recognition of the essential role of vorticity in determining lift and induced drag to the extent that, Lighthill writes, 'Twentieth century developments in the aerodynamics of aircraft wings [at low Mach numbers] have concentrated on winning ever greater quantitative precision for each element within Prandtl's fundamental picture'. A discussion of vorticity cannot of course omit a consideration of boundary layer detachment, its transition, and the effect on flow resistance. With the words 'However justifiably a historian … may adopt a heroic narrative style for outlining key discoveries on boundary layers and wakes, … such a style would be out of place for describing … turbulence research' the reader is then introduced to an account of Reynolds stresses, the 'blind alley' of mixing-length theories, Taylor's work on stability, turbulent diffusion, and homogeneous turbulence, Tollmien–Schlichting waves, Schubauer's transition experiments, Landau's model equation, Kolmogorov's theory, and other landmark developments in this field.

The central theme of the following section is the interaction of flow and waves. Here the historical mode is tempered by the wish to impart – with often beautifully simple and deep explanations – an understanding of the underlying physics. Whitham's work on N-waves, Curle's explanation of sound radiation by the interaction of fluctuating aerodynamic forces and adjoining solid surfaces, and, of course, the author's own celebrated analysis of jet noise, are featured in the first part. Surface and internal waves are then dealt with, including nonlinearity, dispersion, and the result of their balance, wave action, wave resistance, the phenomenon of along-crest energy propagation, acoustic streaming, and others.

In the following section, 'Transforming the human condition through aeronautics and ocean engineering', the derivation of the so-called aircraft range equation

$$X = (L/D)\,(1/s)\log W_0/W_1),$$

expressing the range X in terms of the lift L, drag D, specific fuel consumption s, and initial and final weights, W_0 and W_1, points to the importance of the 'respective achievements in the three professional disciplines (aerodynamics, propulsion, structures) that make up aeronautical engineering'. The reduction of induced drag by wings of a high aspect ratio, the greater efficiency attending increased speed, and the turbofan engine, are all dealt with with great clarity and simplicity. In the part devoted to compressibility effects we find, among others, a description of the shock wave pattern associated with supersonic flight, an explanation of the shape of the supersonic airliner Concorde, and considerations on the design of supersonic wind tunnels. The section concludes with Kelvin's ship wave pattern, wave resistance, Inui's invention of the bulbous bow, and offshore structures.

The last section opens with Newton's theory of tides and describes the principal aspects of fluid motion on the planetary scale. The ideas on shallow-water waves, vorticity, dispersion, etc. introduced in the previous sections are woven together to produce a unified description of the motion of the ocean and the atmosphere which includes, among others, wind patterns, tropical storms, El Niño, and weather forecasting.

As noted before, this chapter is neither a comprehensive history of 20th century fluid mechanics nor a full account of the ideas of the field. To mention a topic where the author himself has made important contributions – thus dispelling any hypothesis of bias in the selection of subject matter – there is no mention of low-Reynolds-number flow, swimming, or flying in Nature. Drops, bubbles, and other multiphase flows such as suspensions are entirely absent. Several other 'omissions' can readily be cited, but this would miss the point of the work. Of course, fluid mechanics pervades our life and the technology that surrounds us in manners that go beyond the ground covered here. But if the intent is to point to a few landmark achievements that had a dramatic impact on the human condition in the century that is coming to a close, it would be difficult to disagree with Lighthill's choice of material.

Just as selective as the choice of topics is that of the scientists featured in these pages and the prominence accorded to them. As may already be clear from the previous summary, the great hero is Ludwig Prandtl whose 'revolutionary discovery of the boundary layer in 1904 had the same transforming effect on fluid mechanics as Einstein's 1905 discoveries had on other parts of physics'. One does not have to be convinced that this work – overall – was greater than that of a Rayleigh or a Taylor to recognize that his impact on the fluid mechanics of flight was superior to any one else's in this century.

A hundred pages are insufficient to do justice to the history and conceptual structure

of such a vast field. On the historical side, for example, and to remain with Prandtl, one would be interested in the role played by Kirchhoff's 1869 free-streamline theory in orienting his thinking, in the influence of Lanchester's ideas on the development of the lifting line picture, in a nuanced discussion of the contributions of his many gifted collaborators. Many questions of this type concerning Taylor, von Kármán, Kolmogorov and all the other greater and lesser protagonists quickly come to mind and one wishes that Lighthill might some day devote a longer work to a more comprehensive coverage of this terrain.

Often, what scientists know about the history of their subject and its relation to others is the result of piecing together fragments gathered with a fair degree of randomness. It may not be clear why certain questions were asked at a certain time nor how the answer that we have in our textbooks was arrived at. One of the great pleasures of reading this chapter is to see how things hang together, the logic – both conceptual and historical – in the chain of arguments and events that took us to the present. It is sometimes said that a historical viewpoint in the teaching of science does not make for good pedagogy. This chapter may induce the reader to reconsider this notion.

A. Prosperetti

Flow around Circular Cylinders; Volume 1. Fundamentals. By M. M. Zdravkovich. Oxford Science Publications, 1997. 672 pp. £120.

This book has emerged from the lifetime's work of the author. His publications have included eight comprehensive reviews: in particular these cover the subjects of oscillating cylinders, cylinders in waves and flow in tube banks. These subjects are treated in the forthcoming Volume 2, on Applications, the contents of which are included in the contents pages of Volume 1. The referencing system is a help to the reader. It also contains somewhat hidden information in the form of references which are not quoted in the text but which relate to particular sections. These would have been better included in one sentence at the end of the sections concerned.

Volume 1 is divided into parts A, B and C. Part A treats a nominally two-dimensional cylinder over the whole range of Reynolds numbers *Re*. An overview of the section is given in the first chapter. The difficulties of precise definition of ranges of *Re* is attributed to 'disturbing, influencing and governing parameters'. Throughout the book original photographs of flow visualization are well reproduced. There are also interesting, informative and appealing historical footnotes. In general the text is easy to read.

Chapter 3, the first lengthy chapter, treats the periodic laminar wake and is followed by transition to turbulence in the wake in chapter 4 and in the shear layers in chapter 5. The *Re* for the start of oscillations shows a discrepancy between values obtained from flow visualization in water and hot wires in air. It is not noted that the difference is between values in towing tanks and wind tunnels. Roshko's stable, unstable and irregular ranges of vortex shedding and Williamson's modes of shedding and attendant discontinuities associated with parallel and inclined vortex shedding and their interaction are discussed in chapter 4. There is, however, no mention of the effect of free-stream turbulence on measured quantities. Chapter 5 starts with three stages of transition in Roshko's irregular state: transition waves, transition eddies and turbulence. Varicose and antisymmetric instabilities are discussed. Chapter 6 covers higher *Re* up to 10^6 and the transition in the cylinder boundary layers and begins with

a table of influencing parameters L/D, B/D and free-stream turbulence intensity. Here and elsewhere credit is given to the pioneering work of Mark Morkovin.

In Part B theoretical models are discussed. Here the stress is on the early history of the solution of the Navier–Stokes equations including the earlier vortex methods. There is no mention of more modern work except by way of 'hidden' references to Leonard, Saffman and Braza *et al*. Turbulence models are not considered. Convective and absolute instability are discussed briefly.

Part C deals with real flow effects. The current practical applications concerning atmospheric and oceanic boundary layers are documented in chapter 15 and the subject of heat exchanges in chapter 17.

Chapter 18 concerns aeolian tones, and Lighthill's theory of aerodynamic sound is outlined. I was pleased to see that Shaw's acoustic theory was included even though it was not accepted when first introduced. There is a possible relevance to absolute instability here.

There are some typographical errors throughout the book but it takes very little ingenuity to sort them out: the flow of this very readable book is not disturbed. Research into the flow past circular cylinders will continue. The book will form essential introductory reading for those entering the field.

J. H. Gerrard