# REVIEWS

**Fluid Dynamics.** By D. E. RUTHERFORD. Edinburgh: Oliver and Boyd, 1959. 226 pp. 10*s*. 6*d*.

**Hydrodynamics.** By D. H. WILSON. London: Edward Arnold (Publishers) Ltd., 1959. 149 pp. 30*s*.

When Sir Horace Lamb's *Hydrodynamics* was first published in 1879, fluid dynamics was a sufficiently compact science to make it possible for an author to record most of the known principles and many of their more important applications between the covers of a single volume. During the subsequent half-century the subject grew to such an extent that, when the last edition of Lamb's famous book appeared in 1932, it was, despite its greatly increased content, already a rather unbalanced account of the subject as a whole. And during the last quarter-century the scope and depth of the science has increased beyond all recognition, making the idea of a single all-embracing treatise quite obsolete.

But the idea of an elementary textbook, designed to give students of theoretical fluid dynamics a broad introduction to the whole subject, is not obsolete. Indeed, it must never become so if the teaching of fluid dynamics in standard university courses is to retain its usefulness. The writing of such a book, however, presents the author with a very difficult problem, that of choosing appropriate material. Moreover, he is not entitled here, as he may be in the writing of a monograph or more advanced treatise, to let his own interests dictate the choice. For the relative space devoted to each topic will be regarded by the student as a measure of the relative importance of each topic, so that if the student is to get a reasonably well-balanced picture of the modern subject the choice of material is of comparable importance with the way it is presented. Dr Rutherford is therefore to be congratulated for producing a book which gets away from the idea that elementary fluid dynamics consists mainly of techniques for solving problems concerned with the irrotational flow of a liquid. This, indeed, is the chief virtue of the book under review. So many books dealing almost exclusively with potential flow have been published over the years that one almost feels that Lamb's great book has, through no fault of its author, cast a shadow, rather than a light, over the teaching of the subject.

Nevertheless, Dr Rutherford's choice of material is not as well balanced as it might be. Of the five chapters, the first (39 pages) deals with the basic concepts, the next two (90 pages) with non-viscous incompressible flow, the fourth (62 pages) with compressibility, and the last (29 pages) with viscosity. By almost any standards, viscosity has here received far less than its fair share of attention, and this becomes even more apparent when one examines the content in more detail. It seems strange, for instance, that a book which can find space for the transonic modification of linearized compressible-flow theory contains only a descriptive account of boundary-layer theory, culminating in the remark that many features of this theory are unsatisfactory. And surely much of the point in teaching the elements of viscous flow is to give the student some sort of mechanistic explana-

tion of the more artificial devices of non-viscous flow theory, such as Joukowski's hypothesis in aerofoil theory. Yet, in this particular connexion, we read (p. 67) only that the fluid velocity is infinite at the trailing edge 'unless we adopt' this hypothesis.

Dr Rutherford is at his best when treating the more formal parts of the subject. His style of presentation is then brilliantly clear, and in this respect the high standards of the University Mathematical Texts are certainly maintained. He is at his worst, and occasionally it is quite a bad worst, when discussing general principles and their background ideas. It is especially unfortunate, for instance, that we read near the beginning of the book (p. 4) that non-viscous flow theory 'will lead to results which approximate to the motion of those parts of a real fluid which are far from rigid boundaries'. Someone who is already familiar with the theory of laminar flow at large Reynolds numbers might be able to twist the meaning of these words into a description of the truth; but the raw student, with only three pages behind him, will take them literally and thereby gain a completely false picture of the role of non-viscous flow theory in fluid dynamics. Many other potential sources of misunderstanding occur throughout the book, though perhaps none is as serious as the one just mentioned. Typical examples are the failure to qualify the statement of Kelvin's circulation theorem (p. 34) to allow for the important class of rotational flows caused by gravity, the absence of any discussion of the thermodynamic significance of the purely formal definition of pressure in viscous flow (p. 199), and the curious use of the low Reynolds number approximation to neglect the 'stretching' terms, but not the 'convection' terms in the three-dimensional vorticity equation (p. 206). Less important, but nevertheless annoying, is the repeated mis-spelling of the name of Osborne Reynolds, in the form 'Reynold's number', in the last chapter.

The book as a whole leaves one with the impression that it has been written by a naturally lucid author who is, on this occasion, writing outside his normal field of study.

By comparison, Mr Wilson's *Hydrodynamics* follows a traditional pattern much more closely: it is what it claims to be, an introduction to classical hydrodynamics written for students of mathematics and theoretical physics. The opening pages are concerned with vector analysis and the connectivity of spaces, and throughout the following chapters on equations of motion, two-dimensional motion, two-dimensional vortex motion, conformal representation, and axisymmetrical motion, the formal mathematical spirit of these first few pages seems to persist. In fact, these chapters tend to read like a mathematical essay based on a set of axioms to which the underlying physical ideas are quickly reduced, and there is a danger here that the student will forget that he is reading about fluids rather than a class of vector fields satisfying certain constraints. However, the analysis itself is both well presented and suitably up-to-date (it includes the relatively recent circle and sphere theorems of Milne-Thomson, Weiss and Butler). The principal omission from this introductory account of classical hydrodynamics is the theory of wave motion, and it might have been better, for the sake of homogeneity at least, to replace the final brief chapter on viscosity by one on waves.

The most serious drawback of Mr Wilson's book is the one already implied at the beginning of this review, that a study of classical hydrodynamics by itself cannot nowadays be regarded as an adequate introduction to fluid dynamics. If an undergraduate were able to spend the whole of his time studying only fluid dynamics, a book of this kind might well be a suitable text for the appropriate courses; but for a course whose length reflects the legitimate demands of other subjects, such an unbalanced account cannot be recommended.

IAN PROUDMAN

**Turbulent Transfer in the Lower Atmosphere.** By C. H. B. PRIESTLEY. University of Chicago Press, 1959. 130 pp. 28*s*.

The scientific study of the vertical transfer of heat and water vapour in the lower atmosphere dates effectively from 1911 when the liner *Titanic* struck an iceberg in fog on its maiden voyage across the Atlantic and foundered. It hardly needed this fatality for meteorologists to realise the importance of transfer processes, but the event led to the *Scotia* expedition to the Newfoundland Grand Banks in which G. I. Taylor participated. His observations laid the foundations of the theory of turbulent transfer in the atmosphere and of air-mass modification deriving from the transfers (as recorded in the early papers in volume 2 of *Scientific Papers*, by G. I. Taylor). Water vapour (latent heat) is wholly supplied and sensible heat partly supplied to the atmosphere from below by turbulent process, and the total of this supply of energy, deriving ultimately of course from the sun, is the main source of power for the atmospheric engine. The flux of momentum from air to surface is a concomitant of the energy fluxes and provides the only external force, other than gravity and mountain drag, to which the lower atmosphere is subjected.

Taylor's theory was expressed in terms of an eddy transfer coefficient related empirically to some representative wind and difference of temperature in the vertical, and was applied to transfer processes over more or less deep layers. That was followed, in the decade or so before the last war and immediately after, by the application of boundary-layer knowledge, primarily to the lower part of the affected layer in which turbulent fluxes could be assumed independent of height. Attention was directed particularly to the determination of surface fluxes from the vertical variation of macroscopic (mean) properties, of wind speed, temperature and vapour pressure. The quantitative effect of thermal or density stratification on the transfer process did not, however, readily appear.

Dr Priestley, who has led an active group on transfer study near Melbourne over most of the post-war period, now provides us with a monograph which takes up the story of transfer at roughly the above stage and describes the recent theoretical and observational developments, largely in terms of the work of his group. The accent again falls on transfer in the constant flux layer, now with particular reference to mechanism and to the effects of thermal stratification, and mainly in respect of heat transfer. But the behaviour of deep layers is also critically considered.

Following the introduction, the author first discusses the eddy flux and its measurement near the surface, enlarging separately on the shearing stress in relation to the wind profile, and on heat convection in relation to the temperature profile. There is then a chapter on the spectrum of turbulence and the structure of free convection followed by a theoretical treatment of buoyant motion, the latter along the lines of Priestley's recent work but with attention paid also to Morton, Taylor & Turner (*Proc. Roy. Soc.* A, **234**, 1956, 1). Special aspects arising in the study of evaporation are considered briefly and the book then concludes with a thoughtful discussion of the application of transfer theory to what is commonly called synoptic meteorology, the concern being with 'the pattern in space and time of the surface heating or, more generally, that of the total energy source' in relation to typical weather systems.

The direct measurement of energy and momentum fluxes at the earth's surface itself is usually difficult and often impossible, for which reason the general tendency is towards measurements of fluxes *near* the earth's surface by the co-variance technique, the vertical flux of heat, for example, being given by $\rho c_p \overline{w'T'}$, where $w'$ is the vertical component of eddy velocity, $T'$ the associated temperature anomaly and $\rho c_p$ the heat capacity per unit volume. These measurements, however, are also far from simple, as is now well known, and reliable values are only to be obtained from instruments with a wide frequency response and much labour. The efforts of Priestley's group to make representative measurements over a wide range of stability (or of Richardson number) are to be highly commended. Yet the fact that a majority of these measurements missed, by selective sampling in frequency, significant fractions of the fluxes (up to about 30 %), indicates the scope for much further effort. Moreover, there is evidence now from more than one source that the spectral form of the momentum and heat flux covariances may be materially different, so that the ratio of eddy viscosity to eddy diffusivity which is inferred from the fluxes and gradients may be distinctly uncertain. One does not regret the author's attempt to assemble inferences from the data, whose limitations are not glossed over, but some of the inferences at least must temporarily remain in doubt.

No work of consequence has been done in the laboratory on heat transfer in boundary layers whose structure is affected by the heat transfer or thermal stratification in the layer, on account of the difficulty in obtaining large (positive or negative) Richardson numbers in the laboratory. Priestley, therefore, can only appeal to observation in the real but uncontrolled and somewhat 'messy' atmosphere for empirical relations concerning forced convention which can provide a test of theory. The case is otherwise for free convection from plane surfaces, with the work of Malkus and Townsend among others, but the author has not seen fit to consider this in relation to the atmospheric data and theory except for passing reference to Townsend. Perhaps the laboratory studies need to be taken further before they can be used effectively in the meteorological problem.

The current position regarding the relation of vertical fluxes near the earth's surface to the 'external' parameters, the latter depending on the problem posed, is that there is a reasonably valid body of knowledge available for conditions

sufficiently near neutral static stability and, for heat flux only, in conditions so unstable that free convection obtains. Some understanding of the intermediate (general) condition and the case of extreme stability begins to appear, but theory is halting and good observation still needed. Priestley gives an admirable account of the position and shows how theory and recent observation are leading to better understanding of the relevant mechanisms. If he implies greater penetration than is perhaps justified, that is excusable in one who has made, directly and indirectly, so considerable an impression on the subject. The reader must keep his wits about him and he may then be promised a stimulating experience, in which physical intuition and discipline will be found the master of mathematical detail. One would have liked an author's prospect at the conclusion of each main section, but its absence encourages the reader to supply his own and thereby perhaps to balance his own view against Priestley's as to just how far the subject has got. The aspects of dynamical meteorology which characterize the subject and make it strange to fluid dynamicists, namely, those arising from rotational and baroclinic effects, are largely absent here, and it is to be hoped that they will look carefully at this monograph. A fluid dynamicist can read it out of his own experience and perhaps, as a result, assist the meteorologist in his tremendous task.

P. A. SHEPPARD