REVIEWS

Fluid Mechanics. By Victor L. Streeter (3rd ed.). McGraw-Hill, 1962. 555 pp. 69*s*. 6*d*.

Mechanics of Fluids. By Irving H. Shames. McGraw-Hill, 1962. 555 pp. 69*s*. 6*d*.

Essentials of Engineering Fluid Mechanics. By Reuben M. Olson. International Textbook Co., 1961. 404 pp. $10.50.

The winds of change have been blowing hard in recent years through American technological education. Departmental barriers have been torn down and some new ones erected, courses and syllabuses have been profoundly modified, new unities and groupings of subject matter have been sought and many brave new text-books have been written. Fame in the space age is the spur; and if in consequence these changes have sometimes been made with too calculating an eye on what is currently popular in government research agencies or have sometimes been too violent and extreme or occasionally have been made for no better reason than to follow the fashion, nevertheless the general trend has been in the right direction. Theoretical foundations have been laid more rigorously and the contents of the courses have become more scientific with less emphasis on the mere acquisition of data and the learning of techniques.

However, as Mr Olson says so succinctly in the preface to his book 'fluid mechanics is fluid mechanics', by which he means to stress the fundamental character of the subject; it is and will always remain a well-defined basic subject of study for all engineers. However, this also implies that the subject is not easily eroded or modified by the winds of change. The subject certainly experienced a major change years ago when Prandtl's boundary-layer theory bridged the huge gap between the elegant, classical hydrodynamics of inviscid flow and the seemingly crude, if useful subject of hydraulics. Fluid mechanics was then able to develop on a sound basis and, with aeronautical developments setting the pace, it rapidly achieved scientific maturity. Further major changes can only come in the development of specialized and advanced off-shoots such as hypersonic flow, rarefied gas flow and magneto-hydrodynamics; for the essential core of the subject at the level of an elementary text-book for undergraduates, the changes can only in the main be limited ones of emphasis and presentation. These three text-books exemplify this point. Professor Streeter's book is the third edition of a book first issued in 1951 and the largest changes from the earlier editions are a revision and extension of the treatment of compressible flow and the introduction of vectors. The subject-matter of his book is in essentials much the same as that of the other two books by Professor Shames and Mr Olson. Thus, all three books aim to cover at an elementary level for engineering students the basic properties of fluids, the elements of thermodynamics, hydrostatics, fluid dynamics (the equations of continuity, momentum and energy), dimensional analysis and dynamic similarity, a few elements of potential flow, viscous effects and boundary layers, compressible flow, flow in ducts, pipes, open channels and nozzles, drag and lift, turbo-machines and flow measurement techniques. These are by and large the standard topics of all reputable text-books in fluid mechanics since the appearance of the third edition of Prandtl's superb little classic *Strömungslehre* in 1942 (later published in English as *Essentials of Fluid Dynamics*, Blackie, 1952).

However, these three books certainly differ in treatment and emphasis. Professor Streeter's book is terse, business-like and concentrated. It has few airs and graces. It covers rather more ground than the other books and is unashamed in the detail devoted to practical and, in particular, hydraulic applications. The treatment of dimensional analysis and dynamic similarity is sensible and avoids the usual error of vesting this topic with a confusing aura of magic. It occurs early in the book and this is surely where it should be.

In contrast Professor Shames is loquacious to a fault. If it is possible for an author to be too helpful to his reader then Professor Shames is. Every possible pitfall, serious or trivial, is carefully reconnoitred and marked for future avoidance. But perhaps the most striking thing about his book is the way in which the winds of change are proudly proclaimed with the implication that the subject is presented from a significantly new viewpoint. Thus, an innocent young reader might well infer that the basic equations of continuity, momentum and energy are developed in a completely new and more fundamental way than hitherto (which they are not), and that this development is inspired by the needs of the space programme. For example, fixed and moving systems of reference axes are here labelled inertial and non-inertial space reference systems, and it is proudly pointed out that the use of the latter enables the student to consider problems of flow inside rockets and space vehicles undergoing linear and rotational accelerations. I am reminded of the lecturer in Applied Mathematics who when dealing with a problem involving a ladder leaning against a wall thought it necessary to stimulate the interest of his aeronautical engineering students by stating that the wall was a hanger wall! Again, although Professor Shames could find no room for the elements of aerofoil theory he devotes several pages to the problem of determining the axial source-sink distribution equivalent to a body of revolution at zero incidence for no other reason than it leads readily to a system of equations suitable for programming on a digital computer. Brief references are to be found in his book to turbo-jets, ramjets, rocket motors and even ionic propulsion, but the simple actuator disk theory of the propeller is omitted. Yet this theory offers perhaps the finest illustration there is for introducing the young student to basic momentum concepts. No effort and presumably expense has been spared in the printing, lay-out and diagrams of this book, for they are uniformly superb.

The book by Mr Olson comes somewhere in spirit and treatment between the other two. The writing is clear and unlaboured and the practical aspects of the subject are well emphasized. Most of the fundamentals are brought out effectively, but in certain instances very crude and approximate treatments are presented as if they were the whole story (see, for example, the treatment of boundary layers and heat transfer). The discussion of dimensional analysis comes far too late and is not very satisfactory, and the treatment of compressible flow is confined to one-dimensional flow.

All three books are liberally supplied with examples.

In general, the level of these books is roughly that of the first and second years of a typical course in Fluid Mechanics in this country for undergraduates studying civil or mechanical engineering. For such undergraduates probably Professor Streeter's book is the most useful of the three. However, it must be noted that none of the books deals adequately with boundary layers, which after all provide the key to modern Fluid Mechanics. Gravity waves receive very scanty treatment. Further, the discussions of the more aerodynamic aspects of the subject, e.g. wing theory and compressible flow, are deficient and uninspired. Conformal transformation theory and its applications are absent from all three books. For these reasons none of the books is suitable for students of aeronautical engineering whose needs are much better served by other books.

After studying these three books I found it illuminating to look again at Prandtl's book *Strömungslehre* to which I referred earlier. Certainly, the winds of change have blown and many a brave new topic has received its brief mention in the texts and therefore an impressive niche in the indexes of these newer books. But for a student wanting to understand the essentials of the subject and wanting to appreciate the unity of thought underlying its many fascinating topics and applications, Prandtl's twenty-year-old book is still in my view the best value for money. What these books have to offer the student which Prandtl's book does not, are many worked examples and more detailed hydraulic applications; presumably one should not minimize the importance of these in helping students to master particular points of difficulty and to pass examinations.

As a coda I would like to suggest to any would-be writer of yet another undergraduate-level text-book on fluid mechanics a topic for inclusion that has not hitherto found its way into such books despite the fact that current and future developments point to the need for it. I refer to an elementary treatment of the physics of fluids and their properties in terms of their molecular structure and in particular to the kinetic theory of gases. Engineering education has by and large managed very well in the past by treating the materials of engineering interest as continua. Of course the engineering student is told that the macroscopic properties of the fluids with which he is concerned as, for example, viscosity and heat conductivity, result from the discrete, molecular nature of matter, but the idea is not usually developed in any detail. It seems certain that, in the future, engineering will be concerned much more than in the past with the fact that materials, both solid and fluid, are made up of discrete particles and the young engineer should now be learning something of the physics that relates to this important concept.

A. D. Young

The Theory of Subsonic Plane Flow. By L. C. Woods. Cambridge University Press, 1961. 594 pp. 120*s*.

The application of potential theory to flows involving separations and wakes provides a rich source of boundary value problems, first explored by Helmholtz, Kirchhoff and Rayleigh. Although the gross structure of these flows is produced by viscosity, in a manner better understood now than in their day, we must still use an inviscid model to make progress in any given case. The model has to be both mathematically tractable, and consistent with the type of boundary layer and wake suggested by experience (or by a separate calculation). Apart from the classical investigations for bluff bodies, Borda mouthpieces and the like, a wide range of flows past relatively slender obstacles of interest in aerodynamics is amenable to this kind of treatment. Dr Woods has studied many of these in the past twelve years, and his book drawing the work together is an important and interesting one. His aim has been to give a unified account of past researches and of his more recent ones, using the same mathematical techniques and variables throughout. The book is restricted to two-dimensional potential flow, viscosity coming in only by implication in the choice of flow models. This limitation of the subject matter is perfectly reasonable, but may lessen the book's appeal for those whose main interest is in the physics of a flow. The book will be most useful to the research worker who already knows what his flow field looks like, and seeks ways of coping with the potential flow by which it is approximated. It will also be useful to workers in other fields—solid mechanics, and diffraction theory, for instance—in which similar boundary-value problems occur. For their benefit, the mathematical techniques have been presented separately in the first two hundred pages, an arrangement which makes for clarity in any case.

The first two chapters provide an admirably concise introduction to inviscid theory, presented with an eye to the subsequent applications. The development is in terms of the Chaplygin function $\tau = \Omega + i\theta$, Ω being $\int(1-M^2)^{\frac{1}{2}}\, dq/q$ where q is the magnitude of the velocity, θ its inclination, and M the Mach number. τ is an analytic function of position. Compressibility is introduced by means of the 'tangent gas' approximation which treats the relation between p and $1/\rho$ as linear. Except for incompressibe flow, this restricts one to small perturbations from an undisturbed stream, so the generality implied by the choice of 'subsonic' in the title is genuine only in the case of slender obstacles.

Part II, chapters 3 to 5, is an account of the parts of complex variable theory relevant to the problem of finding a function $\tau(z)$ analytic in a region, when the real and imaginary parts are prescribed on different segments of the boundary. Much of the groundwork here, although very simple—for example, the Plemelj formulae, and the Poincaré–Bertrand theorem—has only become easily accessible to applied mathematicians fairly recently through the translation of the book by Muskhelishvili, on which the author draws. The most important basic solution, used especially for channel flow, is that for an infinite strip, in which Ω takes prescribed values on the lines $y = 0, h, (-\infty < x < \infty)$, and θ tends to prescribed limits as $x \rightarrow \pm\infty$. In chapter 4, after a digression to introduce the main properties of elliptic functions, the solutions are obtained to a fascinating variety of more general problems, notably those in which the boundaries can be assembled from rectangles. Chapter 5 deals with conformal mapping.

After these preliminaries we come to the detailed consideration of a number of classes of flows that, while differing physically, are reducible to one or other of the boundary value problems already treated. The general method is set out in a few pages in chapter 6. Chapter 7, pp. 224–300, is concerned with flow in channels, under which heading occur design problems, both direct and indirect, wind tunnel blockage and the effect thereon of porous and perforated walls, and jet flows. Ventilated wind tunnels are used primarily to eliminate choking at transonic speeds, and a more important type of interference than that discussed arises from shock waves, but perhaps this is excluded by definition from the scope of the book. In chapter 8, pp. 301–363, the Dirichlet problem of finding the fully attached flow past an aerofoil of arbitrary profile, and the inverse problem in which the pressure distribution is prescribed, are treated. Also discussed in chapter 8 are Helmholtz flows involving separation bubbles, which are of course the rule rather than the exception in practice, and which Dr Woods was the first person to treat mathematically. The solution is obtained as a special case of that for the even more general class of flows in which there are regions of porosity and inflow on the aerofoil surface. Except as a means of boundary layer control, distributed porosity has not up to now been used in practice, so any interest possessed by this generalization must be mainly mathematical, and it certainly makes it harder for the reader to find out exactly how the physically interesting problems are tackled. In fact, since the solution can only be carried through in limiting cases, I wonder if these problems might not just as well have been formulated in terms of the complex velocity $w = u - iv$ and using a linearized approximation from the outset. Mixed boundary conditions can be applied just as easily on w. To be sure, the author's aim has been to treat all problems in the τ-plane, but this approach seems rather inflexible when it entails leaving out H. Glauert's simple relation between vorticity and downwash for a thin wing.

The linear perturbation approach is certainly mentioned in the course of the discussion of semi-infinite profiles in chapter 10. The most interesting example of these is perhaps the jet flap, described on pp. 407–425, for which one type of boundary condition holds on a finite interval representing the wing, and another, obtained from a separate calculation of the flow within the jet, on the remainder of the profile. This device was first investigated experimentally in 1930 at Caltech by Schubauer, who gave it the name 'jet-foil', but there seems to be a conspiracy of silence about his work. The scheme suddenly became topical in the mid-fifties, and while an adequate theory was being worked out a certain amount of discord developed between various groups of workers whose approaches were slightly different. Echoes of this persist into the author's account, which so far as the history of the subject is concerned must be recognized as an *ex parte* statement. The boundary conditions of course closely resemble those of unsteady aerofoil theory, a useful account of which is given earlier in chapter 9, pp. 364–387.

Chapter 11, pp. 426–487, deals interestingly with wakes and cavities, for which the difficulties in formulating a realistic model are formidable. For instance, unless a cavity were cusped its downstream end would have to be a stagnation point of the free stream, where the free stream pressure is a maximum, and therefore incompatible with that in the cavity. Squire's argument for determining the laminar separation points on a circular cylinder from consideration of the pressure gradient in a free streamline flow is shown to be capable of considerable generalization. Classical flows past bluff obstacles are presented with some modern notes on the wakes produced by aerofoil spoilers, and behind oscillating obstacles. One wonders whether it would also be possible to treat periodic flow past a fixed obstacle, which must have some relation to the phenomenon of alternate vortex-shedding.

In chapter 12, pp. 487–521, are treated steady Dirichlet and Helmholtz flows past aerofoils in cascade, a configuration well adapted to the earlier solutions with spacewise-periodic boundary conditions. The author's theory for unsteady flow through a cascade is also reproduced, in preference to the 'similar but less concise' treatment by Chang and Chu. The last 60 pages contain discussions of aerofoils at lift in steady motion (chapter 13) and in unsteady motion (chapter 14) in channels and jets, and in the porous-walled tunnel, a sort of half-way house between the two. These are all subjects of obvious practical interest. But the engineer seeking to correct his measured forces and moments for wind tunnel interference will have to dig deep to find the formula he needs.

Altogether this is a massive achievement, and a book one is very glad to own. My main criticism, already implied above, is that by presenting every topic strictly within the mathematical framework developed in his own researches the author has made some of the earlier work (for instance, that on aerofoil theory by H. Glauert, Theodorsen, and others) seem more complicated than it does in the original papers. One is doubtful, too, whether the generalization to compressible flow afforded by the τ-plane really offsets the extra degree of remoteness from the physical flow, especially as the basic mechanics of the flows treated in this volume are hardly affected at all by compressibility, at any rate in the subsonic speed range. Apart from these, my only general criticisms are that experimental comparisons, and critical discussion of the theoretical results—in so far as there are results—are sadly lacking, and that a number of the problems —for instance, those presented by the perforated aerofoil—are somewhat artificial. Although they are of mathematical interest, one might not have expected these generalizations to receive quite so much prominence in a book appearing, after all, in the Cambridge Aeronautical Series. The book might have made more impact if it had been shorter (and once the mathematical groundwork had been presented in the first two hundred pages, much of the analysis could have been omitted from later chapters), and if, notwithstanding the apologia in the preface, the choice of subject matter and the method of treatment had been slightly less personal. For primarily this is a monograph presenting the author's own contributions against a background of the relevant pure mathematics.

D. A. SPENCE

Fundamental Physics of Gases. By K. F. HERZFELD, VIRGINIA GRIFFING, J. O. HIRSCHFELDER, C. F. CURTISS, R. B. BIRD, AND ELLEN L. SPOTZ. Princeton University Press, 1961. 131 pp. $1.95.

This paperback contains material from one section of *Thermodynamics and Physics of Matter*, which in turn comprises Volume I of the Princeton Series on High Speed Aerodynamics and Jet Propulsion. According to the preface, the Princeton Aeronautical Paperbacks series 'has been launched (to) make available in small paperbacked volumes those portions of the larger Princeton Series which it is felt will be most useful to both students and research engineers'. The text is a direct reproduction of the original section, complete with its table of contents, section headings (which mysteriously begin with B, 1), references, and presumably errors. A rough estimate indicates that the price per page is almost the same for the paperback series as for the original clothbound series. Thus the student of special aspects of aerodynamics may afford a considerable saving to himself by waiting for the requisite paperbacks to appear.

Fundamental Physics of Gases was prepared with the same thoroughness evident in the *Molecular Theory of Gases*, a more complete treatise by three of the contributors to this work. Recitation of the principal headings gives a good indication of the content: quantum mechanics and application to molecular structure (38 pp.), bond energies (16 pp.), activation energy (14 pp.), statistical mechanics (16 pp.), kinetic theory of gases (33 pp.). To use this book the reader should have a general grasp of quantum theory in atomic physics and inorganic chemistry. Being a specialized contribution, the text contains no reference to problems of fluid flow.

The cited references and bibliography contain 42 and 6 items, respectively. The fact that only four of these postdate 1950 should not deter one since the book deals principally with fundamental theories which were developed some time ago. Happily or unhappily, depending on one's viewpoint, practically none of that experimental data which is so perishable in the field of gas physics was contained in the original text. Hence its timelessness.

To grasp the *raison d'être* of this little book and of its nine companions, namely,

Fundamental Physics of Gases	Vol. I	Section B
Liquid Propellant Rockets	II	L
Solid Propellant Rockets	II	M
Gasdynamic Discontinuities	III	D
Small Perturbation Theory	VI	E
Higher Approximations in Aerodynamic Theory	VI	A
High-Speed Wing Theory	VII	A
Flow of Rarefied Gases	III	H
Turbulent Flow	V	B
Statistical Theories of Turbulence	V	C

we must recall that the Princeton High Speed Series was conceived and launched in the late forties. Fourteen years and three general editors later, five of the intended twelve volumes have yet to appear. It is axiomatic that the appearance of any collection of works is paced by the slowest author. Resolute adherence to a fixed idea on the content of any volume then means that many sections dealing with a rapidly advancing field will be hopelessly out of date the day the volume appears, despite the conscientious efforts of those authors who got their manuscripts in on time. Such is the case with the Princeton Series. Recognizing this, the editors have wisely elected to reprint many sections which have retained both their value and popularity.

One further observation seems pertinent when the reasoning just presented is carried to completion. Why not publish the individual sections in paperback form first? Then, when a sufficient number in various general fields have appeared and proven their worth, a properly constituted series of volumes in cloth binding could grace our library shelves.

W. C. GRIFFITH