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REVIEW

A First Course in Fluid Dynamics. By A. R. PATERSON. Cambridge University Press, 1983. 528 pp. £37.50 (hb), £12.95 (pb).

Inviscid Fluid Flows. By H. OCKENDON and A. B. TAYLER. Applied Mathematical Sciences, vol. 43. Springer, 1983. 146 pp. £10.85 (pb).

Both these books are written for mathematics undergraduates at British universities, in the majority of which Applied Mathematics is a compulsory part of the course. In Britain, moreover, Applied Mathematics rightly involves the study of the applications as well as of the mathematics, and most of the standard applications arise from the physical sciences. Some courses restrict themselves to the formulation of physical laws in mathematical form and to the demonstration of how mathematical techniques have led (and can still lead) to fundamental advances in physical understanding. In a subject like Quantum Mechanics, for example, this is the only possible approach and it is educationally extremely valuable. Something more is needed, however, if we are to help prepare our undergraduates to play a useful role in those areas of modern industrial society that are not concerned with the frontiers of physical research. We must try to give them some experience of *modelling*, formulating the essential features of real, possibly unfamiliar, problems in mathematical form and obtaining practical results therefrom. A subject like Fluid Mechanics is, as readers of this Journal will know, a particularly suitable one for the development both of modelling on the basis of established physical laws, and of the understanding of subtle physical mechanisms; for that reason it must remain central to the teaching of Applied Mathematics, in the U.K. and elsewhere.

The authors of these two books are well aware of the value of Fluid Mechanics in this context. To quote from the preface of Ockendon and Tayler: 'Applied Mathematics is the art of constructing mathematical models of observed phenomena so that both qualitative and quantitative results can be predicted by the use of analytical and numerical methods...Fluid Mechanics offers a rich field for illustrating the art of mathematical modelling.' Or as Paterson says: 'The fluid dynamics in this text provides many examples of this reduction of reality to a simple model which can be treated mathematically and which shows the nature of the phenomenon under discussion'. Their hearts are thus in exactly the right place; their approaches, however, differ considerably.

Paterson's book is based on a course given to second-year students at Bristol University. He assumes that they have had courses on vector calculus (including simple Cartesian tensors), differential equations and Newtonian dynamics, but no previous continuum mechanics. The order of the material, in seventeen chapters, is fairly conventional: kinematics (including rate of strain and vorticity), hydrostatics, elementary thermodynamics, stress, the Navier–Stokes equations and simple exact solutions for viscous flow, inviscid fluids and Bernoulli's theorem, potential flow and the force on accelerating bodies, simple linear acoustics, simple linear surface and interfacial waves, one-dimensional gas dynamics and shocks, one-dimensional hydraulics including bores and solitary waves, complex potentials and the lift on an aerofoil at incidence. This looks like an old-fashioned course on the hydrodynamics of ideal fluids, but it is not like that because the author is constantly trying to help the students develop their own physical understanding of how fluids move, and to show them how real problems can be modelled and solved using simple mathematical tools. He wants them to see the essential physics without being overwhelmed by complicated new mathematical techniques; these are introduced gradually, with good explanations of their value. Moreover, he does not embark on an analysis of flows in which viscosity is negligible before he has explained at length the circumstances in which the neglect of viscosity is justified: thin boundary layers, flows without rigid boundaries, small oscillations, impulsive starts, etc. Another big advantage of the book is the large number of examples (with hints for their solution) attached to each chapter. They are graded in difficulty, and having to work through them will enhance a student's understanding enormously.

There are inevitably one or two places where I would have treated the subject differently: it is rather unsatisfactory for Kelvin's theorem and the dynamical laws of vortex motion to be stated, and examples of their application given, in the early kinematic chapters (chapter 5), when the proof and consequent understanding are not given until much later (chapter 10). Again, the discussion of flow in a channel with porous walls and a uniform transverse velocity (§9.3–4) is misleading, since it implies that there is no vorticity outside the boundary layer, whereas in fact the vorticity is non-zero (but relatively small) there. Also, the author does not take the opportunity to emphasize the non-trivial interaction between inertia and viscosity in this flow. Another missed opportunity is the failure to give the formula for the time of shock formation in the tube flow driven by an accelerating piston. Yet again, the discussion on p. 477 of flow separation and the Kutta condition at a sharp trailing edge is misleading (implying separation on the upper surface before the edge), and the 'reasons why the Joukowski aerofoil is not now used for most aeroplanes' are absurd. However, there are few such drawbacks, mainly minor.

The only serious defect of the book is the author's manner of writing. He chooses a chatty, colloquial style, no doubt in the interests of solidarity with his undergraduates, which unfortunately leads him sometimes into long-winded garrulity and sometimes into such serious lack of precision as to be obscure or even misleading. For example: 'outward velocity' on a cylinder for 'normal component of velocity' (p. 237); or (in discussing vorticity in a uniform shear flow) 'adjacent sheets of fluid slide over each other, and 'need rollers' to do this – the rotation rate of these rollers is an angular velocity along the direction of the vorticity' (p. 72); or 'Of course there are no such 'ideal' fluids around, but we have seen that at high Reynolds number and away from boundaries and other awkward regions, a fluid will behave in a near enough ideal fashion' (p. 205). My old English master would have marked Dr Paterson down heavily for the number of times the verb 'get' appears! The Art master would also not give very high marks for the quality of the diagrams, which appear to have been copied directly from freehand sketches and fall far short of C.U.P.'s normally high standards.

Nevertheless, Paterson's approach to the subject is exactly what this reviewer would recommend for a first course in Fluid Dynamics, and despite the grammatical differences it is a worthy precursor to Batchelor (*An Introduction to Fluid Dynamics*, C.U.P., 1967) and Lighthill (*Waves in Fluids*, C.U.P., 1978), which are best for those third- or fourth-year students becoming really interested in Fluid Mechanics. I should think that this book would also be suitable for senior or graduate Engineering students in North America.

Ockendon and Tayler's book is intended for third-year undergraduates at Oxford. They are assumed to have covered 'standard elementary material on inviscid incompressible hydrodynamics and [to have] had an introduction to partial differential equations and wave motion'. The aim is not to instil physical understanding in their students, as a fundamental part of the mathematical curriculum (perhaps that would be a lost cause?), but rather it seems to be to seduce into fluid mechanics students who already know rather a lot of mathematics and who might be entertained by seeing some sophisticated methods used to solve real problems. Ideally, Applied Mathematics would not be taught this way, but given that one sometimes has to resort to seduction to achieve one's ends, this too is a good book. The authors have chosen a number of interesting topics, and deal with each of them concisely but elegantly. The models are presented so briefly that they resemble more a set of axioms than a physical discussion, but the mathematics is powerful and can be seen to be so.

There are seven chapters. The first (19 pages of text) summarizes all the fluid mechanics and thermodynamics that the student is supposed to know already, explains that solutions of Laplace'e equation in irrotational incompressible flow will be examined only in the context of flows with free boundaries, and makes one minor howler in linking the Nusselt number with surface tension. In the 18 pages of Chapter 2 ('Free Boundary Problems') the authors in §1 introduce the hodograph method for jets and wakes; in §2 they derive the full nonlinear equations for surface gravity waves on water of finite, non-uniform depth; in §3 they derive the dispersion relation, define the group velocity and use the method of stationary phase (which the students are supposed already to know) to analyse the dispersion of small-amplitude gravity waves (including a brief derivation of the ray-tracing equations using the WKB method), and briefly discuss capillary and interfacial waves; in §4 they look at three-dimensional Stokes waves and include a derivation of the Kelvin ship-wave pattern; and in §5 they produce the modified wave equation for one-dimensional tidal waves on a channel of non-uniform depth. Phew! The rest of the book proceeds at the same breakneck speed. Chapter 3 ('Non-linear surface waves') has 16 pages; it develops and uses the method of characteristics, it analyses hydraulic jumps (including a brief use of weak shock theory), cnoidal waves and solitary waves, the last in a manner much more systematic than the *ad hoc* approximation scheme used by Paterson. Chapter 4 is concerned with compressible flow, including sub-/super-sonic nozzle flow (the discussion of choking is over-simple), one-dimensional unsteady flow (rarefaction waves in particular) and two-dimensional steady flow (including the Prandtl–Meyer expansion). Chapter 5 is on shock waves, both normal and oblique, and includes analyses of unsteady shock structure (leading to the equation named after J. M. Burgers, here given an apostrophe before the s), blast waves and high-speed flow past bodies. Chapter 6 ('Approximate solutions for compressible flow') derives the linearized equations for three-dimensional acoustics, thin-wing theory and slender-body theory, and notes their limitations in transonic or hypersonic flow. The book concludes, like Paterson's, with a chapter on complex variable methods, illustrated by particular examples such as the lifting flat plate at incidence, and attached or separated flow past a thin wing. Each chapter ends with a page or two of excellent but challenging problems.

This book (admittedly billed as 'lecture notes') contains so much material, crammed into such a short space, that the treatment is inevitably sketchy. The authors derive their mathematical solution and then move on to the next topic just when the previous one is becoming interesting, physically as well as mathematically. The enquiring mind will be left unsatisfied, but perhaps that is a good thing, encouraging students to ask questions, and lecturers and tutors to give expansive answers. In view of the renewed fundamental interest being shown in inviscid fluid mechanics these days, it is perhaps a pity that more attention was not given to vortex dynamics, but I think the seduction could be quite effective without it. My only regret is that, despite the preface, there is an absence of physical discussion and a lack of opportunity for the students to practise mathematical modelling on their own.

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