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REVIEWS

Fluid Dynamics for Physicists. By T. E. FABER. Cambridge University Press, 1995. 440 pp. ISBN 0521429692, £22.95.

This book is written by a physicist from the Cavendish Laboratory in Cambridge where G. I. Taylor worked for more than 50 years and founded much of modern fluid mechanics. The Cavendish has given working space to many eminent fluid dynamicists, including G. K. Batchelor whose influential text-book *An Introduction to Fluid Dynamics* was published in 1967. It is a sad fact that fluid dynamics nevertheless is not taught as part of the core undergraduate curriculum in Physics in Cambridge, and this book is, in part, an attempt to re-awaken physicists to the excitement of the subject. The material it covers is at the heart of fluid dynamics and is illustrated by many beautiful pictures of fluid flow. These photographs undoubtedly capture the appeal of the subject for students and professionals alike.

Chapter 1 defines a fluid and introduces some important and very powerful ideas such as dimensional analysis and similarity. By discussing the flow in a syringe a number of important ideas are given a concrete application which illuminates them in a very effective way. Inviscid flow is discussed in chapter 2 and is applied to cavitation and free-surface flows. Gas dynamics is then discussed as a direct extension of the hydraulic flow. Potential flow is the subject of chapter 4 and it is here where there are the most obvious analogies to other material taught to undergraduate physics students, and several interesting, and to this reviewer, new ones are made. Subsequent chapters consider surface waves, viscous flow including Hele-Shaw flow and Stokes flow, vorticity, instabilities, turbulence and non-Newtonian fluids. This is an impressive list and many interesting ideas are to be found in these topics. The discussion of surface waves is quite detailed and includes gravity waves, the effects of capillarity, waves at an interface and solitary waves. An impressive range of fluid instabilities is also discussed including convective and shear instabilities and a very nice range of examples are shown from laboratory experiments. The chapter on vorticity is somewhat disappointing as it is mainly a discussion of boundary layer theory with very little discussion of vorticity itself. Vorticity is a central concept which unifies much of our understanding of fluid mechanics and it is a significant omission not to include a general discussion.

In general, I found many of the approaches to be illuminating and I enjoyed the slant offered by a physicist. However, there are some situations where the author has not always adopted the most straightforward description of the physics in a problem. For example, the discussion of Taylor–Couette instability uses an argument based on Kelvin's circulation theorem and an energy argument. In my view, a more fundamental and revealing discussion can be given using conservation of angular momentum, which shows clearly how the instability is related to the centrifugal force which is not balanced by the pressure gradient associated with the curvature in the flow. I was also disappointed to see so few experimental results. While I understand the need to show evidence of theoretical ideas clearly, much is lost by sanitising the data. Fluid dynamics is both a subject of experimental as well as theoretical enquiry and physicists should definitely be concerned with experiments. There is no suggestion that there is any uncertainty in the data, and in some cases (notably turbulence spectra) even the scales have been removed from the plots. Much of the challenge in fluid dynamics is to provide quantitative estimates of fluid flows. Since almost every theoretical calculation involves approximations, the skill of the fluid dynamicist is to estimate the errors these approximations introduce and this can only be done in the knowledge of the uncertainties of the data.

I also found some of the mathematical derivations unnecessarily tortuous and they may be a little misleading to the inexperienced reader. The difficulty with fluid dynamics is in the underlying physics, not in the mathematics. Batchelor's book is challenging because it deals with complex physical processes (in fact there are relatively few equations for the amount of text) which require a special form of intuition to understand. This intuition can be developed by observing fluid flows, being taught by people who understand the subject, and reading books. I hope this book will encourage physics departments to build fluid mechanics laboratories and to provide lecture courses which will teach undergraduates about this fascinating subject.

The author hopes his book will be read for pleasure. I believe it will be. It is very nicely presented and his alternative view point is a welcome addition to the other introductory books on the subject.

P. F. LINDEN

Introduction to Circulating Atmospheres. By I. JAMES. Cambridge University Press, 1994. 422 pp. ISBN 0521 41895X £40.

This is a very worthwhile textbook which is a good complement to standard and authoritative books on geophysical fluid dynamics such as those by Gill and Pedlosky. The book builds on many important developments in dynamical meteorology over the last fifteen to twenty years. These developments have resulted from an interplay between better observational data and the increasing use of numerical models, not so much for weather or climate prediction, but as vehicles for experiments that test the links between simple theories on the one hand and observations on the other. One of the leading groups in pushing forward these developments has been that at the University of Reading, of which the author is a member. Dr James has made an important contribution here in summarizing some of this recent research progress in the more compact and permanent form of a textbook. The book is suitable for postgraduate and advanced undergraduate students and will also be a very useful acquisition for many researchers in atmospheric dynamics, geophysical fluid dynamics and related subjects.

The book begins with two introductory chapters summarizing the relevant physical laws and briefly describing observational and modelling aspects, the latter including numerical techniques and physical parametrization (the representation of processes such as radiation, convection and boundary-layer turbulence in numerical models of the large-scale flow). Chapter 3 then considers some thermodynamic issues that are particularly relevant, moving from simple radiative models to observed heating distributions.

The substance of the book really begins in chapter 4, in which the zonal mean circulation (i.e. the circulation averaged around latitude circles) is discussed. Understanding the structure of the zonal mean circulation in the two-dimensional height–latitude plane has always been seen as one of the central problems for atmospheric dynamicists and indeed, up to relatively recently, as James notes, this essentially defined the problem of 'the general circulation'. As is entirely appropriate in the current state of knowledge, James notes that it is his intention to go beyond this, to consider the fully three-dimensional variation of the circulation. But he chooses the zonal mean circulation as his starting point. This is a good idea. If any aspect of the global circulation can be understood in simple terms then one might imagine that this is it. After describing the relevant observational picture, James moves on to review the important Held and Hou model. Regardless of its precise relevance to the real atmosphere, this model plays a valuable role in focusing on important dynamical balances and its place in this book is well-deserved. James presents heuristic extensions of the model to include effects of moisture and of friction and then moves on to consider the extratropical Eliassen problem, again an important paradigm on which understanding of more complicated and realistic systems can be based.

The next chapter, on mid-latitude disturbances to the time-mean flow, has the characteristic mix of observations and quantitative and qualitative theoretical insights. The author adopts the traditional approach of using the energy cycle to characterize baroclinic waves, though he also points out some of the limitations of this approach. Sensibly he chooses the Eady model as a vehicle to illustrate some of the details of baroclinic instability, though other simple models are mentioned too. Again it is entirely appropriate that there is a detailed account of nonlinear baroclinic life cycles, whether or not such life cycles can be unambiguously identified in a real, 'baroclinically turbulent' atmosphere. The realization that the observed patterns of momentum fluxes associated with the baroclinic eddies were almost impossible to explain on the basis of linear unstable modes, but arose naturally and quite explicably in the nonlinear life cycles, was surely a substantial advance in the subject.

Chapter 6 uses the stationary eddies, i.e. the time-mean departure of the circulation from longitudinal symmetry, as motivation for discussing the phenomenon of Rossby wave propagation. There are a variety of simple mathematical models that are relevant, many of them covered here. As in many branches of fluid dynamics, one of the problems is that realistic flows are such that many of the conditions for the quantitative accuracy of the simple models are not satisfied. As more data become available and as increases in computer power allow modelling and investigation of more realistic flows, there are some who question the relevance of the simple models. Some of these issues are raised by the author, but his bottom line, that the simple models 'give a vocabulary which enables the results of much more complex, generally numerical calculations, to be described', can surely not be overstated.

The following two chapters deal with loosely grouped, but rather distinct, topics. Chapter 7 is entitled 'Three-dimensional aspects of the global circulation' and first covers tropical dynamics, including the equatorial waveguide and a discussion of monsoon circulations. Then attention turns to midlatitudes and the issue of longitudinal variations in the transient eddies and the interactions between transients and the time-averaged flow is addressed. This topic is considerably more difficult than the corresponding problem of interaction between the eddies and the longitudinally averaged flow, not just because of algebraic complexity, but the material here is a useful summary of current understanding. At the end of the chapter there is a short section on water vapour transport, rather independent of what has gone before, except perhaps through its possible implications for the maintenance of the storm tracks. Chapter 8, entitled low-frequency variability, is even more diverse, covering tropospheric teleconnection patterns, the quasi-biennial and semiannual oscillations in the stratosphere, the intraseasonal oscillation, El Nino and the Souther Oscillation, midlatitude blocking and, finally, ultra-low-frequency variability. Each of these topics could almost have been a chapter in itself and there is space here for little apart from description and one or two relevant pieces of dynamical theory. In such a situation the choice of what to include is necessarily subjective. But I was a little surprised to see, for example, that details of Plumb and McEwan's QBO laboratory experiment were included, when much else had been left out. This chapter might have been improved by strengthening the links with accounts of basic dynamic processes earlier in the book.

Chapter 9 discusses the stratosphere. There at least two reasons for including such a discussion. First of all there are many possible feedback mechanisms, dynamical, chemical and radiative, between troposphere and stratosphere and considering one or the other in isolation is ill-advised. Secondly, many of the dynamical ideas that are central to the understanding of tropospheric circulation have similar relevance to the stratosphere. Stratospheric dynamics has been covered in detail relatively recently in the book *Middle Atmosphere Dynamics* by Andrews, Holton & Leovy (Academic Press, 1987), and the discussion here cannot rival that. But, within the constraint of space, James does a reasonable job in surveying the stratospheric circulation, in noting some of the relevant dynamical ideas, and in very briefly summarizing ozone chemistry and transport. His final section, stratosphere–troposphere exchange, is noteworthy in addressing a strangely neglected, yet surely important, aspect of the global circulation, namely the maintenance of the tropopause (the boundary between troposphere and stratosphere, clearly defined by transitions in chemical and dynamical quantities). But his reviewer definitely does not agree with the statement that 'the flux of mass associated with the [large-scale] Lagrangian circulation of the stratosphere is controlled by poorly understood processes at the tropopause'.

The book ends with a chapter on planetary atmospheres (and their experimental analogues). The author's opinion that 'by contrasting and comparing the behaviour of a variety of planetary atmospheres our subject has indeed matured and come of age scientifically' may be overstating the position a little, but this is nonetheless a fascinating topic.

Looking at the book as a whole, there are some places where the choice of material seems strange (e.g. the mention of over-reflection as a mechanism for instability in the context of the Charney problem) and others where presentation is downright confusing (e.g. in discussion of the spin-down problem for a homogeneous fluid and then its implicit extension to a stratified fluid). There are a number of typographical errors, e.g. in references to previous text or figures, and the clarity of some of the figures was reduced by poor labelling. But these problems notwithstanding, this is a valuable new textbook in atmospheric dynamics, particularly in its presentation of a combination of observational data, numerical model results and simple theory to communicate the important ideas, and it is heartily recommended.

P. Haynes