REVIEWS

The Dynamics of the Upper Ocean. By O. M. Phillips. Cambridge University Press, 1966. 261 pp. 60*s*. or $11.50.

Only ten years ago, both dynamical meteorology and dynamical oceanography appeared, to many aerodynamicists at least, to be isolated subfields of fluid mechanics with their own special problems, their own special journals, and their own special jargons. Then it was that Professor Corrsin (*J. Fluid Mech.* **2**, 1957, 616–21) found it necessary to describe a review of atmospheric turbulence as 'oriented more from meteorology than from fluid dynamics' and to complain (in another context) that: 'simplified laboratory studies aimed at an understanding of the basic mechanisms of phenomena are often described as "unrealistic" by professional oceanographers'. Now, much has changed, and geophysical fluid mechanics can fairly be regarded as an established discipline in which meteorologists, oceanographers, and refugees from a régime of ever increasing Mach number can communicate and create. It is against this background, and to this new discipline, that Professor Phillips presents his monograph. As he states: 'The time seems particularly opportune...to attempt to provide a coherent account of the recent developments [in the dynamical processes that occur in the upper ocean] in the hope of making them accessible to a greater number of oceanographers and, at the same time, of stimulating other workers in this rewarding and fertile field of geophysical fluid mechanics.'

The title of the monograph, while not inappropriate, may invite reproaches from some oceanographers in consequence of the rather limited range of topics: surface waves (occupying over half the monograph), internal waves, and turbulence. The tides are scarcely considered, and Coriolis effects are introduced only in a brief treatment of the Ekman transport. This is, however, neither a definitive treatise nor a text-book; it is a research monograph which does not hesitate to present theoretical developments that are 'necessarily rather tentative and subject to revision...in the hope of stimulating others to remedy the deficit... [Its] success or failure...will...be measured by the degree to which it provides the basis for future developments or, possibly, *dissent*.' I have supplied the italics because, while accepting the author's premise, I suspect that he has included developments that are rather too tentative for the seeming authority of hard covers and a library call number, and which might better have been presented in the more open forum of a journal. Still, this is a question of individual taste, and most of us will be willing to suffer uncertainty in return for the author's enthusiastic and imaginative presentation.

The author opens with a historical résumé and points out that 'theory and observation may at last be becoming mutually relevant'. He then develops the equations of motion, using both vector and Cartesian-tensor notation to maximum advantage. The principal results are based on the assumption of incompressibility and, for internal waves, the Boussinesq approximation, in which the variation of density appears only through the Brunt–Väisälä frequency. [This rather cumbersome term appears to have found widespread acceptance in geophysical fluid mechanics, although Eckart uses *Väisälä frequency* in his *Hydrodynamics of Oceans and Atmospheres,* and some meteorologists use *Brunt frequency.* Perhaps, with the unhappy example WKBJ in mind, we should consider some more descriptive designation such as *intrinsic frequency.*]

The treatment of surface waves places special emphasis on nonlinear interactions, statistical description, and the growth and decay of wave spectra on the open sea. These are topics that have developed substantially over the past decade, and there is no significant overlap with the more classical treatments of Stoker (*Surface Waves,* Interscience, 1957) and Wehausen & Laitone (*Handbuch der Physik,* vol. IX, Springer, 1960). The treatment is lucid, but sophisticated; for example, the vector group velocity is simply defined as the gradient of the angular frequency with respect to the scaler wave-number, and Fourier–Stieltjes integrals are introduced with only a passing reference to Cramer's text-book.

Chapter 3, 'The dynamics of surface waves', contains an excellent description of the effects of viscosity on attenuation and mass transport, with special reference to the recent contributions of Longuet-Higgins (such as the striking result that the limiting vertical gradient of the velocity of a marked column of fluid below a surface wave as the viscosity tends to zero is exactly twice the value found by Stokes for an irrotational motion). Powerful and effective use is made of the kinematical and dynamical conservation equations that have been developed by Longuet-Higgins, Stewart, Ursell, and Whitham. And, appropriately, there is a connected account of weak, nonlinear interactions—a phenomenon first appreciated in an oceanographic context by the author and subsequently developed by him, Benney, Hasselmann, Longuet-Higgins, and others. In balance, this chapter seems likely to stand the test of time, although it does contain some rather speculative material, such as the description of slicks (p. 40).

Chapter 4, 'Ocean surface waves', deals with the description of a random surface-wave field, the air flow over the sea, the transfer of momentum from wind to waves, and wave propagation and attenuation. Most of this material is new, and much of it is still to be adequately confirmed by observation. It is especially here, in my opinion, that the author, as an acknowledged authority presenting his case with mathematical conviction, has occasionally allowed enthusiasm to overwhelm caution and has run the risk of giving non-specialists the impression of a rather more firmly established body of knowledge than actually exists. I refer particularly to the discussion of wave generation by wind.

Starting from the hypothesis that the wind field over a surface-wave field may be regarded as only slightly perturbed from the corresponding field in the absence of waves, the momentum transfer from a turbulent wind to gravity waves may be regarded as due to two, more or less distinct, mechanisms: the resonant action of the unperturbed pressure fluctuations on the surface (as originally proposed by the author) and the coupled action of the perturbation pressure induced by the surface motion (induced shear stresses are important only for rather short waves). A central difficulty in the calculation of the latter pressure arises from the practical necessity (at least in the opinions of both the author and the reviewer) of working from appropriately averaged equations for the perturbation motion, in which the wave-induced perturbations in the turbulent Reynolds stresses, say r_{ij}, must be determined by the invocation of some *ad hoc* hypothesis. The simplest hypothesis is $r_{ij} \equiv 0$ (as in the reviewer's quasi-laminar model) and leads to the prediction that the momentum transfer to a particular component of a surface-wave field is concentrated in 'the matched layer' (author's term), where the mean wind speed is equal to the wave speed of that component; the horizontal component of the so-called 'vortex force'—namely the mean value of the product of wave-induced vorticity, say Ω, and wave-induced vertical velocity, say $\mathscr{W}$—is concentrated in this layer by virtue of the fact that Ω and $\mathscr{W}$ are elsewhere in exact quadrature.

The author modifies this last hypothesis by postulating that Ω and $\mathscr{W}$ are correlated outside of the matched layer, with a correlation coefficient that is independent of both elevation and wavelength and which he determines by comparison with Motzfield's (1937) wind-tunnel measurements for flow over a *stationary* wave model. This is not the place to debate the plausibility of the author's hypothesis (although I am, to say the least, sceptical), but I find no adequate basis for his statement that, although 'the uncertainty in this determination is considerable (possibly $\pm 30\,\%$), [it] is acceptable for present oceanographic purposes'. Surely, on the author's professed tenets, this should be established by observation with due consideration for scale effects! Such a speculative development is both interesting and provocative, but I should have thought that, for the present, it might have been more appropriately confined to a journal.

I limit myself to two more explicit comments on the momentum-transfer problem. The statement (p. 105): 'When the matched layer is higher than $k^{-1} = \lambda/2\pi$, $\beta(kz_m)$ [the dimensionless momentum flux in the "matched layer"] is in effect zero, because of the greatly diminished mean profile curvature at z_m [the elevation of the matched layer]' is rather misleading; β is asymptotic to the product of $(kz_m)^{-1}$, representing the decay of the profile curvature, and $\exp(-2kz_m)$, representing the decay of the mean-square of the wave-induced vertical velocity, and the latter decay clearly dominates the former. It would not be too surprising, on the other hand, to find that the momentum flux induced by the perturbations in the turbulent Reynolds stresses also decreases with increasing kz_m, albeit not exponentially by virtue of the implicit integration over z. Finally, there is the statement that 'the momentum flux to the longer waves ($c > 5u_*$) is always a small fraction, of the order of $10\,\%$ at most, of the total momentum transfer to the water surface'. This appears to be true on a laboratory scale, but the available field measurements (especially those of Snyder & Cox) suggest that it may be far from the truth over the open sea.

Chapter 5 is devoted to internal waves, which necessarily have frequencies below the maximum value of the Brunt–Väisälä frequency, say $N(z)$, where z is the depth. The author does not attempt to catalogue the solutions for arbitrarily assumed $N(z)$ (cf. the following review), but sensibly focuses on those qualitative features that can be inferred from more general considerations. The discussion is enlightening and contains much that is new, especially on interaction phenomena.

Chapter 6 is devoted to oceanic turbulence. Following a very readable account of energy spectra and local similarity, the author develops his recent suggestion that the gradient of the Reynolds stress is proportional to the local curvature of the mean velocity profile in consequence of a mechanism that is essentially similar to that of the aforementioned quasi-laminar model for momentum transfer from wind to waves. Here again, however, the distinction between fact and conjecture is unfortunately blurred, despite the author's reservation that 'the formulation of such hypothesis and their defence may not...be uncontentious'.

The final sections deal with turbulence in the surface layer of the ocean. I cannot claim any special competence on this subject, but I do question the statement (p. 225) that the region beneath the thermocline is 'generally non-turbulent'. The observationally inferred diffusivities for heat, salinity, and radioactive tracers in the abyssal depths all have a value (some orders of magnitude larger than the respective values for purely molecular diffusion) that is consistent with turbulent diffusion (Munk, *Deep Sea Res.* **13**, 1966, 707–30). This may reflect some more ordered form of convection than turbulence, but it scarcely justifies the conclusion that turbulence is absent. It is only fair to add, however, that, in this same chapter, the author both recognizes the existence of turbulence below the thermocline and stresses the distinction between turbulence and other possible random motions.

The monograph concludes with a bibliography of over 200 entries and a combined subject and author index.

There are a few minor slips. Drs Backus and Swinbank will find their names consistently misspelled, and (p. 10) the total pressure $p+\frac{1}{2}\rho u^2$ is identified as the 'dynamic pressure'. The proof-reading appears to have been quite thorough (I found no typographical errors).

Summing up, this is an important book, presented with grace and verve, and impaired only by the author's occasional failure to distinguish adequately between scientific fact and stimulating conjecture. I recommend it to all who are working, or aspire to work, in 'this rewarding and fertile field of geophysical fluid mechanics'.

John W. Miles

Methoden und Ergebnisse der Theoretischen Ozeanographie. II. Interne Wellen. By Wolfgang Krauss. Gerbrüder Borntraeger: Berlin. 1966. 245 pp. DM 110.

This is one of a three-volume series (volume i: *Dynamik des homogenen und quasihomogenen Meeres*; volume ii: *Statistische Methoden zur Beschreibung von Seegang, Turbulenz und Vermischung*) on theoretical oceanography and was prepared originally as a text-book. It provides an exhaustive coverage of internal waves in a vertically stratified, inviscid, incompressible fluid on the basis of the linearized equations of motion, the Boussinesq approximation, and the hypothesis of uniform rotation. The secondary effects of variable Coriolis acceleration, horizontal stratification, shear flow, eddy viscosity, and nonlinearity also are considered briefly. The last third of the volume deals principally with data analysis using modern spectral and statistical techniques. There are a seven-page appendix of English summaries, a glossary of symbols, a bibliography of over 300 entries, and subject and author indexes.

The presentation can perhaps best be described as pedestrian, and, in contrast with that by Phillips (see above review), is unlikely to stimulate either controversy or enthusiasm. Moreover, I am left with the impression that Professor Krauss has not been sufficiently discerning in surveying the available literature. For example, he reproduces the reviewer's 1961 proof of the theorem that the phase speed of an unstable wave in a stratified shear flow must lie between the minimum and maximum flow speeds but appears to have overlooked the more powerful semicircle theorem presented by Howard in the same issue of the same journal. And he does not even mention the significant, recent developments in weak nonlinear interactions by Phillips and others. He does appear to have been more thorough in covering the earlier literature, but it is at least surprising, in a book devoted exclusively to water waves, that there are no references to either Laplace or Kelvin (*Kelvin waves* are mentioned). I was interested to learn that the Väisälä frequency (as Krauss designates it) was discovered independently by Väisälä (1925), Milch (1925), Brunt (1927), and Hasselberg (1929). [It appears, then, that those who choose the designation *Brunt–Väisälä frequency* should, in all justice, interpolate *Milch* and perhaps add *Hasselberg*, at which stage we would surely succumb to *VMBH frequency* (see above review)].

All in all, this is a useful book in that it collects in one place much that is otherwise scattered throughout the literature. It cetainly deserves to be in any library that caters to fluid mechanics, and the specialist may wish to have it in his personal library. We can be thankful to have it, yet disappointed that we have not more.

JOHN W. MILES

Dynamics of Nonhomogeneous Fluids. By CHIA-SHUN YIH. Macmillan, 1965. 306 pp. 90*s*.

This book deals with a variety of interesting topics arising from the author's extensive study of the flow of fluids with a non-uniform density in a gravitational field. There are six chapters of which the first deals with theoretical preliminaries. In chapter 2 the theory of waves of small amplitude is developed for a fluid stratified with respect to density or entropy under the action of gravity. The theory is applied to an isothermal atmosphere with fixed and free boundaries, to a stratified liquid with density discontinuities and to atmospheric waves in the lee of mountains. Chapter 3, the longest, is on steady flows with disturbances of finite amplitude. After deriving a general equation for the two-dimensional flow of an incompressible, inviscid, but stratified, fluid under the action of gravity several exact solutions are obtained. The results obtained include the solutions for stratified flow into a sink, stratified flow over a barrier, and some extensions to similar problems in compressible flows. The solutions are compared with experimental results. Flows of homogeneous layers of fluid, internal hydraulic jumps and surges or gravity currents are considered next, and the chapter concludes with a short section on unidirectional laminar flows.

Chapter 4 deals with various aspects of hydrodynamic stability including the effect of viscosity and thermal diffusivity on gravitational instability, the instability of the surface separating two superimposed flowing fluids, wave generation by wind and the stability of shear flows of a continuously stratified flow. The stability of liquid flow down an inclined plane is the last topic in this chapter.

In chapter 5 the author turns to the problems of flow in porous media under the action of gravity. The topics treated include: homogeneous two-dimensional flows with a free surface; the movement in a porous medium saturated with one fluid of masses of a second fluid shaped as circular or elliptic cylinders, spheres or ellipsoids; the flow of a stratified fluid into a two-dimensional sink and over a barrier; the fingering or penetration of one fluid into another; and the effect of gravitational convection in seepage flows. Chapter 6 deals with flow in rotating and accelerating systems and in particular with the analogy between such flows discussed in earlier chapters. The topics treated include gravity and Rossby waves, hydraulic jumps, large amplitude steady flows of a rotating fluid into a sink and past a sphere, the stability of rotating fluids and fluids subject to varying acceleration. The book concludes with some 30 pages of reference and bibliography.

The above list of contents shows that the book is an interesting and useful account of many problems in a wide area of fluid mechanics which have not hitherto been collected together. Furthermore, the author has not confined himself to theoretical presentations, but has included many figures showing numerical results as well as photographs and figures illustrating experimental work. For instance, the sections on stratified flow into a sink and over a barrier are particularly well illustrated, there are photographs of hydraulic jumps in stratified and rotating fluids and a number of illustrations showing the solutions to rotating flow problems for comparison with the stratified flow results.

As might be expected the variety and sophistication of the numerous topics treated have led to condensations and omissions which may introduce difficulties for the reader who is not himself an expert in this particular field of fluid mechanics. The author has realized the difficulties of selection and has deliberately made this a personal book, in the sense that he has woven into an interesting pattern solutions to many problems to which he has contributed. The result is correctly described on the fly-leaf as a professional-level treatment.

On the whole this approach has been successful and stimulating. There are however some peculiar omissions. In chapter 1, for instance, there is a presentation of a method of transforming the equations governing the flow of a non-homentropic perfect gas to those governing the flow of a homentropic gas, when no gravity field is present in either case. This discussion should surely contain some reference to the work of Munk & Prim (*Proc. Nat. Acad. Sci.* **33**, 1947, pp. 137-141; see also pp. 41-43 of *Fundamentals of Gas Dynamics: Vol III, High Speed Aerodynamics and Jet Propulsion,* edited by H. W. Emmons, Princeton 1958), so that the reader may appreciate that there are several ways in which such transformations can be effected and that, if gravity effects are neglected, flows of a perfect gas with the same distribution of stagnation pressure have the same geometrical pattern for their streamlines, whatever the variation of stagnation temperature from one streamline to another.

The required condensation of the theoretical treatment of the numerous problems has been carried out with considerable skill. Some difficulties are inevitable. The reference to the controversy on the 'upper boundary condition' in the discussion of lee waves, pp. 69–71, calls for more knowledge of the subject than the reader may be able to distil from the text, if the physical implications are to be appreciated. The analysis and discussion on internal hydraulic jumps is also hard to follow, and there may be other places in which the pace is too rapid for some.

By assembling together so many interesting problems in one volume, the author will also succeed in stimulating further research. Its direction is not easy to predict, but it is clear that some attention needs to be paid to the influence of the upstream and downstream boundary conditions in practical stratified or rotating flows.

This is a useful book both as a reference for the research worker and as a stimulus to developing interest in this challenging area of fluid mechanics.

W. R. Hawthorne

SHORTER NOTICES

An Index to the Two-Phase Gas–Liquid Flow Literature. Prepared by S. W. Gouse. M.I.T. Press, 1966. 867 pp. $15.00.

This massive compilation of the titles and publication details of papers on two-phase flow (excluding atomization, cavitation and condensation) shows, among other things, that the number of papers doubled in approximately every ten years between 1870 and the Second World War, and that since then the doubling time has been five years, the current total (at the end of 1965) being 5253. The papers are listed and numbered in the order in which they were found, and various indexes (subject, author, source publication) are provided to enable a reader to track down a paper by its number.

Vibrations in Hydraulic Pumps and Turbines. Published by the Institution of Mechanical Engineers, 1967. 181 pp. £8.

The Institution held a symposium on this topic at Manchester in September 1966, and the texts of the 14 contributed papers and the ensuing discussion have been published both in the *Proceedings of the Institution of the Mechanical Engineers* and, here, in separate hard-back form on fine paper.

'Meteor' Forschungsergebnisse. Published by Gebrüder Borntraeger.

This handsomly produced new journal, complete with colour photographs, is in four parts, of which the two likely to be concerned with fluid mechanics are:

Reihe A. Allgemeines, Physik and Chemie des Meeres. Edited by G. Dietrich (Kiel), W. Hansen (Hamburg) and J. Joseph (Hamburg). Subscription DM 40.

Reihe B. Meteorologie and Aeronomie. Edited by K. Brocks (Hamburg) and H.U. Roll (Hamburg). Subscription DM 45.60.

It seems that the subscription refers to one issue only. Issue no. 1 of part A contains three papers and issue no. 1 of part B six papers. The summary of each paper is given in both German and English, and so are all figure captions.

Journal of Plasma Physics. Cambridge University Press. £7 or $24.50 per volume of 4 parts.

This sister journal to the *Journal of Fluid Mechanics* begun publication in February 1967, and will appear initially at the rate of one volume per year. The editor is J. P. Dougherty (Cambridge), and the associate editors are D. Bershader (Stanford), F. D. Kahn (Manchester) and W. B. Thompson (La Jolla). The printing format and editorial system and policy are generally similar to those for *Journal of Fluid Mechanics*, and the editors of the two journals intend to collaborate in decisions on the most appropriate medium for papers in the region of overlap of fluid mechanics and plasma physics.

Dynamics of Fluids and Plasmas. Edited by S. I. PAI. Academic Press, 1966. 543 pp. £9. 12*s*.

This book contains the proceedings of a symposium held in honour of Professor J. M. Burgers at the University of Maryland in October 1965. The main sessions of the symposium were devoted to biomechanics, turbulence and plasma physics. In addition there was a lecture on rheology and one on stellar dynamics and galatic spirals (only an extended abstract of the latter being included in the proceedings). The range is a tribute to the breadth of Professor Burgers' interests. But it will take a versatile reader to understand every paper in the volume.

Molecular Flow in Vessels. By Y. N. LYUBITOV. Consultants Bureau, Plenum Publishing Corporation, 1967. 172 pp. $22.50.

This English translation of a Russian work gives an account of the flow of rarefied gases, particularly through tubes of various shapes. Specialists in free molecular flow may find it useful. Paper back, but very expensive.

Rarefield Gas Dynamics, Vols. I and II. Edited by C. L. BRUNDIN. Academic Press, 1967. 1781 pp. £7. 8*s*.

The size of volumes of proceedings of the biennial international symposia on rarefied gas dynamics continues to grow. This record of the fifth symposium, held at Oxford in July 1966, contains the text of 103 papers, and has been published relatively quickly by direct reproduction from a typescript. The papers fall into four major groups: gas–surface interactions, kinetic theory, transition flow, and ionospheric aerodynamics.