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REVIEWS

Waves in Fluids. By JAMES LIGHTHILL. Cambridge University Press, 1978. 504 pp. £17.50.

The theory of waves in liquids and gases, while only a part of the general science of wave motions, consitutes a vast subject in its own right, and the number of important applications of it seems to expand endlessly, not only in the more familiar branches of physical science and engineering in which it is rooted, but also in the developing environmental and life sciences. In consequence every author entering this field is confronted with the problem of selection of material. Sir James Lighthill's solution, in writing this 'comprehensive introduction to the science of wave motions in fluids', is to choose a representative type of wave as the theme of each of his four chapters, each type of wave being used to develop new fundamental ideas and to utilise and extend those that have already been presented. The examples that illustrate the themes are wide ranging, the main sources being from noise-abatement research, hydraulics, the theory of circulation of the blood, oceanography and the science of the atmosphere. A quick glance at the Bibliography is sufficient to show the diversity of matters referred to in the text, from the 'buzzing of insect wings' early on to the 'Sierra Wave' at the very end of the book and including historical allusions such as that to the 'horse of W. Houston, Esq., discovering drag reduction' along the Glasgow and Ardrossan Canal! The four chapters are provided with a prologue that sets out very clearly the plan and purpose of the book and an epilogue that gives a brief sketch of other kinds of wave and further developments of the ideas involving more difficult study.

The subject of the first chapter is sound waves. From the derivation of the linearized wave equation in three dimensions we are led to a detailed study of mechanisms of sound generation from compact source fields. Examples of single, dipole and quadrupole fields are illustrated by photographs from ripple-tank simulations. There are sections on sound radiation from non-compact source regions and on the means of dissipation of acoustic energy. In this chapter there emerges the idea that the method of ray-tracing (geometrical acoustics) can be applied when the geometrical scales of a problem are very much greater than the wavelength. Later chapters continue to develop this approach, establishing by generalization the much wider validity of the method.

The second chapter begins with the general theory of longitudinal wave propagation. While for uniform fluid in a uniform tube the basic equation is the same as for plane sound waves, the wave velocity depends upon the 'distensibility' of the tube, a concept that is used in examples of the propagation of blood along an artery and of flow of water in an open channel of uniform but arbitrary shape. The ideas are extended to deal with propagation through junctions, branches, cavities and constrictions, all treated as 'compact' elements. Examples of these systems are likewise drawn from physiology and from river flows. This part of the chapter concludes with an account of modifications that result from friction. A study of one-dimensional nonlinear flow now follows, with the theory of simple waves, the introduction of shock waves and a treatment of the related subject of hydraulic jumps. The mathematical formulation is preceded by a physical argument that produces the well-known Riemann transformation for one-dimensional unsteady flow. By this means Professor Lighthill lays the basis for the later section of this chapter on one-dimensional propagation in tubes and channels with gradually varying composition and cross-section. This in turn is applied to nonlinear propagation along the 'ray tubes' of geometrical acoustics, from which a calculation is made, by way of example, of the sonic boom created at ground level by a high-flying supersonic aircraft.

The last two chapters give the linear theory of dispersive waves under the generic titles of 'Water Waves' and 'Internal Waves', representing respectively examples of isotropic and anisotropic propagation. The simple treatment of surface gravity waves that opens Chapter 3 contains one of the very few errors in printing that this reviewer has found: a reference to 'irrotational incomprehensible flow', singularly out of place in a book that makes even complex flows vividly comprehensible! The description of the various kinds of dispersive surface waves is followed by an account of the processes by which they are attenuated; it is, indeed, part of the plan of the book to look at attenuation in each chapter in turn. After this group velocity is introduced, a subject once considered difficult and even a little mysterious on which Sir James has shed much light in his own writings (as, indeed, on many other topics in this book). A section on wave patterns made by obstacles in a steady stream contains a delightful, descriptive quotation from the poet Robert Frost and the finale to this excellent chapter is provided by an analysis of ship waves.

Chapter 4 is the longest in the book and is mostly concerned with gravity waves in fluids with continuous stratification. After a general introduction it considers the condition under which internal gravity waves and sound waves are decoupled from each other. All oceanic internal waves and most internal waves in the atmosphere satisfy this condition, and these waves are analysed with many interesting allusions. The idea of vector group velocity for anisotropic systems develops with increasing generality as the chapter proceeds. The author calls the section on the general theory of ray tracing in inhomogeneous anisotropic dispersive wave systems the 'centre of gravity' of the book, because it contains much of what has gone before as special cases and because it opens the way to new applications and further extensions, such as to systems of waves that interact with a mean flow. The chapter abounds with fresh concepts such as trapped waves, caustics and waveguides for fluids; much of the material relates to recent work and provides a challenging conclusion to the main text.

Nonlinear effects on dispersive waves receive a brief treatment in the second part of the epilogue. The first part refers to more difficult systems of waves in which the restoring forces are either Coriolis forces in rotating fluids or magnetic forces in electrically conducting fluids. In both cases the applications are of geophysical importance, the one because of the influence of the earth's rotation on the ocean and the atmosphere, the other in relation to waves in the ionosphere and also to the movement of the liquid-metal core of the earth.

There is a Bibliography which takes the form of a commentary on relevant books and papers. It first gives texts that provide the necessary background to the book in respect of basic mechanics, the dynamics of fluids and essential parts of pure mathematics, as well as texts dealing with the topics covered or touched upon in the book itself. Then, in separate sections, it runs over the literature on acoustics, water waves, stratified fluids and the subjects of the epilogue. This will prove to be a very useful feature to many readers in guiding them to original sources and fuller discussions of phenomena referred to in the book (and of some further ones).

There are many other pleasing aspects of this book. The author reminds the reader quite frequently of the stage that has been reached, relating it to what is to come in a preliminary, descriptive way. Each chapter is provided with examples; these supplement the narrative and the reader is (at least in part) guided through them. Quantities occurring in the text have their significance explained and are estimated numerically so that their relative importance can be judged in the appropriate context.

The book will become a standard work for reading and consultation by all interested in fluid flow. It will be invaluable to research students who have a sufficient mastery of the background topics listed above from the Bibliography, while an excellent undergraduate course could be prepared from it by a suitable selection of material. Even among the most experienced readers few, if any, will fail to find in it new insights into some familiar formulae or results among the abundance of explanations, comments and comparisons that illuminate the chapters.

D. C. PACK

Marine Hydrodynamics. By J. N. NEWMAN. MIT Press, 1977. 402 pp. $24.95.

Like other branches of engineering, naval architecture was at first entirely empirical and then became more scientific during the last two centuries, particularly through the introduction of hydrostatics. But, unlike other branches of engineering, naval architecture has not until recently tended to become more and more mathematical. This is not surprising, for many aspects of ship design are concerned with extreme conditions where the correlation between theory and experiment is not good. Recently, however, there have been a number of problems where the application of mathematical theory (sometimes incorrectly) has led to significant advances, as in the case of the bulbous bow. It is now widely accepted among naval architects of the leading ship-building nations that theory and practice each have their place and can be mutually illuminating to the well-trained ship designer, and that the training of the best naval architects should involve a more fundamental grasp of mechanical principles, and particularly of hydrodynamics.

This much-desired development has however been delayed by the lack of a suitable textbook, and Professor Newman's book must be regarded as an important landmark in the training of naval architects. The author is himself a naval architect whose theoretical work is well known to readers of this Journal. The book has grown out of lectures which he has given to undergraduate and first-year postgraduate students in the Department of Ocean Engineering at MIT, and which have also been used elsewhere in the United States. It is assumed that students have considerable previous knowledge of advanced calculus, including Laplace's equation, Green's theorem and complex-function theory. Many of the topics selected for treatment are taken from those branches of marine hydrodynamics of which the author has direct theoretical and practical experience; a previous knowledge of fluid mechanics is not assumed.

In this review it is possible to touch on only a few of the topics treated in this book. In a brief introduction the reader is told about viscous and gravitational forces.

Dynamical similitude for a ship's hull is possible only if both the relevant dimensionless combinations (the Reynolds number and the Froude number) are the same for the model as for the full scale. Thus model experiments are, strictly speaking, inapplicable, and additional simplifications must usually be made. This theme is elaborated in a remarkable chapter 2, on model testing, where dimensional analysis is applied to 14 different situations, some familiar (such as water waves, viscous drag on a sphere and on a flat plate), some less familiar (such as the submerged hydrofoil and the cavitating screw propeller), some only approximate (such as the force on a ship's hull mentioned above). These are accompanied by numerous comparisons with experiments and by references to the recent literature. The student who works through this chapter (there are 15 exercises to test his understanding) cannot lack motivation to work through the rest of the book.

The next three chapters briefly cover the fundamentals of viscous and inviscid fluid mechanics and their application to lifting surfaces. The topics in the viscous chapter include a derivation of the Navier–Stokes equation, laminar and turbulent boundary layers, and roughness effects; the inviscid chapter includes a proof of Kelvin's circulation theorem. These have been familiar in the best aerodynamics textbooks for many years, but it is only recently that naval architects have become ready for them. These chapters also include many less conventional topics, such as Rankine ovoids, the representation of bodies by distributions of sources and dipoles, added masses and moments of inertia, and the force on a body in a non-uniform stream. The chapter on lifting surfaces is motivated by the application to rudders, yacht sails and keels, screw propellers and cavity flows.

Chapter 6 is the longest in the book (90 pages) and is concerned with water waves, of special relevance to naval architects. Besides the familiar linear theory of regular wave trains it contains such topics as the dependence of velocity on amplitude, mass transport, group velocity, two-dimensional and three-dimensional wave resistance and thin-ship theory and comparison with experiment. There is a lengthy treatment of ship response in regular waves, including the Haskind reciprocity relations, and the chapter concludes with a section on ocean wave spectra.

The final chapter is concerned with slender-ship theory (applicable when the length of the ship greatly exceeds the other dimensions). This topic has been attracting much attention in recent years, and still represents one of the frontiers of modern ship research.

This is a textbook that is written by an expert practitioner, theoretician and teacher. Some of the topics are treated in detail, many more are treated more briefly, and many are omitted altogether but I think that the author has shown excellent judgement in his selection. Of particular value are the references to recent literature, and the well-chosen exercises at the end of each chapter. This pioneering work should attract many good students to this challenging field of study, and it will set the standard for many years to come.

F. Ursell