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REVIEWS

Introduction to Fluid Mechanics. By J. A. FAY. MIT Press, 1994. 605 pp. ISBN 0 262 06165 1. £22.95 or $34.50.

Fluid Dynamics: Theoretical and Computational Approaches. By Z. U. WARSI. CRC Press, 1992. 683 pp. ISBN 0 8493 4436 0. £65.50.

When you buy one of these texts on fluid mechanics you certainly get a lot of paper for your money. Each of the pages of the two books has an area of about 450 cm^2, and the two books together weigh about 3 kg. On the left side of each page of the first book there is a generous margin of width 5.5 cm, which might be intended for the recording of notes by students. But whatever the purpose of the great size of each book it is an off-putting feature for a reader, especially one who does not need to write notes during classes. Admittedly the two halves of a large heavy open book lie nicely flat on a table.

Turning to the contents of the book by Fay, it is evident that it has some good features. The chapter titles are mostly conventional, as would be expected for a student text on a classical subject, and are as follows: 1. Introduction; 2. Fluid statics; 3. Conservation of mass; 4. Inviscid flow; 5. Conservation of momentum; 6. Laminar viscous flow; 7. Turbulent viscous flow; 8. Conservation of energy; 9. Flow in fluid systems; 10. Dimensional analysis and modelling; 11. Irrotational flow; 12. Compressible flow.

The chief merit of the contents, it seems to me, lies in the practical nature of the explanations of the theory, the choice of applications of the theory, and the many worked problems. The author has called on his wide experience of engineering fluid mechanics to good effect, and it is a pleasure to see, through the eyes of a student reader, that fluid mechanics is a useful and widely applicable subject, as well as being a delight to applied mathematicians. The drawn figures, many of which are associated with the problems, are clear and well designed. However, it is a pity that there are so few photographs of flow systems. A few more photographs like the dramatic picture on the front cover of a row of 400 kW wind turbines each rotating about a point 30 m above the ground would contribute to the practical attitude that the author advocates throughout the book. It is no doubt a matter of cost, and one cannot complain about the purchase price. On the whole a good text for senior engineering undergraduates in North America, it could also be read with profit by students in applied mathematics, although the format may put them off.

The book by Warsi is less user-friendly. The author describes it as 'theoretical but not mathematical,' although I am not sure he adheres to that specification. The print is small, there are innumerable equations but not many figures, and the exposition is rather wordy although usually careful and clear. The author makes an ambitious effort to be comprehensive in six chapters with the following titles: 1. Kinematics of fluid motion; 2. The conservation laws and the kinetics of flow; 3. The Navier–Stokes equations; 4. Flow of inviscid fluids; 5. Laminar viscous flow; 6. Turbulent flow, each of which is divided into many sections (28 in chapter 5 and 32 in chapter 6). The subject matter is mostly rather dry theory without the insights that give a text-book character, although students might welcome the attention to mathematical detail. The author hopes his book will draw 'students and readers from all branches of engineering and applied mathematics', but one may doubt whether that is a realistic hope, given the strong competition that happily now exists.

D. G. CRIGHTON

Interpolating the Ocean: Inverse Methods in Physical Oceanography. By A. F. Bennett. Cambridge University Press, 1992. 346 pp. 0-521-38568-7. £35 or $59.95.

A greater part of the business of physical oceanography is, from a purely mathematical perspective, interpolation. Measurements are made at points on the surface, on the boundaries, along the trajectories of autonomous instruments, and so on; the oceanographer's dream is to learn from these scattered observations the velocities, temperatures and other physical properties throughout the body of the ocean and through time. The ideal of predicting these things from the fundamental differential equations and their boundary conditions is impractical for all the obvious reasons: the nonlinearity of the equations, the complexity of shape of the lower boundaries, the ignorance about the forcing functions at the top boundary and the general uncertainty of initial conditions. At first sight the suggestion of mere interpolation appears hopeless too – the idea of filling in between the tie points with some arbitrary function does little to inspire confidence in the final results. But the process of interpolation can (and indeed, must) be infused with information about the field being interpolated; after all, even a mathematical function cannot be accurately interpolated from a table unless its derivatives are known to be bounded. Similarly, various inverse methods of physical oceanography can be characterized by what is assumed about the behaviour of the ocean between the measurement points.

Andrew Bennett's book, *Inverse Methods in Physical Oceanography*, is essentially about modern approaches to this problem, much of the material stemming from the author's own research. The author hopes to present at the level of advanced graduate students a coherent development of a set of ideas centring on variational methods that are used to keep the predictions of the underlying model in line with observation, and at the same time make the model adhere to physical constraints.

The simplest approach is to assert that the smooth (that is, large scale) part of the fluid velocity is the only important thing. Then the 'physical' constraint is that the solution be as smooth as possible between observation sites. This leads in chapter 2 to the smoothing spline solution, derived here by a variation treatment.

Clearly this is the most naive sort of calculation. Perhaps a better approximation would result if one assumes that the ocean is the realization of a stochastic process with known statistical properties that can be used to guide the interpolation. This assumption results in what the author calls Gauss–Markov smoothing.

A much more elaborate type of prescription is to insert the equations of motion in approximate form to control the behaviour. This idea is taken up first in chapter 5 where linear dynamics are assumed. A quadratic penalty function is assigned to misfits which can arise from measurement error, inaccuracies in the approximate dynamics, and errors in the initial conditions. The resulting object, even for a single-level stream function, is a formidable integral over 6 dimensions, but it is the beauty of the variation method that there is never a need to evaluate the integral to obtain the prescriptive equations. Chapter 7 expands the scheme to include nonlinear dynamics.

Because the resultant equations from the variational process are partial differential equations they require boundary conditions; these may not be available in a natural way particularly if the region under investigation is a mass of water far from a coastline. The Charney–Fjørtoft–von-Neumann conditions are developed and integrated into the inverse formulation in chapter 8, and the question discussed of possible discontinuities and instabilities and what to do about them in a practical solution. All these topics, and others that include the design of arrays of sensors, and a Kalman filter method for forecasting, are illustrated with case studies and copious references to the modern literature.

Even though the prose is well-written and lively, I found this book hard to read. I recognize that part of my difficulty arises from the fact that I am not an oceanographer, but that is not the whole story. Bennett evidently believes it would be too pedestrian to begin a discussion of a topic with a summary of the mathematical model under investigation, what the assumptions are, when they might be applicable and when not, and so on. All this is taken to be obvious to the reader from the context. Thus, in the early section on Gauss–Markov smoothing, the stream function is introduced without noting that it is assumed to be a stochastic process, presumably stationary in time, but not necessarily in space. This only becomes evident as the author begins to derive properties by averaging over ensembles, which in practice must be time averages, unless spatial stationarity and ergodicity are assumed; none of this background is mentioned. In the illustrative example, spatial stationarity is taken for granted without remark. Later in the same chapter the smoothing spline is derived and its properties compared with the Gauss–Markov procedure. Nowhere does Bennett state explicitly that the assumptions behind the two procedures are entirely different: one applies to a stochastic field, the other to continuously differentiable functions without statistical properties. Indeed, throughout the book, no distinction is made in either notation or discussion between random variables and real numbers, or ordinary functions and stochastic processes.

Although I would have found such signposts helpful, to some my complaint may seem to be a pedantic gripe. This book contains a wealth of information about a powerful set of techniques, which are likely to come into wider use. Research oceanographers will probably have no trouble understanding what assumptions are being made from the context, but students, even advanced graduate students, may need some guidance.

R. L. PARKER

Modern Methods in Analytical Acoustics. By D. G. CRIGHTON, A. P. DOWLING, J. E. FFOWCS WILLIAMS, M. HECKL and F. G. LEPPINGTON. Springer, 1992. 738 pp. DM 89.

Many academics from around the world who work in the area of theoretical acoustics will have heard of the celebrated 'acoustics roadshow'. This was an intensive lecture series, offered in various different forms and at many locations over the years, given by experts in the techniques used in acoustics. The founding members of the team were Professors J. E. Ffowcs Williams, D. G. Crighton, F. G. Leppington and Dr C. Ellen who delivered the first series of lectures at the Admiralty nearly 30 years ago. As the series has been repeated in Europe and USA, so the scope of lectures and the size of the team have grown. However, the primary aim of the group, namely the teaching of analytical techniques fundamental to specific areas of wave mechanics, has remained. The 'roadshow' always attracted large crowds, whether it was given to industrial scientists, engineers or academics, because the notes proved to be an invaluable reference source for the understanding of wave processes and phenomena. There has always been a great demand in the acoustics community for 'bootleg' copies of these notes. It is perhaps in response to this demand that the authors have finally drafted the course into book form, and it now appears as part of the Lecture Notes series published by Springer. It must be mentioned that the book offers more than a copy of the last evolved state of 'roadshow' lecture notes – it has been carefully planned and constructed by the authors to offer a unique introduction to the state of the art methods used by acousticians today alongside specific areas of wave motion and unsteady fluid mechanics. Parts of the book, included for completeness, have not been given in any lecture series, and there is a definite attempt to bring in the newly developing aspects of acoustics (e.g. nonlinear phenomena, wavelets).

The book has been arranged into three parts. These deal with, in their words, I The classical techniques of wave analysis, II The generation of unsteady fields and III Wave modification. Although referred to as classical, part I aims to offer the reader a comprehensive introduction to all of the major mathematical tools currently available to researchers in this area. Many of the chapters deal with analytical approaches, including complex variable theory, Fourier transforms, Green's theorem and the asymptotic evaluation of integrals. There are also introductions to random processes, digital sampling, fast Fourier transforms and wavelets, statistical energy analysis and numerical methods. The latter chapter introduces finite element and boundary element methods which have been extensively employed in scattering and vibration problems. Part I also introduces the fundamental building-block solutions in acoustics, for example monopole, dipole and higher-order solutions of the Helmholtz equation, the Sommerfeld half-plane diffracted field. These occur naturally in the text, as examples of the methods. The Wiener–Hopf technique, which is traditionally considered a 'difficult' topic for new researchers, is very well explained, and this is followed in chapters 6 and 7 by excellent accounts of the methods of matched asymptotic expansions and multiple scales as applied by acoustics and vibration theory. Indeed, chapters 1, 4, 6, 7 will offer invaluable introductions to researchers in all branches of applied mathematics and engineering.

The middle third of the book is concerned with informing the reader of the multitude of phenomena associated with fluctuating sound fields, their generation and interaction with structures. The opening chapters of part II give a simple and effective derivation of Navier–Stokes equation, which leads to the inhomogeneous wave equation. They then introduce Lighthill's approach to determining the sound induced by convected turbulent fields (or vorticity) in free-space and near boundaries or compact bodies. Other chapters examine thermoacoustic and moving sound sources, propeller and helicopter noise and flow noise effects on surfaces. The closing chapter of part II concentrates on steady-state acoustic motions in a fluid which is driven by a vibrating flexible surface. Fluid–structural interaction problems of this type are now of great importance in underwater- and aero-acoustics.

The final nine chapters, grouped under the rather cryptic title of wave modification, tackle a range of interesting, important but rather disparate aspects of wave diffraction, propagation and attenuation. They also introduce several methods which could, had their application been in a more classical area of acoustics, have appeared in part I. For example, a chapter on inverse scattering problems highlights the approaches by Imbriale & Mitra and Colton & Monk, the inverse spectral transform is discussed in connection with the Korteweg–de Vries equation and solitons, and various techniques are offered to solve Burgers-like shock equations occurring in nonlinear acoustics. Chapters on linear aspects include an overview on scattering and diffraction, resonance and resonators, bubbles and reverberation effects. The penultimate chapter offers an introduction to dynamical systems, including chaotic behaviour, with little reference to acoustic phenomena. However, its inclusion is valid here as real applications in acoustics, which have chaotic or other complex nonlinear states, are now emerging. The book is completed by a chapter on anti-sound and its relevance to active control.

Modern Methods in Analytical Acoustics should undoubtedly become a reference text for all practising researchers and postgraduates in this area. This is because it examines a coherent and well-established field in a way which no other book has yet satisfied. The various mathematical, statistical, and numerical techniques outlined below can all, of course, be found in greater detail elsewhere, but the emphasis, depth, and style are appropriate for the required end. The shear diversity of methods illustrated, together with concrete phenomenological applications of such techniques, demonstrates the breadth and vitality of modern acoustical research. Indeed, the book is comprehensive, running to over 700 pages, but despite this still manages to offer only a brief introduction to each topic! As a book in lecture note form, it has the advantage of being informal, even chatty, in style and offers excellent introductory chapters which assume a very basic level of knowledge. This will make it very appealing to Masters and PhD students, and could offer opportunities for incorporation into undergraduate lecturing material. However, as part of the Springer Lecture Notes Series, the book has certain disadvantages. Many of the 26 chapters of the book have very short or no introductions, and so fail to give the uninformed reader a sense of the structure and relative importance of the various sections within each chapter. Also, references to key texts and articles are kept to a minimum throughout, with no overall bibliography provided. An extended reference list at the end would have been very useful, as would running headers indicating section numbers etc. In textbook form the work would, to my mind, have to be rearranged, with more emphasis on continuity and development of ideas. Several chapters would be difficult to include in such a format. However, these criticisms are minor, and what is delivered is an excellent book, from world-leading authorities in the field, which has a real role to play as a research and reference text. I recommend all acousticians to buy two copies, one for their office, and one for reading at home!

I. D. Abrahams