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# BOOK REVIEWS

**Computational Moving Boundary Problems.** By M. Zerroukat & C. R. Chatwin. Wiley, 1994. 212 pp. ISBN 0-86380-168-4. $38.50.

The mathematical modelling of physical phenomena involving (*a*) transport through adjacent materials or domains with different physical or kinematical properties, (*b*) interfaces whose role is not only to demarcate distinct physical regions, but also to affect the momentum, heat, or mass exchange, (*c*) both of (*a*) and (*b*), result respectively in so-called free-boundary, moving-boundary, or advancing-front problems. Two examples in fluid dynamics are the motion of vortices in an otherwise irrotational flow, and the evolution of interfaces between inviscid or viscous fluids in the presence of surface tension. From a mathematical standpoint, the distinguishing feature of these problems is that the motion or steady shape of the interfaces must be found, along with the rest of the unknowns, as part of the solution.

The ubiquity of moving-boundary problems, combined with the challenge of solving them, has made them a popular study area among physical scientists, applied mathematicians, and numerical analysts alike. The added feature of an *a priori* unknown or evolving boundary requires modifying the conventional numerical methods for solving partial differential equations. Several approaches have been developed over the years, with different disciplines and schools of researchers favouring different methodologies. The main goal in all cases is to facilitate the implementation of the boundary conditions at the stationary or evolving front.

Ways to amend finite-difference methods in particular include: (*a*) interpolation through a fixed grid to the location of the free boundary; (*b*) use of an adaptive grid, an adaptive time step, or both, so that the boundary passes through the finite-difference grid nodes; (*c*) use of boundary-fitted coordinates; (*d*) use of an indicator function that evolves according to a specified law; an iso-scalar surface of this function coincides with the front; (*e*) interpretation of the front as an immersed boundary, resulting in a generalized governing differential equation.

This short monograph by Zerroukat & Chatwin focuses on the first and second of the aforementioned classes of methods. Examples are taken mainly from the field of heat transfer with melting or solidification. Chapter 1 introduces the general subject and provides an overview of the following chapters. Chapter 2 is an introduction to heat-transfer moving-boundary problems in one dimension, and includes a discussion of established finite-difference methods. Chapter 3 presents traditional and recently developed finite-difference methods for the unsteady heat conduction equation in one dimension, and Chapter 4 puts these methods into practice. Chapter 5 discusses the particular problem of oxygen diffusion into an absorbing medium. Chapter 6 considers multi-phase problems, and chapter 7 considers melting during laser treatment.

The book is written well, the discourse is clear, and the presentation of the numerical examples and case studies is careful and instructive. But following the material requires prior knowledge and some hands-on experience with finite-difference methods. Large portions of the text are dedicated to discussing numerical methods that have been developed by the authors in recent years; a more balanced presentation would be more appropriate. Moreover, a guide to acronyms and full bibliographic citations would be desirable.

To this reviewer's knowledge, a comprehensive book on moving-boundary problems in which a broad class of applications are discussed, and a thorough presentation of alternative methods is offered, has not yet been written.

C. Pozrikidis

**Dynamical Systems and Numerical Analysis.** By A. Stuart & R. Humphries. Cambridge University Press, 1996. 685 pp. ISBN 0-521-49672-1. £40.

Congratulations to the authors for a scholarly and thorough introduction to the maturing interface between dynamical systems and numerical analysis.

The integration of ordinary differential equations (ODEs) by difference equations is a central topic in numerical analysis, and autonomous ordinary differential and difference equations are the central topics in dynamical systems theory. So it is only natural that there should be links between the two domains. It is shocking that it has taken so long for such links to be regarded as normal. Here is one of the first books to merge the two subjects whole-heartedly, and the authors have done a fine job.

They give clear and detailed introductions to both dynamical systems theory and the basic classes of numerical method for ODEs: Runge–Kutta methods and linear multistep methods. Then they go beyond the traditional local and global truncation error analysis for the initial value problem to address questions like when a numerical method has an attractor near to an attractor of the ODE, and when a numerical method applied to a Hamiltonian ODE preserves Poincaré's invariant. Such issues are becoming increasingly important.

The book is characterized throughout by impeccable mathematical analysis: nothing is left vague. Perhaps too much detail is given for some readers, but I expect the authors are right to err on the safe side. In addition, each chapter ends with a detailed discussion of the relevant literature, making it easy to understand the history and to follow any topics further.

It would form an ideal base for a graduate course on numerical analysis of dynamical systems.

My only regret is that it does not go further. For example, shadowing – the theory of when there is a true solution uniformly close to a numerical solution – is a vital topic, mentioned at the end of one chapter, but considered to be too large to add to an already substantial book. Also, on the historical side, I believe that the idea of modified equations – approximating a near-identity map to high order by an autonomous flow – goes back considerably further than the authors indicate, being commonplace to writers like Takens in 1974, and having its origins in Krylov and Bogolyubov's method of averaging (1934).

R. S. MacKay

## SHORT NOTICES

**Flow and Heat Transfer in Rotating-Disc Systems. Volume 2: Rotating Cavities.** By J. M. Owen & R. H. Rogers. Wiley, 1995, 295 pp. ISBN 0-471-95745-3. £45.

This book is the companion to Volume 1: *Rotor-Stator Systems*, which was published in 1989 and reviewed in *J. Fluid Mech.* vol. 241, 1992, p. 724.

The present publication extends the earlier volume to situations where a complete cavity rotates but is subject to perturbations such as a radial inflow and/or outflow.

Applications to turbo-machinery and to gas-turbine engines are very close to the authors' interests. With the present day emphasis on research directed towards 'national wealth creation', the book is relevant at the interface between applied science and engineering at the present time.

Although many readers of *JFM* may see the problems discussed as geometrically rather complex, and may see the mathematical and computational techniques as rather empirical at times, they will also see that the fundamentals of our subject do lie close to the surface of the authors' writing. Thus some prototype problems spring to mind from the pages of this book, both of a theoretical and an experimental kind, in such a way as to attract readers of this *Journal*. One can quibble about certain aspects of the book, the inadequate quality of the reproduction of flow-visualization photographs for example, but the book is well-written (albeit tersely) and would, I believe, repay study.

**La Turbulence.** By M. LEISEUR. Presses Universitaires de Grenoble, 1994. 149 pp. ISBN 2-7061-0588-7.

This book on turbulence is written in the French language and for the French spirit. It gathers a broad range of topics ranging from Kolmogorov's and Richardson's laws to $K-\epsilon$ modelling with discussions of various fluid dynamical instabilities, boundary and mixing layers, cyclones, tornadoes, subsonic, supersonic and hypersonic aerodynamics, even a little bit of fractals and philosophy. The book starts with a description of the turbulence encountered on a Lyon–Madrid flight and ends with some thoughts about predicting the unpredictable and conquering the impossible. There are few equations and many beautiful colour pictures in this book, which makes for an easy read, accessible to a broad scientific public with some understanding of fluid mechanics, mathematics and physics.

**Domain Decomposition Methods in Sciences and Engineering.** Edited by R. GLOWINSKI, J. PÉRIAUX, Z.-C. SHI & O. WIDLUND. Wiley, 1997. 512 pp. ISBN 0-471-96560X. £60.

The 8th International Conference on domain distribution methods for partial differential equations took place in Beijing in May 1995, and this volume of proceedings contains the texts of 51 presentations.

**Metastable Liquids.** By P. G. DEBENEDETTI. Princeton University Press, 1997. 411 pp. ISBN 0-691-08595-1. $69.50.

This book provides a comprehensive treatment of the properties of liquids under conditions such that the stable state is a vapour, a solid, or a liquid mixture of different composition. It examines the fundamental principles that govern the equilibrium properties, stability, relaxation mechanisms, and relaxation rates of metastable liquids. Both traditional topics, such as stability theory, and modern developments are treated in detail.

**Reasoning About Luck: Probability and its Uses in Physics.** By V. AMBEGAOKAR. Cambridge University Press, 1996. 231 pp. ISBN 052144-737-2. £12.95.

Every fluid dynamicist who has worked with statistical concepts knows that on moving to, say, turbulence from problems in other branches of fluid mechanics he has to a certain extent to change his attitude. It requires some time to adjust oneself to the statistical way of thinking. The book under review is unusual in explaining and giving the feeling of different statistical disciplines. In fact, it was a course of lectures delivered by the author at Cornell University which formed the basis of this book. The special feature of the course was that it was delivered for 'non-Science' students and is part of a series of such courses. The requirements for a reader's mathematical knowledge are indeed rather low (although not as low as the author declared at the beginning). However the author was able to consider many important subjects, including not only the elements of statistical mechanics, thermodynamics and quantum theory, but also the elements of modern concepts of chaos. I think that both teachers and students will gain from reading and using this small book.

**The Pleasures of Counting.** By T. W. Körner. Cambridge University Press, 1996. 534 pp. ISBN 0521-56823-4. £17.95.

This book is a collection of essays concerning diverse applications of mathematics to practical problems. The circle of these problems is rather wide – from epidemics to the railroad problem, and from submarine wars to deciphering coded messages (the famous Enigma and similar material). Some of the essays could be of interest to a fluid mechanicist especially one interested in history, as are chapter 6 ('Physics in a darkened room'), chapter 8 ('A Quaker Mathematician') and chapter 9 ('Richardson on War'). For non-specialists this book could also provide an opportunity to learn a little about the work of G. I. Taylor and L. F. Richardson, in particular about G. I. Taylor's invention of a new anchor and his first published work, namely, an experiment performed at the suggestion of J. J. Thompson.

The book deserves to be available in libraries where mathematicians, pure and applied, browse. They will find there many interesting facts delivered from a non-standard viewpoint, particularly useful in teaching. The impression of the book is lowered a little by the author's inadequate way of referring to important sources, essentially used by him in his exposition. Also some important formulae (see, for instance, p. 120) should be corrected. For the reader's convenience the formulae should be numbered. The presentation of dimensional analysis (chapter 6) should be more accurate, in particular the actual definition of the dimension.

**Chaotic Dynamics: an Introduction.** By G. L. Baker & J. P. Gollub. Cambridge University Press, 1996. 256+xiv pp. ISBN 0-521-47685-2. £14.95 (paperback).

This is an expanded version (256 vs. 182 pp.) of the five-times-reprinted 1990 edition (reviewed with the appellation 'excellent book' in *J. Fluid Mech.* vol. 223, 1991, pp. 662–663). It contains a new chapter, *Experimental characterization, prediction and modification of chaotic states*, and the closing chapter, *Chaos broadly applied* (formerly *Concluding remarks*), has been extended to include material on spatio-temporal chaos, strong turbulence, and chaotic mixing that will be welcomed by teachers of fluid mechanics. The presentation remains accessible to advanced undergraduate or first-year graduate students in science and engineering and is eminently suitable for an introductory course.

**Nonlinear Effects in Fluids and Solids.** Edited by M. C. Carroll & M. A. Hayes. Plenum Press, 1996. 358 pp. ISBN 0-306-45179-4. $89.50.

The editors and publishers of this book are strangely shy about its origin and raison d'etre. To begin with, there is almost nothing about fluids. The only guidance to the purpose of the book is that given by the first sentence of the preface: 'This volume of scientific papers is dedicated with gratitude and esteem to Ronald Rivlin and is offered as a token of appreciation by former students, colleagues and friends.' Fair enough; a reader will know what he is getting when he has made some progress, which is unlikely to be until after some time. The person being honoured deserves better editorial service.

**Annual Research Briefs 1996.** Center for Turbulence Research

This is not a book in the ordinary sense, but it looks like a volume of *JFM* and it deserves the attention of the turbulence community the world over. The CTR is attached to both NASA Ames Research Center and Stanford University, and this annual volume contains the 1996 progress reports of the research fellows and students supported during the year by the CTR. The reports have the same structure as a normal paper in *JFM*, and range widely in topic. They are generally of a high standard.

**Annual Review of Fluid Mechanics, vol. 29.** Edited by J. L. Lumley & M. Van Dyke. Annual Reviews Inc., 1997. ISBN 0-8243-0729-1. $60.

Here is the list of articles and authors in the current volume of this periodical.

G. I. Taylor in His Later Years, J. S. Turner
Electrohydrodynamics: The Taylor-Melcher Leaky Dielectric Model, D. A. Saville
Core-Annular Flows, D. D. Joseph, R. Bai, K. P. Chen, and Y. Y. Renardy
Convection in Mushy Layers, M. Grae Worster
Quantification of Uncertainty in Computational Fluid Dynamics, P. J. Roache
Computing Aerodynamically Generated Noise, Valana L. Wells and Rosemary A. Renaut
Nonlinear Bubble Dynamics, Z. C. Feng and L. G. Leal
Parabolized Stability Equations, Thorwald Herbert
Quantitative Flow Visualization in Unseeded Flows, Richard B. Miles and Walter R. Lempert
Convection into Domains with Open Boundaries, T. Maxworthy
Fluid Mechanics of Spin Casting of Metals, Paul H. Steen and Christian Karcher
Blood Flow in Arteries, David N. Ku
The Phenomenology of Small-Scale Turbulence, K. R. Sreenivasan and R. A. Antonia
Unstructured Grid Techniques, D. J. Mavriplis
Modern Helicopter Aerodynamics, A. T. Conlisk