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# REVIEWS

**Dimensional Analysis.** By G. I. BARENBLATT. Translated from Russian by P. MAKENIN. Gordon & Breach, 1987. 135 pp.

Bridgman's little *Dimensional Analysis* published in 1922 was the first book on the subject and remains, despite numerous competitors, still the best introduction for any student. Barenblatt has chosen the same title for his own short book, to emphasize that he considers his work to be a continuation of that begun by Bridgman. It is an amplification, intended for the general reader, of his previously published, more specialized book on *Similarity, Self-Similarity, and Intermediate Asymptotics* (Consultants' Bureau, 1979; reviewed in this Journal, vol. 101, pp. 222–224).

This new book divides neatly into halves, the first being a survey of what is traditionally understood as dimensional analysis. It modernizes Bridgman's account and improves it on various points, including a corrected statement of the famous pi theorem (so that my students need no longer ask why the pressure ratio across a normal shock wave is alleged to depend on no pi's at all), and enlivens it with a half-dozen striking photographs and several dozen drawings.

It is astonishing that no previous book on the subject has ever mentioned that dimensional analysis will sometimes reduce the number of coordinates as well as the number of independent parameters. This has the important consequence of reducing a partial differential equation (in two variables) to an ordinary differential equation, and so yielding a self-similar solution. Barenblatt devotes the second half of his book to self-similarity and its subtleties. After discussing the Taylor–Neumann–Sedov solution for a strong point explosion, he turns to less familiar matters, exemplified by two contrasting linear problems: the rapid addition of a quantity of heat to a small region nearer to one end of a finite bar, and plane potential flow past a finite wedge. In neither problem is the full solution self-similar, but the heated bar has 'complete self-similarity' in two different intermediate stages of the development; hence those are 'self-similar solutions of the first kind', meaning that they are revealed by dimensional analysis. On the other hand, the wedge has 'incomplete self-similarity' near its vertex, where there is locally a 'self-similar solution of the second kind'. This means that, as in Guderley's pioneering 1942 solution for the collapse of a spherical shock wave, the form of the similarity is not revealed by dimensional analysis, but only in the course of solution of an eigenvalue problem.

The four phrases quoted above are part of a Russian vocabulary required to understand much recent work in similitude. As examples, the book concludes by prescribing a recipe for dimensional analysis, and then applying it to three more sophisticated (and perhaps controversial) solutions: the velocity distribution in the wall region of a turbulent shear flow, the relationship between the breathing rate of animals and their mass, and the spreading of a ground-water mound.

I would advise a student interested in similitude to study Bridgman and then Barenblatt. Having taught a course on this subject for some years, I would naturally quibble over a few points that I hope to see refined in a second edition. In particular, it is regrettable that the classification of self-similar solutions into first and second kinds excludes from both categories Prandtl's self-similar solution for the laminar boundary layer on a flat plate, and indeed the entire Falkner–Skan family, including

Hiemenz's and Homann's exact solutions of the full Navier–Stokes equations. We must beg our Russian colleagues to sandwich in a category of 'self-similar solutions of the one-and-a-halfth kind', those that are concealed from dimensional analysis but are revealed, before solution, by differential stretching of coordinates and other groups of transformations.

M. VAN DYKE

**Viscous Vortical Flows.** By L. TING and R. KLEIN. Springer, 1991. 222 pp. DM 42.

The equations governing the evolution of the vorticity field in an unbounded flow are nonlinear, and progress has been possible only by approximations to the support of the vorticity or by numerical simulation. In both cases a price has to be paid. When the support is simplified to a vortex sheet or to a vortex filament the Biot-Savart integral diverges. In numerical work in three dimensions it is hard to reconcile the need to resolve the vorticity field with the need to satisfy boundary conditions at infinity. Many workers resort to unphysical periodic boundary conditions to cope with this difficulty.

The majority of the investigations into these problems have been based on the inviscid equations. The work presented here is unusual in being based on the full Navier–Stokes equations and, because the size of viscous effects is chosen in a particular way, comparison with other work cannot be made by a straightforward limiting process. Thus the work described, which has been carried out over some 25 years by Ting and his collaborators, stands a little apart.

Chapter 1 of the book is devoted to a description of the far field of a vortical flow. The authors say – correctly in the case of this reviewer – that these results, due to Truesdell and to Moreau, are unfamiliar. Their importance is twofold. Use of the results enables accurate outer boundary conditions to be applied on the boundary of the computational domain for the numerical work of chapter 3. Secondly, they can be used to obtain in a satisfying way the radiation from a compact vortex field whose motion is known.

Chapter 2 begins with a discussion of the infinite straight filament or vortex patch. The authors point out that, when such a patch is embedded in a potential flow of much larger lengthscale, two timescales emerge, the shorter being that of waves on the patch boundary. Multiple-scales analysis is deployed to show that the centre of the patch moves with the velocity of the potential flow. However, the analysis stops short of a re-derivation of Kida's elegant result for a small patch of uniform vorticity, and it is disappointing to find that the authors have nothing to say about filamentation, where one might expect viscous diffusion to be important.

Chapter 2 continues with a treatment of the curved vortex filament, the method of matched asymptotic expansions being employed. The small parameter is the ratio of the core size to the lengthscale of the filament as a whole, and, in order to avoid a second independent parameter arising, the viscosity is chosen so that the timescale of viscous diffusion of the core is equal to the evolutionary timescale of the filament. Even with this restriction the analysis is very complex and, while the presentation of the matching is clear, the chapter is tough going. It would have been good to have seen some comparisons with other work, such as Crow's seminal 'cut-off' theory, and one wonders what an aerodynamicist will make of the fact that for trailing vortices the Reynolds number of the crossflow would have to be of order 100 for the present theory to apply to their mutual interaction. Nevertheless, this is analysis of high quality, and its clear exposition is perhaps the most valuable part of the book.

Chapter 3 is devoted to numerical work. A careful discussion of computational efficiency is given and an interesting attempt is made to use embedded computational domains to achieve both resolution and an accurate far field. Also described is a scheme for using the Lamb vortex as a computational element, although no comparison with other 'blob' methods such as Krasny's is attempted.

The most interesting part of chapter 4 is an account of some very recent work by Klein and Majda on improvements to Hasimoto's treatment of the vortex filament. The resulting equation adds to the cubic Schrödinger equation a linear integral operator. This new amplitude equation will be of interest to experts on solitons.

In short, the book will be useful for the experienced worker in the field; the less experienced worker might be at risk of overlooking work of potential value to him.

D. W. MOORE

The following volumes of conference proceedings have also been received:

**Hydrodynamics of Dispersed Media.** Edited by J. P. HULIN, A. M. CAZABAT, E. GUYON and F. CARMONA. North-Holland, 1990. 296 pp.

**Numerical Treatment of the Navier–Stokes Equations.** Edited by W. HACKBUSCH and R. RANNACHER. Vieweg, 1990. 166 pp. £28.00.

**Proceedings of the Eighth GAMM-Conference on Numerical Methods in Fluid Mechanics.** Edited by P. WESSELING. Vieweg, 1990. 618 pp. £60.75.

**Particles in Gases and Liquids: Detection, Characterization, and Control.** Edited by K. L. MITTAL. Plenum, 1990. 407 pp. $89.50.

**Convective Heat and Mass Transfer in Porous Media.** Edited by S. KAKAÇ, B. KILKIŞ, F. A. KULACKI and F. ARINÇ. Kluwer, 1991. 1095 pp. £154.00.

**New Trends in Nonlinear Dynamics and Pattern-forming Phenomena.** Edited by P. COULLET and P. HUERRE. Plenum, 1990. 357 pp. $85.00.

**Computers in Fluid Power.** Edited by C. R. BURROWS and K. A. EDGE. Wiley, 1991. 361 pp. £79.50.

**Advances in Turbulence 3.** Edited by A. V. JOHANSSON and P. H. ALFREDSSON. Springer, 1991. 540 pp. DM156.

**Separated Flows and Jets.** Edited by V. V. KOZLOV and A. V. DOVGAL. Springer, 1991. 898 pp. DM358.

**Turbulence Control by Passive Means.** Edited by E. COUSTALS. Kluwer, 1990. 173 pp. £50.00.

**Turbulence and Coherent Structures.** Edited by O. METAIS and M. LESIEUR. Kluwer, 1991. 620 pp. £86.00.

**Continuum Models and Discrete Systems.** Edited by G. A. MAUGIN. Longman. Vol. 1, 1990, 324 pp. £42.00; Vol. 2, 1991, 364 pp., £36.99.

**Laminar–Turbulent Transition.** Edited by D. ARNAL and R. MICHEL. Springer, 1990. 710 pp.

**Nematics. Mathematical and Physical Aspects.** Edited by J.-M. CORON, J.-M. GHIDAGLIA and F. HÉLEIN. Kluwer, 1991. 478 pp. £74.00.

**Directional Ocean Wave Spectra.** Edited by R. C. BEAL. Johns Hopkins University Press, 1991. 218 pp. £46.50.

**Macroscopic Theories of Superfluids.** Edited by G. GRIOLI. Cambridge University Press, 1991. 213 pp. £30.00 or $49.95.