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REVIEWS

Similarity, Self-similarity, and Intermediate Asymptotics. By G. I. BARENBLATT. Translated from Russian by N. STEIN and edited by M. VAN DYKE. Consultants Bureau, 1979. 218 pp. $35.

We fluid dynamicists live on intimate terms with dimensional analysis, working almost instinctively in terms of force coefficients and Mach and Reynolds numbers, and are surprised to learn that earlier in this century our colleagues sometimes plotted experimental results in raw dimensional form. We are also familar with self-similar solutions, knowing for example how Sedov and Taylor deduced from simple dimensional considerations that the blast wave from an intense explosion spreads as the 2/5-power of time. In fact, the well known book of Sedov may have given us the erroneous impression that all self-similar solutions are revealed by dimensional analysis. However, we need only recall the Prandtl–Blasius solution for the laminar boundary layer on a flat plate to realize that self-similarity is often revealed only by additional group properties of the problem beyond dimensional invariance. In Russian these are both termed self-similar solutions of the first kind.

We are less familiar with self-similar solutions of the second kind. Perhaps the best known example is Guderley's local solution for a converging spherical shock wave at the instant it collapses onto the centre. The radius decreases (and then grows again) as the 0·717-power of time. However, that exponent cannot be found from dimensional or other properties of the problem, but only from a solvability condition in the course of integrating the solution numerically.

We may have supposed that a self-similar solution of this kind is rare, or even exceptional. Not so, says Barenblatt. Self-similarity of the first kind is actually the exception, with the second kind providing a much richer set of solutions. In this pioneering book he introduces us to such important new concepts as *incomplete self-similarity* and *intermediate asymptotics*, and shows how they enlarge the scope of similitude – even to shed new light on turbulence.

A key point is that although any self-similar solution is the exact solution of a degenerate problem, it is at the same time the asymptotic solution of a non-degenerate and hence non-self-similar problem. For example, the result of Sedov and Taylor solves the idealized problem of a finite amount of energy released at a point, but it is used instead as an approximation to the solution of the non-self-similar motion produced by release of the energy within a finite volume, at such relatively large times that the flow tends toward self-similarity.

In this case the transition from the non-self-similar motion to self-similarity is *complete*: the dimensionless parameter containing the initial size of the explosion, which spoils the self-similarity, can be disregarded at times when it becomes large (or small). Then the self-similar variables can be found by dimensional analysis. Likewise the non-self-similar boundary layer on a blunted plate approaches the Prandtl–Blasius self-similar solution at distances downstream large compared with the blunting. Then the self-similarity is revealed by invariance of the limiting problem under a simple affine transformation. These self-similarities are of the first kind.

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By contrast, Guderley's implosion is an *incomplete* self-similarity. It is the limiting form, as the shock-wave radius tends to zero, of the non-self-similar motion produced, for example, by detonating the explosive lining of a large sphere. However, it turns out that in this case the ratio of shock-wave radius to sphere radius cannot be neglected no matter how small; instead, it enters into the limiting self-similar solution in an essential way, according to a power law whose exponent – in general irrational – cannot be found by dimensional analysis or other group properties of the limiting problem, but only by solving numerically a nonlinear eigenvalue problem. The self-similarity is of the second kind.

Does a non-self-similar process, left to evolve, invariably tend toward a limiting self-similar form? (Does the drag coefficient of a sphere ultimately approach some simple power-law behaviour at Reynolds numbers beyond all existing experiments?) Barenblatt reserves the possibility that no such limit exists; but experience suggests that there is usually either complete or incomplete self-similarity. The difficulty is that we cannot know in advance with which situation we are dealing. Barenblatt recommends that we assume in turn complete, incomplete, and no similarity, and compare in each case with all available numerical, experimental, and analytical information.

More precisely, the non-self-similar motion may tend to an *intermediate* asymptotics, where it no longer depends on the initial details, yet is still far from its ultimate state. For example, the Sedov-Taylor self-similarity is good approximation for a relative long time if the explosion is sufficiently intense and concentrated (as it was at Los Alamos); but that intermediate asymptotics is eventually followed by a final asymptotics in which the strong shock wave has decayed to an acoustic wave, and so expands almost linearly in time.

I think this book will become a little classic. Behind its somewhat daunting title (and more daunting price!) lie ideas that demand careful reading; but they are enlivened by amusing examples and exhilarating possibilities. Is the Pythagorean theorem proved by dimensional analysis, or is that a swindle? Is the decay of homogeneous turbulence incompletely self-similar except at enormous Reynolds numbers? Is Prandtl's logarithmic law for a turbulent shear flow only the complete self-similar extreme of an incomplete self-similarity that gives a power-law variation, with exponent depending on the global Reynolds number? We will have to study these questions until they too become familiar.

M. Van Dyke

Ocean Acoustics. Edited by J. A. DeSanto. Springer, 1979. 285 pp. $37.04 (paperback).

Ocean acoustics enters the world of fluid mechanics in two distinct ways. First, acoustics may be regarded as a branch of fluid mechanics, and for example internal wave characteristics and acoustic wave characteristics can both come from the same set of general equations. Secondly, acoustics may be used as a tool to probe the structures and motions of the ocean. Both these aspects are well represented in DeSanto's book, and the second in particular is a theme of great current interest which runs right through the book.

The book consists of an introduction (chapter 1) followed by six chapters written

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by different authors. The subject matter of the book is really sound propagation, and the many other parts of ocean acoustics are not covered. Both deterministic and stochastic processes are treated, with frequency range generally from a few Hertz to several hundred Hertz. DeSanto points out the variety of techniques that are used to investigate propagation, and that all of them are discussed within the articles of this book. In fact, the major part of the book is occupied by two chapters, on theoretical and numerical methods respectively, and the reviewer believes these are also the most important part of the book by which it must stand or fall.

The first main article is chapter 2 on theoretical methods, by DeSanto himself. He starts from first principles with the general equations for fluids and develops his account into a unified theoretical treatment of ocean sound transmission. This is very well done but is not always easy reading. He makes a somewhat personal selection of detailed topics on which to concentrate, such as the corrected parabolic equation, propagation of coherence functions in a waveguide, and scattering from rough surfaces, but manages to fit everything into his logical framework. The article really transcends his description of it as a review.

Chapter 3 on numerical models is by F. R. DiNapoli and R. L. Deavenport. One is greatly impressed by the sheer numbers as well as the variety of computer models now in use. The authors cover all this in a substantial article, including a good description of recent ideas on the finite-element approach. Admittedly the compression of the material does make the going hard. Similar reviews have appeared previously in reports of limited availability, but here is much more material available in a book. As a passing comment, the reviewer notes that the numerical modelling school is now so very strong that it would be possible to spend one's whole life comparing approaches, and unfortunately this is both tidier and cheaper than obtaining experimental data for comparison.

Chapter 4 by J. G. Zornig is titled 'Physical modeling of underwater acoustics'. This is somewhat misleading since the main topic is laboratory model studies of surface scattering, of which an excellent account is given. Chapter 5 by J. P. Dugan is on oceanography in underwater acoustics, and constitutes an interesting review rich in explanatory material. Like the rest of the book it concentrates on the deep oceans at the expense of shallow coastal waters. Chapter 6 on acoustic probing is by N. Bleistein and J. K. Cohen, and centres on their own research on two applications of inverse methods – to the mapping of reflecting interfaces and of sound speed profiles. The last article is by R. P. Porter with a more general review of the practice and the possibilities of acoustic probing, particularly the examination of acoustic fluctuations as a measure of ocean dynamics.

A comment in the preface describes the book as providing a rapid introduction to the field. This could be misunderstood, since it is not the first place most people should look if they want an easy lead-in. A second comment refers to the book as a thoroughly referenced review of the state of the art. The reviewer entirely endorses this and considers it an excellent collection of linked articles.

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