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REVIEW

Qualitative Methods in Physical Kinetics and Hydrodynamics. By V. P. Krainov. American Institute of Physics, 1992. 203pp. £41.50.

Qualitative methods, that is to say order-of-magnitude estimates or scaling arguments, play an important role in a nonlinear science like fluid mechanics where quantitative methods such as closed-form analytic solutions may be impossible and numerical approaches difficult. Teaching of fluid mechanics in the West may not have given due emphasis to this powerful technique. This book (translated from Russian) gives well over a hundred short examples in a wide range of applications. The first third of the book is devoted to kinetic theory applied to gases, plasmas, dielectrics and metals (i.e. 'physical kinetics'), producing estimates for the transport coefficients in a gas with their dependence on pressure and temperature, wave speeds and damping rates of different modes in a plasma, thermal expansion of dielectrics, and electrical and thermal properties of metals. The remaining two-thirds of the book covers topics in fluid mechanics – inviscid and viscous, boundary layers, turbulence, heat transfer and convection, capillarity and sound. Some of the many examples include surface gravity and capillary waves, viscous damping of a vibrating body, the Blasius boundary layer, laminar and turbulent wakes and jets, buoyant plumes, heat transfer, heat diffusion with a diffusivity with a power-law dependence on temperature, sound generated and scattered by bodies.

Each order-of-magnitude estimate is presently briefly and efficiently in a couple of pages or less. Some sections contain several estimates, and additional headings might have been useful to identify them, given that the book has no index. Some estimates can be obtained from different but equivalent arguments, e.g. one can start from either the energy or the momentum equation, or one can make comparisons based on either length or time scales. This is a matter of personal preference, although a point not to be overlooked by a teacher using the book.

The book does unfortunately contain a significant number of serious errors, which in my opinion makes it unsafe for an untutored student. For example, on page 83 the vortex-stretching term is omitted from the vorticity equation. On the following page the potential flow for a translating body is chosen to be a dipole solution on the curious grounds that a monopole would have an infinite volume of fluid moving with the body; the author not realising that the integral of the dipole flow is not absolutely convergent, further the author abandoning the argument on page 98 when considering Stokes flow. In several places it is innocently suggested that for low amplitudes a power series must start with a linear or quadratic term on grounds of symmetry: this assumption of analyticity is not necessarily true in a nonlinear problem, e.g. the drag on a cylinder is inversely proportional to the logarithm of the Reynolds number at low Reynolds number and the frequency of a surface gravity wave is proportional to the square root of the wavenumber.

An omission from the book is discussion of how one tackles a new unsolved research problem. In the simplest problem with no dimensionless groups, dimensional analysis gives the only possible scaling of all the variables. In more typical nonlinear problems with several non-dimensional groups, it is often possible to construct several quite plausible scalings. The author does not address the question of how one selects the correct scaling. In my own experience, one uses several considerations. One can try to recall a similar solved problem where one knows that one is on safe established ground. One can check that a simplification which suppresses one term does consistently predict that the term is smaller than others. One can be lucky, which may later be called inspiration. Of course the proper course is to look at the experiments, both laboratory and computer experiments, examining several features which are predicted to vary differently by the different candidate scalings.

My final difficulty with this book is to see how it might be used. With an introduction to ideal fluids and to viscious fluids each taking a single page, the book clearly can only be used for teaching as a supplement to a more careful extended text. But then I would hope that the more careful discourse would present many views of the subject, including order-of-magnitude estimates. Perhaps there is a role for revising the key points of a subject, although students must be warned about the erroneous arguments. As a guide to research students, the book is limited by its omission of any advice on how to tackle a new unexplored problem, and is misleading by its omission of comparison with experimental data.

E. J. HINCH