Astro. Lett. and Communications, 1998, Vol. 35, pp. 463–464
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Turbulence: The Legacy of A. N. Kolmogorov

URIEL FRISCH *(Cambridge University Press, 1996) 310 pp., softcover, ISBN:0-521-45713-0, US $30.95; hardcover, ISBN: 0-521-45103-5, US $80*

This textbook presents a modern account of turbulence, one of the greatest challenges in physics. The state-of-the-art is put into historical perspective, with special attention to the fundamental contributions of A. N. Kolmogorov. The intended readership for the book ranges from first-year graduate students in mathematics, physics, astrophysics, geophysics and engineering, to professional scientists and engineers. It is written clearly, and I highly recommend it to anyone interested in the field. The book is divided into nine chapters.

The first chapter clarifies the connection between symmetry (both spatial and temporal) and turbulence, discussing the well-known case of the flow past a cylinder for increasing Reynold's number, and provides a description of the content of the other chapters. In Chapter 2 the basic conservation laws are presented, together with the enumeration of all known symmetries allowed by the Navier-Stokes equation. In particular, the scale-by-scale energy budget is discussed.

Chapter 3 features a discussion of why a probabilistic description of turbulence is appropriate, considering that the Navier-Stokes equation is deterministic. This is done in the framework of Birkhoff's ergodic theorem and viewing the Navier-Stokes equation as a dynamical system. In Chapter 4 various probabilistic concepts frequently used in turbulence are introduced.

After these introductory chapters, in Chapter 5 the reader is exposed to experimental data, presented in order to illustrate two basic empirical laws of fully developed turbulence, the true subject of the book. Particularly, a detailed account of experiments concerning the so-called two-thirds law and the energy dissipation law is given.

Chapter 6 (which is very well written) can be considered the central part of the book, and discusses in depth the celebrated Kolmogorov 1941 theory. In this book Frisch derives this theory not from the original assumption of universality (criticized by Landau), but from the clearer concept point of the symmetries permitted by the Navier-Stokes equation. From this starting point the author moves to describe how the symmetries are spontaneously broken for increasing turbulence, and are finally restored in a statistical sense, when the fully turbulent regime is established. In this chapter a very detailed historical account of the development of the basic concepts of the turbulence theory is also given.

In Chapter 7 a phenomenological approach to the subject of fully-developed turbulence is presented, and problems such as the number of degrees of freedom of a turbulent flow, the law of decay of the energy and the possibility of a finite-time blow-up of an ideal flow are very clearly addressed. Chapter 8 deals with the problem of intermittency. It is an impressive chapter, where the conceptual problems presented by this phenomenon are discussed also from an historical point of view.

The nature of the final chapter is quite different from that of the others. It contains supplementary material beyond the scope of the other chapters, such as fractals, diagrammatic methods, and renormalization; also, a very useful section with a review of books on turbulence and fluid mechanics is given.

In conclusion, this is a very beautiful book, well-written, and highly recommended for anyone interested in the field.

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