Kolmogorov Spectra of Turbulence I

This comprehensive two-volume introduction to a modern and rapidly developing field starts at the level of graduates and young researchers. It provides a general theory of developed turbulence with a consistent description of phenomena in different media such as plasmas, solids, atmosphere, oceans and space.

This volume starts with simple dimensional analysis and proceeds to rigorous theory with exact solutions for the stationary spectra of turbulence, the solution of the stability problem, matching of Kolmogorov-like spectra with pumping and damping. The reader is provided with the necessary tools for studying nonlinear waves and turbulence: Hamiltonian formalisms, methods of statistical description, derivation of kinetic equations and their steady and nonsteady solutions.

Preface

Since the human organism is itself an open system, we are naturally curious about the behavior of other open systems with fluxes of matter, energy or information. Of the possible open systems, it is those endowed with many degrees of freedom and strongly deviating from equilibrium that are most challenging. A simple but very significant example of such a system is given by developed turbulence in a continuous medium, where we can discern astonishing features of universality.

This two-volume monograph deals with the theory of turbulence viewed as a general physical phenomenon. In addition to vortex hydrodynamic turbulence, it considers various cases of wave turbulence in plasmas, magnets, atmosphere, ocean and space. A sound basis for discussion is provided by the concept of cascade turbulence with relay energy transfer over different scales and modes.

We shall show how the initial cascade hypothesis turns into an elegant theory yielding the Kolmogorov spectra of turbulence as exact solutions. We shall describe the further development of the theory discussing stability problems and modes of Kolmogorov spectra formation, as well as their matching with sources and sinks.

This volume is dedicated to developed wave turbulence in different media. It contains a detailed exposition so that the reader can use it as an introductory textbook on wave turbulence theory. Moreover, it also provides an introduction to the general theory of developed turbulence, since wave turbulence at low excitation level is closely related to the Richardson-Kolmogorov-Obukhov cascade picture. In the second volume developed turbulence of incompressible fluids will be described.

This text is based on lecture courses given at the Arizona, Chicago and Novosibirsk Universities, at the Moscow Institute of Space Researches, and the Weizmann Institute of Science in Rehovot.

The book is useful for specialists in hydrodynamics, plasma and solid-state physics, meteorology, and astrophysics. We also hope it will prove instructive for students and young researchers starting their academic careers with studies of the problem of turbulence.

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