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978-1-316-51860-1 — Introduction to Turbulent Transport of Particles, Temperature and Magnetic Fields
Igor Rogachevskii
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INTRODUCTION TO TURBULENT TRANSPORT OF PARTICLES, TEMPERATURE AND MAGNETIC FIELDS

Turbulence and the associated turbulent transport of scalar and vector fields present a classical physics problem that has dazzled scientists for over a century, yet many fundamental questions remain. Igor Rogachevskii, in this concise book, systematically applies various analytical methods to the turbulent transport of temperature, particles and magnetic fields. Introducing key concepts in turbulent transport including essential physics principles and statistical tools, this interdisciplinary book is suited for a range of readers, such as theoretical physicists, astrophysicists, geophysicists, plasma physicists and researchers in fluid mechanics and related topics in engineering. With an overview to various analytical methods, such as mean-field approach, dimensional analysis, multi-scale approach, quasi-linear approach, spectral tau approach, path-integral approach and analysis based on budget equations, it is also an accessible reference tool for advanced graduates, PhD students and researchers.

IGOR ROGACHEVSKII is a full Professor at the Department of Mechanical Engineering of Ben-Gurion University of the Negev and visiting Professor at Nordita of KTH Royal Institute of Technology and Stockholm University. He has published more than 160 research articles in several peer-reviewed journals on theoretical physics; dynamo; turbulent transport of temperature, particles and magnetic fields; plasma physics; solar physics and atmospheric physics.

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Analytical Methods for Physicists and Engineers

IGOR ROGACHEVSKII
Ben-Gurion University of the Negev

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Preface

Turbulence, and the associated turbulent transport of scalar and vector fields, is one of the classical problems of physics. It has been studied systematically for more than a hundred years. However, many fundamental questions related to the nature of turbulence remain. Turbulent transport is a part of the field related to turbulence. Many excellent books on turbulence that describe velocity fluctuations in detail have been published over the last hundred years. Some of these books include problems related to the turbulent transport of passive fields. However, there are no books that systematically apply different analytical methods to turbulent transport of temperature, particles and magnetic fields.

The current book is an introduction to the various analytical methods of theoretical physics and applied mathematics used to develop the mean-field theories for studying the turbulent transport of particles, temperature and magnetic fields. In particular, the following analytical methods are systematically applied in this book: the dimensional analysis, the multi-scale approach, the quasi-linear approach, the tau approach (the relaxation approach), the path-integral approach and analyses based on the budget equations. One-way and two-way couplings between turbulence and particles, or temperature, or magnetic fields are described.

This book is written for theoretical physicists, astrophysicists, geophysicists, plasma physicists, space science physicists and also for researchers working in fluid mechanics in engineering sciences. The current book can be useful for postgraduate students, specialist researchers of turbulence and turbulent transport and nonspecialist researchers from related fields. It can be presented as a source of advanced teaching material for specialized seminars, courses and schools. This book has appeared as a development and extension of the material of graduate and postgraduate lecture courses given by the author at Ben-Gurion University of the Negev. Some of these lectures have been given at the Nordic Institute of Theoretical Physics (Nordita) of KTH Royal Institute of Technology and Stockholm University.

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The current book assumes prior knowledge of the basic equations and principles of fluid mechanics and magnetohydrodynamics, as well as initial knowledge about turbulence. For instance, the first part of the textbook *Turbulence* by Peter Davidson (Oxford University Press, 2015) provides a solid introduction to the field. For educational purposes, the current book is written with detailed analytical calculations and numerous practice problems and exercises. Every chapter ends with a "Further Reading" section containing a short review in the field. The book contains 60 exercises of varying difficulty with solutions.

I would like to express my warmest thanks to my friend and coauthor, Nathan Kleeorin, with whom I discussed various aspects related to turbulent transport during our joint research. I am grateful to my friends and colleagues with whom I collaborated in different areas of turbulent transport, magnetohydrodynamics and plasma physics over the past 40 years: Alexey Boyarsky, Axel Brandenburg, Steve Cowley, Oliver Gressel, Alexander Gurevich, Alex Eidelman, David Eichler, Tov Elperin (1949–2018), Jürg Fröhlich, Nils Haugen, Maarit Käpylä, Petri Käpylä, Alexander Khain, Kirill Kuzanyan, Avi Levy, Michael Liberman, Victor L'vov, Baruh Meerson, Dhruba Mitra, Michael Mond, David Moss (1943–2020), Karl-Heintz Rädler (1935–2020), Oleg Ruchayskiy, Alexander Ruzmaikin, Pavel Sasorov, Alex Schekochihin, Jennifer Schober, Nishant Singh, Dmitry Sokoloff, Andrew Soward, Jörn Warnecke and Sergej Zilitinkevich (1936–2021).

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I am grateful to my friend Michael Feldman, who convinced and encouraged me to write this book and helped me a lot. I would like to express my warmest thanks to Rimma Shekhtman for the painting of the cover image for the book. This book is dedicated to my family.

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