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Quantized Vortex Dynamics and Superfluid Turbulence

Springer

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Cover picture: Tangle of quantized vortex filaments computed in a periodic box by D. Kivotides, D. Samuels and C.F. Barenghi.

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Preface

This book springs from the programme *Quantized Vortex Dynamics and Superfluid Turbulence* held at the Isaac Newton Institute for Mathematical Sciences (University of Cambridge) in August 2000. What motivated the programme was the recognition that two recent developments have moved the study of quantized vorticity, traditionally carried out within the low-temperature physics and condensed-matter physics communities, into a new era.

The first development is the increasing contact with *classical fluid dynamics* and its ideas and methods. For example, some current experiments with helium II now deal with very classical issues, such as the measurement of velocity spectra and turbulence decay rates. The evidence from these experiments and many others is that superfluid turbulence and classical turbulence share many features. The challenge is now to explain these similarities and explore the time scales and length scales over which they hold true. The observed classical aspects have also attracted attention to the role played by the flow of the normal fluid, which was somewhat neglected in the past because of the lack of direct flow visualization. Increased computing power is also making it possible to study the coupled motion of superfluid vortices and normal fluids. Another contact with classical physics arises through the interest in the study of superfluid vortex reconnections. Reconnections have been studied for some time in the contexts of classical fluid dynamics and magneto-hydrodynamics (MHD), and it is useful to learn from the experience acquired in other fields.

The second development arises from *atomic physics* and is the discovery of Bose–Einstein condensation in confined clouds of alkali atoms. The study of superfluidity and quantized vorticity is now possible in a wide range of other systems besides helium II. The rapid progress in this area has given momentum to the use of the Gross–Pitaevskii Equation or Nonlinear Schroedinger Equation (NLSE). Researchers have become more aware of the approximations and limitations involved in the NLSE model, but also of its range of validity and great power of prediction. The use of the NLSE has become more established, and the NLSE is proving to be a powerful tool for modeling problems such as vortex nucleation, reconnections and even turbulence.

A further development arises from the results of preliminary theory and experiments in turbulent Helium 3 which suggest that there are significant differences with turbulence in Helium 4 and these are likely to be explored in the future.

It is apparent from this background that the contributions to this book come from investigators with a wide range of backgrounds and expertise: condensed-matter physics and low-temperature physics, classical fluid dynamics and applied mathematics, MHD, atomic physics, and engineering (for the applications of helium II as a cryogenic coolant).

The book is divided into topical chapters. Each chapter begins with one or two introductory review articles, which are suitable for students and new investigators interested in entering the field. The introductory articles are followed by shorter, more specialized papers.

Chapter 1 introduces us to the problem of quantized vorticity and superfluid turbulence, and it summarizes the key aspects and problems which are currently studied. Chapter 2 is devoted to turbulence experiments. Chapter 3 considers the fundamental problem of friction and vortex dynamics. The theory of superfluid turbulence and the interpretation of the experimental results is the subject of Chap. 4. Chapter 5 is devoted to the application of the NLSE model to superfluidity and vortices. Chapter 6 moves away from helium and considers Bose–Einstein Condensation and vortices in the context of alkali atoms. Chapter 7 is concerned with some aspects of classical turbulence and MHD which are relevant in the study of superfluid turbulence. Finally, Chap. 8 deals with Helium 3 and other systems.

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