This book surveys the physics of small clusters of particles undergoing vibrations, with applications in nuclear physics and the physics of atomic clusters.

The book begins with a survey of the experimental information on collective vibrations in atoms, metal clusters and nuclei. Next, the book goes on to develop theoretical tools to understand these findings. Special emphasis is placed on the Rayleigh-Ritz principle, the use of sum rules, and the quantum mechanics of mean field theory, known as "RPA". The important vibrational modes observed in the different systems are then discussed, including the dipole mode of oscillation (important in both nuclei and metal clusters), surface modes of higher multipolarities, and the compressional mode. In the last two chapters mechanisms for the damping of vibrational modes and the effects of excitation energy on the modes are described.

This book will be of interest to experimentalists and theorists studying finite quantum systems in nuclear physics, atomic physics or physical chemistry.

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Contents

Preface

One of the fascinating questions in Nature is trying to understand how the properties of macroscopic systems emerge from the quantal behavior of its constituents. For example, how many atoms does it take to make a solid? Equally interesting is to ask how the macroscopic behavior of large systems emerges as a limit point when one observes the properties of finite systems. A powerful technique, both theoretically and experimentally, to study this question is to examine the response of the system to weak external perturbations. The study of this subject is the central theme of the present monograph.

We start by surveying the experimental information on collective vibrations in atoms, metal clusters and nuclei. It will be apparent that the vibrational modes and their frequencies can reveal much about the nature of the forces acting within the system.

Following the overview, we develop the main tools to provide an understanding of these findings. We place special emphasis on the Rayleigh–Ritz principle, the use of sum rules, and the quantum mechanics of mean field theory, known as 'RPA'.

With the various classical and quantum mechanical tools, we proceed to discuss the important vibrational modes observed in the different systems. The dipole mode of oscillation is prominent in both nuclei and metal clusters, and there are remarkable similarities between the two systems—on very different energy scales of course. Surface modes of higher multipolarity are prominent features of the nuclear response, and quantum mechanics of the many-fermion system produces a rather subtle response. The compressional mode is also important in nuclei, because it bears most closely on the properties of macroscopic nuclear matter.

In the last two chapters we discuss the mechanisms responsible for the damping of vibrational modes and the effects of excitation energy on the modes.

The book is aimed mainly toward students and experimental researchers studying finite quantum systems. We have deliberately avoided technicalities, formalism, and many details. Our emphasis is on the physics of the response of these small systems. In keeping with this spirit, we have not compiled an extensive bibliography, but we hope we have cited enough material, via other books and review articles, for the reader to find more extensive literature. Readers who are interested in carrying out numerical RPA calculations themselves may obtain free copies of relevant programs described in App. E.

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