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Granular Gases

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Preface

“Granular Material” as a subject of physical research has a long standing history. Eminent scientists such as Coulomb, Faraday, Hagen, Huygens, Rayleigh, Reynolds, and others contributed to the body of research. Following the early days, however, the physical approach gave way to engineering disciplines. Among other reasons, the enormous advances in computing power rekindled the scientific interest of physicists. Since about a decade large-scale simulations of granular systems gave new insights in the nature of granular materials – and continue to do so.

In a strict definition, “Granular Gases” are dilute granular systems, i.e., many particle systems, in which the mean free path of the particles is much larger than the typical particle size. This condition implies that the duration of particle contacts is much shorter than the mean flight time. In contrast to molecular gases, in Granular Gases the particle collisions occur dissipatively, i.e., in each binary collision the particles lose part of the kinetic energy of their relative motion. The dissipation of kinetic energy causes a series of non-trivial effects, as formation of clusters and other spatial structures, non-Maxwellian velocity distributions, anomalous diffusion, correlations in the velocity field, characteristic shock waves, and others. In the dilute limit and with the assumption of weak dissipation the formal similarity of natural gases and Granular Gases allows to describe also the latter using the powerful tools of classical Statistical Mechanics, Kinetics, and Hydrodynamics. Granular Gases provide, more than any other granular system, the possibility to conduct simultaneously experimental and theoretical studies and numerical simulations as well. Part 1 of the volume comprises rigorous theoretical results for the dilute limit.

Such theoretical descriptions of a Granular Gas as a many particle system requires comprehensive understanding of the details of collisions of only two isolated grains. Without this knowledge it would be impossible to deduce macroscopic properties of Granular Gases. The properties of binary collisions and simple one-dimensional models are subject of part 2.

Part 3 contains experimental investigations of Granular Gases: In order to maintain a steady gaseous state under conditions of gravity, the material has to be excited externally to balance the loss of kinetic energy due to inelastic particle collisions. Ideally, the energy feed would be homogeneous and isotropical throughout the system, which is certainly difficult to achieve in an experiment. For experimental investigation of Granular Gases it has been proven to be a good compromize to feed energy by mechanical vibrations of the container – to date all earthborn experiments make use of vibrated containers.

Large scale Granular Gases in steady state are found in astrophysical systems as discussed in part 4. The rings around the outer planets of the Solar system have been intensively studied for centuries and lots of data exist from earthbound and missile observations. Although there are still many open questions, several aspects of the rich structure of planetary rings are well understood. Therefore, planetary rings offer a wide field for practical application of Granular Gas theory and may, thus, serve as test systems to validate theoretical results.

The last part 5 of the book is devoted to possible generalizations with respect to increased density. High density Granular Gases, in a broader sense, can be defined as systems with instantaneous binary collisions, i.e., only by the condition that the contact duration is thought to be negligible and, hence, does not affect the overall properties of the many particle system. From the theoretical point of view this definition is more problematic since the assumption of Molecular Chaos as a prerequisite of simple kinetic theory may be violated. Nevertheless, many interesting phenomena occur in systems of increased density and there is a need to generalize theory respectively. The motivation for extending the gas picture to higher density is to bridge the still existing gap between Kinetic Theory and fluid dynamics approaches, which are very successfully applied in engineering.

The articles in the present volume are selected contributions of the conference "Granular Gases" held from March 8 to 12, 1999 in Bad Honnef. Many of the authors are renowned experts in the field and have decisively shaped the present state of knowledge. Therefore, the articles comprised in this volume cover a large part of the present knowledge about Granular Gases, ranging from investigations of two-particle interactions to Kinetic Theory of dilute many particle systems and numerical simulations of rather dense systems.

In order to find a wide readership not only among experts, but also among undergraduate and graduate students, the authors have been asked to present their material in a self-contained and pedagogical way. All contributions have been carefully refereed.

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