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PHYSIQUE DE LA MATIÈRE EN GRAINS
PHYSICS OF GRANULAR MEDIA

Foreword

1. Introduction

In the beginning of the 1980s, de Gennes casually mentioned the sand pile problem during one of his College de France lectures, saying that the physics behind the angle of repose and the triggering of avalanches was poorly understood. Many of us hazily felt that this was an exciting new field of statistical physics, where although all the ingredients needed to describe the system were known since Coulomb, substantial changes to the ideas of Boltzmann and Gibbs were in order. On the other hand, the presence of a very large number of grains (even not as large as the Avogadro number) suggests that some kind of statistical mechanics should exist, where the inelasticity of (multi-) collisions, the friction forces between grains, and mechanical vibrations of various origins would be the building ingredients to understand the statics and dynamics of granular matter. The triggering spark was the influential paper of Bak, Tang and Wiesenfeld who suggested that sand piles could serve as a prototype of 'complex systems', from pinned vortex in superconductors to ecological problems, earthquakes or financial markets. The possibility of simple but often spectacular experiments and realistic numerical simulations of assemblies of grains meant that the subject was indeed ideal meetings point for different competencies which is often a prerequisite for the emergence of a new field.

Twenty years (and two de Gennes full College de France lectures) later, some interesting progress have been made, sometimes controversial granular media specialists from engineering sciences often questioning the physicists endeavor to clarify a 'long and well-known' topic. The aim of this volume is to give a short account of some of the paths explored in the recent period (for slightly older reviews, see [1,2]). However, we cannot claim to be comprehensive: the size limitation of the volume and our inability to convince some authors to contribute partly explain the absence of some important topics. Furthermore, the composition of the volume was decided almost two years ago, and important new ideas have emerged since then, which could not be included. In particular, we have in mind, the interpretation given by Kurchan and collaborators to the seminal ideas of Edwards on the statistical mechanics of powders, and the definition of an effective temperature in these athermal systems. These concepts might turn out to be very important, and we hope that they will be reviewed in a second volume of this type.

This document has essentially benefited from continental European contributions. This by no means implies that we neglect the very active and fundamental contributions of our friends and competitors across the ocean and British channel – some of which were contacted but declined our proposition. We acknowledge the exemplary and efficient international cooperation in the building up of this physics but we modestly observe that this booklet also gives evidence of the active contribution of the French groups in the various facets of this fascinating topic.

2. Organisation of the volume

At present and after a decade of efficient and relentless effort, the 'psammodynamics' (or psammostatics, the science of granular materials) has come to maturity even if a unified general theory (if there is any!) has yet to be discovered. As a matter of fact, it turns out that the science of granular materials is multi-facetted. Depending on the size of the solid particles (which spans over 12 orders of magnitudes), on their relative distance and on the environmental conditions (wetness, chemical interactions, solid–gas or liquid

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interaction, particles as part of complex compounds such as muds, pastes and concrete…) the variety in the behaviour of granular matter is spectacular and the range of possible applications makes it an exciting challenge to both the scientists and engineers.

The present booklet does not claim to cover exhaustively such an extended field of research. It rather pinpoints a few major concerns of today involved physicists. It starts from fundamental questions dealing with interparticle contacts, strain and stresses, flows and rheology, mostly seen from computer simulations and statistical physics (articles 1 to 4) viewpoints. Sections 5 and 6 are a snapshot of the today still controversial and active physics of avalanches.

Taking profit of the last years' achievements, the physics of granular materials has recently blossomed out into a number of interesting topics, both from a human and industrial perspective. For example, the behavior of sand dunes (article 7) stands as a plague for millions of human beings living close to desert borders, poses intricate questions to physicists. The last three articles tackle the question of the 'wet' granular materials in contrast to the 'dry' granulates which have focused the attention of researchers looking for 'first principles' psammodynamics and statics. As a matter of fact, it turns out that both the physics of wet granular media, as well as of granular pastes (e.g. concrete) or of fine powders, exhibits a set of novel and generic effects which do not merely result from the superposition of hydro—or aerodynamics—on the already known physics of dry granular materials. In brief, it turns out that the physics of granular materials is prone to frustrate our intuition which, undoubtedly, is at the origin of the enthusiastic participation of a lot of young researchers in this field.

References

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Jacques Duran
LMDH–UMR 7603 CNRS, Université P. et M. Curie
4, place Jussieu, 75252 Paris cedex 05, France

Jean-Philippe Bouchaud
Service de physique de l'état condensé, CEA-Saclay
Orme des Merisiers, 91191 Gif-sur-Yvette cedex, France