GRANULAR MEDIA

Between Fluid and Solid

Sand, rice, sugar, snow, cement . . . Although ubiquitous in our daily lives, granular media still challenge engineers and fascinate researchers. This book provides the state of the art of the physics of granular media and recent advances in the field.

The book presents the fundamental properties of granular materials: interactions between grains; solid, liquid and gaseous behaviours; coupling with a fluid; and sediment transport and formation of geological structures. Descriptions of the phenomena combine qualitative and formal arguments, coming from areas as diverse as elasticity, plasticity, statistical physics, fluid mechanics and geomorphology. Many examples of the astonishing behaviours of granular media are presented, including avalanches, segregation, dune song and quicksand. This book is ideal for graduate students and researchers in physics, applied mathematics and engineering.

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Foreword

Sand, gravel, rice, sugar . . . Granular matter is familiar and abounds around us. However, the physics of granular media is still poorly understood and continues to fascinate scientists and other people, more than three centuries after the work of Coulomb on slope stability. A pile of grains actually exhibits a great variety of behaviours with unique properties. Strong enough to support the weight of a building, grains can also easily flow like water in an hourglass or be transported by wind to sculpt dunes and deserts. For a long time, the study of granular materials has remained the preserve of engineers and geologists. Therefore, important concepts arose from the need to build structures on solid ground, store grains in a silo or predict the history of a sediment. More recently, the study of granular media has entered the field of physics, at the crossroads of statistical physics, mechanics and soft-matter physics. The combination of results from laboratory experiments on model materials, discrete numerical simulations and theoretical approaches from other fields has enriched and renewed our understanding of granular materials.

This book has been written in this context. Our goal is to provide an introduction to the physics of granular media that takes into account recent advances in this field, while describing the basic concepts and tools useful in many industrial and geophysical applications. This book is intended primarily for students, researchers and engineers willing to become familiar with the fundamental properties of granular matter. Thus, we will favour as much as possible the physical approach to the phenomena over lengthy mathematical developments. In this sense, the study of granular media belongs to a certain school of physics dear to the late Pierre-Gilles de Gennes, who was a pioneer and a transmitter of ideas in this area. With a bucket of sand and a few careful observations, we will meet fields as diverse as elasticity, plasticity, statistical physics, fluid mechanics and geomorphology. Often we will face unresolved issues that are still at the frontier of our knowledge. Here certainly lies, beyond the numerous applications, the profound attraction exerted by the physics of granular media.

This book is the result of courses we gave for many years at ENSTA ParisTech (Paris), Polytech Marseille (Aix-Marseille University), the Ecole Normale Supérieure (Paris) and the Université Paris Diderot. It has benefited from the many questions and suggestions from students, as well as countless discussions with our French and foreign colleagues during their visits to our laboratories. We would especially like to thank the CNRS GDR Midi research community, which, through numerous meetings in Paris, Carry-le-Rouet and Porquerolles, played a key role in this adventure. This work owes much to them.