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Book review

Kinetic Theory of Granular Gases
N V Brilliantov and T Pöschel
2004 Oxford University Press
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Granular gases are composed of macroscopic bodies kept in motion by an external energy source such as a violent shaking. The behaviour of such systems is quantitatively different from that of ordinary molecular gases: due to the size of the constituents, external fields have a stronger effect on the dynamics and, more importantly, the kinetic energy of the gas is no longer a conserved quantity. The key role of the inelasticity of collisions has been correctly appreciated for about fifteen years, and the ensuing consequences in terms of phase behaviour or transport properties studied in an increasing and now vast body of literature.

The purpose of this book is to help the newcomer to the field in acquiring the essential theoretical tools together with some numerical techniques. As emphasized by the authors—who were among the pioneers in the domain—the content could be covered in a one semester course for advanced undergraduates, or it could be incorporated in a more general course dealing with the statistical mechanics of dissipative systems.

The book is self-contained, clear, and avoids mathematical complications. In order to elucidate the main physical ideas, heuristic points of views are sometimes preferred to a more rigorous route that would lead to a longer discussion. The 28 chapters are short; they offer exercises and worked examples, solved at the end of the book. Each part is supplemented with a relevant foreword and a useful summary including take-home messages. The editorial work is of good quality, with very few typographical errors.

In spite of the title, kinetic theory *stricto sensu* is not the crux of the matter covered. The authors discuss the consequences of the molecular chaos assumption both at the individual particle level and in terms of collective behaviour. The first part of the book addresses the mechanics of grain collisions. It is emphasized that considering the coefficient of restitution ε —a central quantity governing the inelasticity of inter-grain encounters—as velocity independent is inconsistent with the mechanical point of view. An asymptotic expression for the impact velocity dependence of ε is therefore derived for visco-elastic spheres. The important inelastic Boltzmann equation is introduced in part II and the associated velocity distribution characterized for a force-free medium (so-called free cooling regime). Transport processes can then be analyzed in part III at the single particle level, and part IV from a more macroscopic viewpoint. The corresponding Chapman–Enskog-like hydrodynamic approach is worked out in detail, in a clear fashion. Finally, the tendency of granular gases to develop instabilities is illustrated in part V where the hydrodynamic picture plays a pivotal role.

This book clearly sets the stage. For the sake of simplicity, the authors have discarded some subtle points, such as the open questions underlying the hydrodynamic description (why include the temperature among the hydrodynamic modes, and what about the separation of space and time scales between kinetic and hydrodynamic excitations?). Such omissions are understandable. To a certain extent however, the scope of the book is centered on previous work by the authors, and I have a few regrets. Special emphasis is put on the (variable ε) visco-elastic model, which enhances the technical difficulty of the presentation. On the other hand, the important physical effects including scaling laws, hydrodynamic behaviour and structure formation, can be understood in two steps, from the results derived within the much simpler constant ε model, allowing subsequently ε to depend on the granular temperature. The authors justify their choice with the inconsistency of the constant ε route. The improvements brought by the visco-elastic model remain to be assessed, since the rotational degrees of freedom, discarded in the book, play an important role and require due consideration of both tangential and normal restitution coefficients, that are again velocity dependent. This seems to be the price of a consistent approach, which does not lend itself to much insight. In addition, the behaviour of driven systems is not addressed, whereas in the realm of granular media, force-free systems are the exception rather than the rule. The differences between constant ε and visco-elastic models is presumably less pronounced in the driven case. Study of driven systems also reveals that the rheology of granular gases is intrinsically non-Newtonian, which is a key feature. Finally, the powerful direct simulation Monte Carlo technique is not described, whereas it is an important tool, particularly relevant for the physics of the Boltzmann equation, and straightforward to implement in its simplest version. N Brilliantov and T Pöschel concentrate on the (equally relevant) molecular dynamics method instead.

In conclusion, the book fills a gap in the field. The companion webpage from where molecular dynamics and symbolic algebra programs can be downloaded is also useful.

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