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Experiments and Simulations on Granular Gases

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Abstract

In this thesis we report experimental and simulation study of granular gases. As a non-equilibrium system composed of macroscopic particles, a granular gas often shows a picture similar to a molecular gas in that the system is dilute and particles interact with each other through instantaneous collisions. Unlike in molecular gases, the collisions are inelastic so that the interactions are a continuous sink of kinetic energy. The study of granular gases is not only of theoretical interest as an important example of non-equilibrium physics, but also of practical value since granular materials play an important role in many industrial processes and natural phenomena. In this dissertation, we study some of the open questions about the statistical properties of granular gases. We investigate the role of the heating mechanism in determining the extent of nonequipartition of kinetic energy. Two species of particles in a binary granular system typically do not have the same mean kinetic energy, in contrast to the equipartition of energy required in equilibrium. In most experiments, different species are unequally heated at the boundaries. We show by event-driven simulations that differential boundary heating affects the degree of non-equipartition even in the bulk of the system. This conclusion is fortified by studying numerical and solvable stochastic models without spatial degrees of freedom. In both cases, even in the limit where heating events are rare compared to collisions, the effect of the heating mechanism persists. We have also performed an experimental study of particle kinematics in a threedimensional system of inelastic spheres fluidized by intense vibration. The motion of particles in the interior of the medium is tracked by high-speed video imaging, yielding a spatially resolved measurement of the velocity distribution. The distribution is wider than a Gaussian and broadens continuously with increasing volume fraction. The deviations from a Gaussian distribution for this boundary-driven system are different in sign and larger in magnitude than predictions for homogeneously driven systems. We also find correlations between velocity components which grow with increasing volume fraction. Following a recent experiment[Phys. Rev. Lett. 92, 164301(2004)] we study two kinds of power fluctuations in a two dimensional granular gas by event-driven molecular dynamics simulations. Taking advantage of the convenience of changing system parameters in computer simulations, we explore this topic in greater detail. The fluctuation relation by Gallavotti and Cohen is applied to two kinds of power fluctuations for both vibrational boundary driving and static thermal boundary driving. The physical properties of the effective temperatures arising from the fluctuation relation is studied. Our numerical experiments directly checked the various aspects in applying fluctuation theorem to granular gases and leave some open questions.