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Theory of Nanoscale Friction

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In a nanoscale friction experiment, the tip of an atomic force microscope (AFM) cantilever is dragged along an atomically flat surface, and the resulting friction force is measured optically from the cantilever deformation. Due to the small size of the system, thermal noise effects coming from the atomistic degrees of freedom play an important role. In this talk, the ideas of stochastic modeling will be applied to atomic friction phenomena. We theoretically study atomic friction experiments in the stick-slip regime within the framework of the Prandtl-Thomlinson model. A differential equation describing the force probability distribution is derived. Analytical approximate solutions of this equation are found for the asymptotic cases of high and low effective spring constant, but for arbitrary pulling velocities. Excellent accuracy of these approximate expressions is demonstrated numerically. In particular, the theoretical expression for the mean force, although obtained for small spring constants, is shown to be accurate also somewhat outside of its expected validity range. Finally, the influence of friction aging effect on the experimental friction forces and the ways to include it into the theory are discussed.

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