Dynamics of a piston pushed by a single particle gas as a microscopic model for Szilárd engine

Abstract:

Motivated by the Szilárd engine, we have studied the dynamics of a piston of large mass M inside a 1D cylinder, pushed by repeated elastic collisions with a single particle (of smaller mass m) which is in contact with a thermal reservoir of temperature T. Additionally, piston is assumed to be moving under influence of an external force. By expanding the underlying master equation of the piston-particle system in terms of the small parameter $(m/M)^{1/2}$, we show that, an effective equation of motion of the piston can be deduced by integrating out the small particle. Given finite but large mass of the piston, we show that at times of order $\sqrt{M}$ the Piston's motion is described by a determinstic dynamics while at larger times, the piston's motion becomes stochastic and is described by a Langevin equation. Interestingly, we note that the dissipation coefficient γ depends on piston position X, and is also function of time. In particular, it changes from an initial value $\sqrt{8\pi m k_B T}/X$ and increases as $\log(t)/X$ asymptotically. We argue that the logarithmic increase of γ is associated to the interesting and unusual slow relaxation of particle confined within the reservoir and the piston.