Indirect control of anomalous transport in a system of two coupled Brownian particles

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Systems under non-equilibrium conditions can display new features as well as unexpected phenomena and processes which in equilibrium systems are forbidden by fundamental laws. One of the most prominent examples include the phenomenon of negative mobility (conductance, resistance): when a constant force is applied to a mobile particle, it moves in the direction opposite to that of the force. It is impossible in equilibrium states because it would violate the second law of thermodynamics.

For a one-particle system, the simplest, one dimensional model is formulated in terms of the Langevin equation for a particle moving in a symmetric spatially periodic potential, biased by a static force and driven by an unbiased harmonic force. This system is out of equilibrium and displays both absolute negative mobility around zero static applied force (the linear response regime) and negative mobility in the non-linear response regime. In the linear response regime, the long-time averaged particle velocity tends to zero when the static force tends to zero. In the nonlinear response regime, the particle velocity can tend to zero even if the static force is far from zero. It is known that the corresponding overdamped system does not exhibit negative mobility and the inertial term in the Newton equation is absolutely necessary for the negative mobility to occur. However, when the particle is coupled to another particle, negative mobility can arise. We present a minimal model and propose a scenario in which only one (say the first) particle is dc-biased by a constant force and ac-driven by an unbiased harmonic signal. In this way we intend to achieve two aims at once: (i) negative mobility of the first particle, which is exclusively induced by coupling to the second particle and (ii) indirect control of the transport properties of the second particle by manipulating the first particle only. For instance, the sign and amplitude of the averaged stationary velocity of the second particle can be steered by the driving applied to the first particle. As an experimentally realizable system, we propose two coupled resistively shunted Josephson junctions. We demonstrate that the second junction can exhibit both absolute negative resistance near zero bias and negative resistance in the non-linear regimes. These anomalous transport features occur for restricted windows of the coupling constant.