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Entropy production in a harmonic chain with fast variables

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We consider a harmonic chain, one-dimensional array of particles connected with harmonic springs, being in thermal contact with heat reservoirs of different temperatures at either end. The harmonic chain mediates a net heat flow from a high-temperature reservoir to a low-temperature one, which results in the net entropy production. The average value of the heat flux is calculated as a function of the inter-particle spring constant K. When K becomes large, the relative position between particles becomes a fast variable while the center of mass is a slow variable. We show that the contribution of the fast variable to the entropy production remains finite even in the $K \to \infty$ limit where the relative motion is frozen. In the limiting case, the center of mass is equivalent to a Brownian particle in thermal contact with two heat reservoirs. This system is known to have a puzzling feature that there is a net entropy production while the Brownian particle itself displays a reversible equilibrium dynamics at an effective temperature. Our study resolves this puzzle by shedding the light on the role of a hidden fast variable.