

# Nonequilibrium steady states in Langevin thermal systems

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Equilibrium is characterized by its fundamental properties such as the detailed balance, the fluctuation-dissipation relation, and no heat dissipation. Based on the stochastic thermodynamics, we show that these three properties are equivalent to each other in conventional Langevin thermal systems with microscopic reversibility. Thus, a conventional steady state has either all three properties (equilibrium) or none of them (nonequilibrium). In contrast, with velocity-dependent forces breaking the microscopic reversibility, we prove that the detailed balance and the fluctuation-dissipation relation mutually exclude each other and no equivalence relation is possible between any two of the three properties. This implies that a steady state of Langevin systems with velocity-dependent forces may maintain some equilibrium properties but not all of them. Our results are illustrated with a few example systems.

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