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Coupled Particles and Heat Transport: A Dynamical System's Perspective

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The understanding of coupled particles and heat transport in complex systems is a fundamental problem, also of practical interest in connection with the challenging task of developing high-performance thermoelectric materials. We will discuss thermoelectric transport phenomena from the perspective of dynamical nonlinear systems, focusing on stylized classical and quantum models, including the disordered hard-point gas and asymmetric quantum-dot ring structures pierced by an Aharonov-Bohm flux. We will show that neither energy filtering nor strong coupling between particle and energy fluxes are necessary conditions for achieving the Carnot efficiency. In particular, we will focus on systems with broken time-reversal symmetry, for which the maximum efficiency and the efficiency at maximum power are both determined by two parameters: a ``figure of merit'' and an asymmetry parameter. In contrast to the time-symmetric case, the figure of merit is bounded from above; nevertheless the Carnot efficiency can be reached at lower and lower values of the figure of merit and far from the strong coupling condition as the asymmetry parameter increases. Moreover, the Curzon-Ahlborn limit for efficiency at maximum power can be overcome within linear response. Finally, we show that a weak magnetic field generally improves either the efficiency of thermoelectric power generation or of refrigeration, the efficiencies of the two processes being no longer equal when a magnetic field is added.

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