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Title:	Quantum thermodynamic resources and bounds on the performance of quantum otto engines
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Keywords:	thermodynamic quantum
Issue Date:	Dec-2021
Publisher:	IISER Mohali
Abstract:	Quantum thermodynamics is an emerging research field aiming to close the gap between the microscopic world of quantum mechanics and the macroscopic world of classical thermodynamics by establishing a novel thermodynamic framework that incorporates and exploits non-classical resources of quantum discreteness, correlations, entanglement and so on. To achieve this goal, quantum analogues of classical heat engines serve as test beds to demonstrate extensions of thermodynamic ideas into the quantum realm. Multifarious proposals for quantum heat engines or refrigerators have been proposed. Amongst these, the study of simple, coupled quantum systems yield important insights into the role of quantum interactions in enhancing the performance of model thermal machines. One of the major issues being addressed in these models is: What are the thermodynamic constraints and bounds on the performance of these quantum thermal machines? In the present work, quantum Otto engines (QOEs), with quantum spins as the working substance, have been investigated. An Otto cycle is widely studied in literature, because the contributions of heat and work can be clearly separated into different steps during the heat cycle. We begin by considering 1 two coupled, effectively two-level systems—each with a degenerate excited state, and then generalize it to the case of two coupled spins of arbitrary magnitudes. For a quasi-static QOE, we prove that level degeneracy can act as a thermodynamic resource, helping to extract a larger amount of work than in the non-degenerate case, either without coupling or in the presence of coupling. We compare our analysis with earlier studies on the role of level degeneracy in finite-time models of thermal machines. Further, by carefully making use of the information from the energy spectrum of the working medium, we look for conditions to better the performance of the coupled system over its uncoupled counterpart using heuristics based approach. An upper bound for the efficiency of the Otto cycle has thus been calculated in these models, setting new benchmarks for Otto efficiency that is tighter than Carnot bound. We also analyze the performance of the engine using the notion of complete Otto cycles inherent in an average cycle and highlight its utility as a heuristic.
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