Magnetostrain-driven Quantum engine on a Graphene flake

Enrique Muñoz, Francisco J. Peña

Physics Institute, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Santiago, Chile
munozt@fis.puc.cl

Abstract

The concept of a quantum heat engine (QHEN) has been discussed extensively in the literature [1-3] as an alternative to efficiently recover, on a nanoscale device, thermal energy in the form of useful work. In a QHEN, in contrast with a classical heat engine, the working substance is in a mixed quantum state determined by a density matrix. Interesting examples of this concept are constituted by photosynthesis in plants [4], as well as human- designed photocells [5], where the working substance are thermalized photons. In this work, we propose an alternative conceptual design for a graphene-based quantum engine, driven by a superposition of mechanical strain and an external magnetic field. Engineering of strain in a nanoscale graphene flake creates a gauge field with an associated uniform pseudomagnetic field. The strain-induced pseudomagnetic field can be combined with a real magnetic field, leading to the emergence of discrete relativistic Landau levels within the single-particle picture. The interlevel distance and hence their statistical population can be modulated by quasistatically tuning the magnetic field along a sequence of reversible transformations (Fig. 1, left), that constitute a quantum mechanical analog of the classical Otto cycle. We formulated a generalization of the first law of thermodynamics which is applicable to this nanoscale device, by using von Neumann's definition of entropy. Within this conceptual framework, we obtained analytical expressions for the efficiency of our proposed graphene engine (Fig. 1, right).

References

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Figures

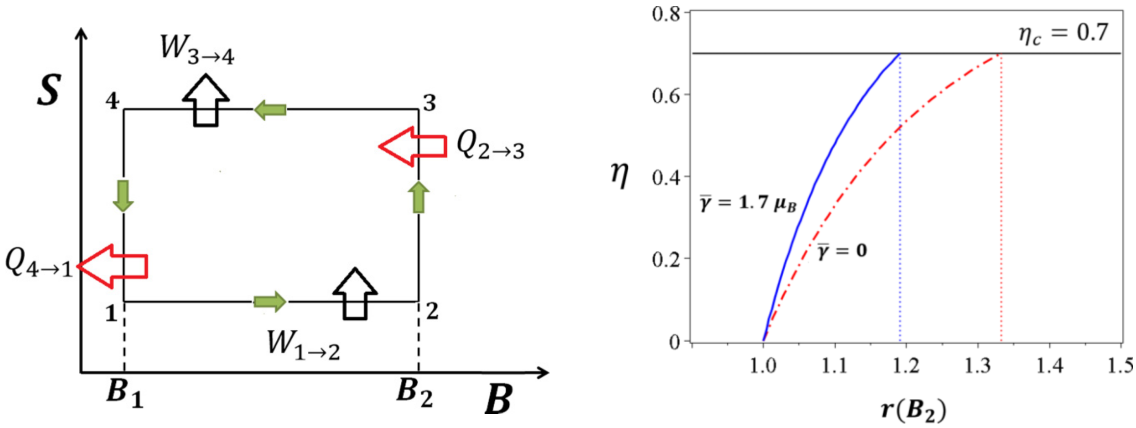

Figure 1. (Left) The thermodynamic cycle describing the engine, in the entropy (S) versus magnetic field (B) coordinates. (Right) The calculated theoretical efficiency of the engine, as a function of the "compression ratio" between Landau radii at each magnetic field value.