Most efficient quantum thermoelectric at finite power output

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Abstract

Machines are only Carnot efficient if they are reversible, but then their power output is vanishingly small. Here we ask, what is the maximum efficiency of an irreversible device with finite power output? It turns out that classical thermodynamics is insufficient to answer this rather simple question; we need quantum mechanics.

We apply a nonlinear scattering theory to thermoelectric quantum systems; heat engines or refrigerators consisting of nanostructures or molecules that exhibit a Peltier effect. We find that quantum mechanics places an upper bound on both power output, and on the efficiency at any finite power. The upper bound on efficiency equals Carnot efficiency at zero power output, but decays with increasing power output. It is intrinsically quantum (wavelength dependent), unlike Carnot efficiency. This maximum efficiency occurs when the system lets through all particles in a certain energy window, but none at other energies. A physical implementation of this will be discussed, as will the suppression of efficiency by a phonon heat flow.

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