Beyond the Carnot Limit: Perpetual Heat Flow in Gravitational and Rotational Non-Equilibrium Systems

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The Carnot limit defines the theoretical maximum efficiency a heat engine can achieve when operating between two temperatures. Exceeding this limit would enable a system to function as a perpetual motion machine of the second kind, which is commonly assumed to be impossible[1]. In 1867, Maxwell claimed that gravity could not produce a temperature gradient in a column of gas, as such a gradient would enable a perpetual motion machine of the second kind[2], where two gases with differing temperature gradients connected at different heights would result in a continual non-equilibrium state within the system, allowing for perpetual heat flow through the system with work extracted as heat flows via heat engines between each column. This view was widely supported by Clausius, Thomson, and Boltzmann, who concluded that gravity could not induce a temperature gradient in a gas column, maintaining that the Carnot limit was unbreakable[3], and while others, like Loschmidt disagreed[4], they failed to provide compelling evidence to the contrary.

However, recent experimental findings have measured gravitational temperature gradients in practically insulated solid, liquid and gas mediums including 0.04 $K \cdot m^{-1}$ in water[5], 2.2 $K \cdot m^{-1}$ in an air-sawdust mixture[6], and 0.2 $K \cdot m^{-1}$ in an iron rod when under gravitational or rotational acceleration[7].

Despite these findings, little effort has been made to evaluate the feasibility of such non-equilibrium systems as a method to extract work from heat.

This study demonstrates that systems utilising temperature gradients induced by gravitational or rotational acceleration can achieve perpetual heat flow enabling the system to exceed the Carnot limit, without requiring the heat engines within the system to exceed the Carnot limit. A gravitational system employing both conductive and radiative heat transfer methods is shown to achieve greater temperature differentials over shorter heights than conduction-only systems, with power output in gravitational systems found to be constrained by the medium's thermal conductivity. Rotational system concepts were shown to overcome these material limitations by using rotational acceleration instead of gravity to achieve higher power outputs and efficiencies than gravity systems.

These findings and concepts aim to inspire interdisciplinary research into extracting work from perpetual heat flow within non-equilibrium systems, leading to a greater understanding of energy and potentially redefining the feasibility of perpetual motion systems of the second kind.

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