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Wiedemann-Franz law Violation in Graphene and Quark Matter

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The Wiedemann-Franz (WF) law states that the ratio of electrical and thermal conductivity, multiplied by temperature, remains constant in conventional metals- an outcome well-explained by Fermi gas and Fermi liquid theory[1]. However, this law breaks down in many-body systems. Notably, quark or hadronic matter produced in high-energy nuclear collisions at RHIC and LHC does not obey the WF law[2, 3]. These systems exist in regimes characterized by temperatures and baryon chemical potentials on the order of MeV to GeV. In contrast, condensed matter systems operate in much lower energy scales, typically in the meV to eV range. While traditional metals with Fermi energies around 2–10 eV conform to the WF law, materials like graphene can exhibit its violation by reducing the Fermi energy through controlled doping[4, 5]. Using Boltzmann transport theory, we investigate the thermal and electrical conductivities in both graphene and ultra-relativistic quark matter. Our findings reveal a clear violation of the Wiedemann-Franz law in both domains, despite their vastly different energy scales.

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