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Theory of the Nernst effect near quantum phase transitions in condensed matter, and in dyonic black holes\(^1\)
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We present a general hydrodynamic theory of transport in the vicinity of superfluid-insulator transitions in two spatial dimensions described by “Lorentz”-invariant quantum critical points. We allow for a weak impurity scattering rate, a magnetic field \(B\), and a deviation in the density, \(\rho\), from that of the insulator. We show that the frequency-dependent thermal and electric linear response functions, including the Nernst coefficient, are fully determined by a single transport coefficient (a universal electrical conductivity), the impurity scattering rate, and a few thermodynamic state variables. With reasonable estimates for the parameters, our results predict a magnetic field and temperature dependence of the Nernst signal which resembles measurements in the cuprates, including the overall magnitude. Our theory predicts a “hydrodynamic cyclotron mode” which could be observable in ultrapure samples. We also discuss exact results for the zero frequency transport coefficients of a supersymmetric conformal field theory (CFT), which is solvable by the AdS/CFT correspondence, mapping the CFT to a black hole problem in 3+1 dimensional anti-de Sitter space. These exact results are found to be in full agreement with the general predictions of our hydrodynamic analysis.

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