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Hydrodynamic approach to electronic transport in graphene

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Following the immense success of graphene research, many novel two-dimensional (2D) materials are currently being investigated aiming at potential applications in nanoelectronics, energy conversion, and storage systems. Modern fabrication techniques allow for routine manufacturing of ultra-clean samples where observable physical properties are dominated by electron-electron collisions. This opens an exciting possibility of observing nonlinear and nonlocal transport phenomena that previously belonged to the realms of hydrodynamics and plasma physics. In fact, the last year has seen an explosion of interest, both experimentally and theoretically, in the hydrodynamic effects in interacting electron systems in ultra-pure materials. In particular, it has been realized that, among other remarkable properties, graphene is an excellent material for realization of hydrodynamic flow of electrons. An additional twist to the story is provided by the quasirelativistic excitation spectrum of graphene near charge neutrality – that of massless 2D Dirac fermions. A fluid emerging in this situation is formed by two species of carriers with opposite charges – electrons and holes – and is neither Galilean-, nor Lorentz-invariant. At the same time, hydrodynamic behavior might be observable in a wide range of novel materials including the 2D metal palladium cobaltate and Weyl semimetals. The latter systems have attracted considerable attention since they exhibit a solid state realization of the Adler-Bell-Jackiw chiral anomaly. Another promising avenue for theoretical developments is the connection between the nearly relativistic hydrodynamics in graphene and Weyl semimetals and the holographic approach to quantum field theory.

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