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A self-consistent theory for graphene transport.[1]

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Arguably, one of the most intriguing properties of graphene transport is the non-vanishing "minimum conductivity" at the Dirac point. The carrier density in these single monatomic sheets of carbon can be continuously tuned from electron-like carriers for large positive gate bias to hole-like carriers for negative bias. The physics close to zero carrier density (also called the intrinsic or Dirac region), is now understood to be dominated by the inhomogeneous situation where the local potential fluctuates around zero, breaking the landscape into puddles of electrons and holes. Here, we propose and discuss a particular hierarchy of approximations to understand graphene transport properties that includes a tight binding approximation for the low energy effective Hamiltonian, Random-Phase-Approximation to treat electron-electron interactions, the semi-classical Boltzmann transport theory to treat scattering of electrons by short and long-ranged disorder, and a self-consistent Fermi-Thomas approximation to treat impurity induced density inhomogeneity [1-2]. We find that this self-consistent theory for graphene transport is in remarkable agreement with recent experiments [3-5]. To better understand the range of validity of this theory we relax some of the assumptions and include the effects percolation [6]; calculate transport properties using an effective medium theory [7]; and examine the effects of phase-coherent quantum transport [8]. We believe that while most of the dc transport experiments on bulk graphene samples at zero magnetic field are in the parameter regime correctly captured by the semi-classical diffusive self-consistent transport theory, we demonstrate theoretically that by tuning external parameters, it is possible to access several other transport regimes.

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