Two distinct ballistic processes in graphene at Dirac point: short time ultra-relativistic vs long time nonrelativistic.

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A dynamical approach to ballistic transport in mesoscopic graphene samples of finite length L and a contact potential difference U is developed. At ballistic times shorter than both relevant time scales, $t_L = L/v_g(v_g$ - Fermi velocity) and $t_U = \hbar/(eU)$, the major effect of the electric field is to create electron-hole pairs. In linear response this gives rise (for width $W >> L$) to conductivity $\sigma_2 = (\pi/2)\left(e^2/h\right)$. On the other hand, at ballistic times lager than the two scales the mechanism of transport is different. The conductivity has its "nonrelativistic" value equal to the one obtained within the Landauer-Büttiker approach resulting from evanescent waves tunneling through the barrier U, $\sigma_2 = (4/\pi)\left(e^2/h\right)$ (for $W >> L$ and $t_U << t_L$). The electron-hole pair creation becomes unimportant in this limit. Between these extremes there is a crossover behaviour dependent on the ratio between the two time scales t_L/t_U. The first mechanism is universal and does not depend on geometry (aspect ration, topology, boundary conditions, properties of leads), while the latter one is quite sensitive to all of them. The ultrarelativistic value was measured precisely in AC conductivity measurements and in DC transport in suspended graphene, while the nonrelativistic value appears in experiments on small graphene flakes.