

Summer school 2008
Princeton

Electron Transport in Graphene

Homework problems

Problem 1: Dirac electron in magnetic field

Find the energy spectrum of a D=2 Hamiltonian:

$$H = v \sigma \cdot (p - eA)$$

in a uniform B field \parallel z-axis

Hint: $H_{\text{Pauli-Schroedinger}} = 2m(H_{\text{Dirac}})^2$

Problem 2: massive Dirac particles in graphene

Consider a carbon sheet with an on-site potential different for the A and B sublattice: $V_A = -V_B = \lambda$

(i) Show that the low energy states are described by a massive Dirac Hamiltonian

$$H = v \sigma \cdot p + \lambda \sigma_3$$

(ii) Find the energy spectrum in a uniform B field

What is the most striking difference with the massless case $\lambda=0$?

Hint: $H_{\text{Pauli-Schroedinger}} = 2m(H_{\text{Dirac}})^2$

Problem 3: Klein scattering

Consider scattering of a massless Dirac particle on a step-like potential

$$U(x < 0) = -U_0; \quad U(x > 0) = +U_0$$

By solving the Schroedinger equation

$$E\psi = [v\sigma \cdot p + U(x)]\psi,$$

(i) Find the transmission and reflection angles as a function of the incidence angle;

(ii) Find the transmission probability.
For simplicity, consider the case of particle energy E equal zero