Dept. of Physics

EPL444: Functional Nanostructures

Minor II

20.02.2015

Total marks: 25

Duration: 11:00 – 12:00 hrs

1. Consider a case of electronic transport in a two-dimenaional electronic device characterized by the dimensions 20 nm and 30 nm along x and y directions. If the mean free path of electrons in the device at T = 100 K is 300 nm and de-Broglie wavelength of electron in the device is 90 nm, write down the nature of electron transport in the device. [1]

2. If the mean free path of charge carriers in a one dimensional GaAs device is 75 nm and the length of the device is 600 nm, what is the average no. of collision that electrons undergo while moving with thermal velocity in the device?

What is the nature of electron transport in the device? [1+1]

3. Discuss in brief the mechanisms which may lead to destroying of phase coherence of electrons moving in a crystal at T = 200 K. [3]

4. Consider a one-dimensional GaAs diode at liquid nitrogen temperature (T = 77 K) where the effective mass of electron $m^* = 0.0067 m_0$. m_0 is the rest mass of an electron. The mobility of GaAs at such temperatures is typically $\mu = 105\ cm^2V^{-1}s^{-1}$.

i) What is the thermal energy of electrons in the one dimensional (degree of freedom of electrons = 1) system? Determine the thermal velocity (v_T) of electrons in the device. [1.5 × 2]

ii) For the above device, calculate the mean free path (l_e) of electrons. [2]

iii) If $Lx \sim l_e$, calculate the current density J for the ballistic diode at $\Phi_0 = 0.1$ V. [5]
(Assume dielectric constant to be unity).

5. Discuss, with a schematic representation of Coulomb Staircase, the conductivity of a single electron transistor through a quantum dot as a function of source to drain voltage. [4]

6. Consider a field effect transistor based on graphene deposited on Si/SiO_2 where highly doped Si is used as the gate material. SiO_2 is the insulating layer between graphene and Si. Explain qualitatively with a schematic plot the resistivity measured between source and drain (ρ_{2D}) as a function of gate voltage (V_g) if the measurement is performed at very low temperature (T ~ 1 K). Assume that the carrier density is only effected by V_g at this temperature. [5]

$m_0 = 9.1 \times 10^{-31}$ kg, $\varepsilon_0 = 8.854 \times 10^{-12}$ coul^2/newton-m^2