9/21/07

ECE 495N, Fall'07 MSEE B010, MWF 330P – 420P

Fundamentals of Nanoelectronics

HW#3: Due Friday Sept.28 in class.

All exercises, page numbers refer to

S.Datta, Quantum Transport: Atom to Transistor, Cambridge (2005)

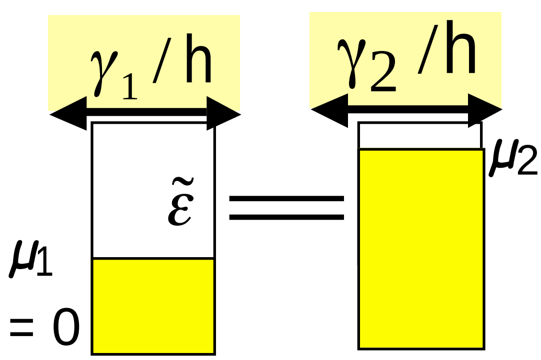
ISBN 0-521-63145-9.

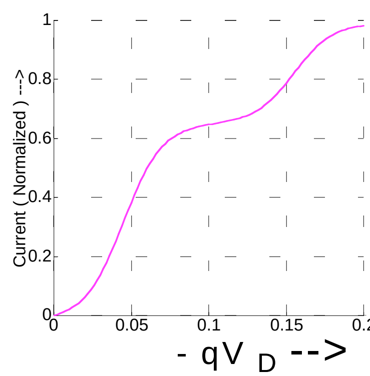
Please turn in a copy of your MATLAB codes for Problem 1.

You can use the MATLAB code at the end of the text as a guide,

but the code you turn in should be your own work, not copied from the text.

Problem 1: A box has two degenerate energy levels having energy $\tilde{\varepsilon}$ = 0.05 eV, before including any self-consistent field due to electron-electron interactions. Write a MATLAB code to calculate the current for a negative voltage on the drain (contact 2), assuming that the the energy level remains fixed with respect to the source and neglecting any broadening of the energy levels. Assuming $\gamma_1 = \gamma_2 = 0.005\,eV$, U_0 = 0.1 eV and $k_B T = 0.025\,eV$ you should obtain a plot like this for the current normalized to $I(\max imum) = \frac{q}{h}\frac{2\gamma_1\gamma_2}{\gamma_1+\gamma_2}$





Show that the current value at the plateau for intermediate voltages (around 0.1V) is given by $I(plateau) = \frac{q}{h}\frac{2\gamma_1\gamma_2}{\gamma_1+2\gamma_2}$ (Hint: at this voltage electrons are not available in either contact to take the channel to the 11 state; so it resides in the 00, 01 and 10 states).

9/21/07

Problem 2: A channel has two energy levels ε_1 and ε_2 corresponding to four levels 00, 01, 10 and 11 in the multi-electron picture. Apply the law of equilibrium in the multi-electron picture to obtain the equilibrium occupation probabilities assuming zero interaction energy ($U_0 = 0$) for the four levels and show that

$$P_{00} = (1 - f_1)(1 - f_2) \quad , P_{01} = (1 - f_1) f_2, \; P_{10} = f_1(1 - f_2) \text{ and } P_{11} = f_1 f_2$$

where f_1 and f_2 are the equilibrium Fermi functions corresponding to the two energy levels.

Problem 3: A channel has four degenerate energy levels all having the same energy $\varepsilon = 0$ eV with an interaction energy that can be written as $U_{ee} = U_0 N(N-1)/2$, where $U_0 = 0.1$ eV. The figure below shows the change in the ***equilibrium*** number of electrons, N inside the channel as the electrochemical potential μ is changed. What are the values of μ at which the transitions in N take place (labeled $\mu 1$, $\mu 2$, $\mu 3$ and $\mu 4$ in the figure) ?