ECE 659 Spring '09 Weeks 12-13: Energy Transport

HW#8: Due Friday April 24, 2009 in class

Consider a device (temperature T) with two sharp energy levels ε_1 - ε_2 = $\hbar\omega$, with the upper one in equilibrium with contact 1 and the lower one in equilibrium with contact 2. The current through this device can be written as

$$I = I_0 [F(-\hbar\omega) f_1(\varepsilon_1)(1-f_2(\varepsilon_2) - F(+\hbar\omega) f_2(\varepsilon_2)(1-f_1(\varepsilon_1)]$$

where the absorption and emission rates characteristic of the surroundings (at temperature T_s) are given by

$$F(+\hbar\omega) = \frac{1}{\exp(\hbar\omega/kT_s)-1}$$

$$F(-\hbar\omega) = \exp(\hbar\omega/kT_s)\, F(+\hbar\omega)$$

The energy taken from the battery is I*V which is equal to the sum of the energy given up to contacts 1, 2 and the surroundings:

$$E_{C1} = (\mu_1 - \varepsilon_1) * I$$

$$E_{C2} = (\varepsilon_2 - \mu_2) * I$$

$$E_{surroundings} = (\varepsilon_1 - \varepsilon_2) * I$$

Assume that $\varepsilon_1 = 2k_BT$, $\varepsilon_2 = -2k_BT$ and that the chemical potentials in the two contacts are related to the applied voltage V by the relation $\mu_{1,2} = \frac{\varepsilon_1 + \varepsilon_2 \pm qV}{2}$.

1. Assuming T_s = T, plot (a) I versus V, (b) E_{C1} versus V, (c) E_{C2} versus V and (d) $E_{surroundings}$ versus V over the voltage range $-5k_BT < qV < +5k_BT$.

What is the voltage range over which the contacts are cooled ?

What is the voltage range over which the surroundings are cooled ?

2. Assuming T_s = 20*T, plot I versus V. What is the open circuit voltage ?

What is the short circuit current ?

Please remember to turn in a copy of your MATLAB codes.