COLLEGE OF ENGINEERING & TECHNOLOGY

Department: Electronics and Communications Engineering

Instructor: Dr. Amr Bayoumi **Date: March 14, 2014**

Course Title: Advanced Devices **Spring 2014**

Course No.: EC738 **Problem Set #1**

Femi Level

Question 1 :

Plot (on the same graph) both the Fermi-Dirac and Boltzman functions as a function of energy (in eV) for T= -100C, 0C and 100C.

Hint: use eqn. 2.4-2.6

Question 2:

Plot the intrinsic carrier concentration for silicon, n_i, as a function of temperature for the range of -100C to +200C.

Note that from eqn. 2.10:

$N_c(T) = N_{co}\ (T/300)^{3/2}$

$N_v(T) = N_{vo}\ (T/300)^{3/2}$

$N_{co} = 3.22\text{x}10^{19}\text{cm}^{-3}$, $N_{vo} = 1.8\text{x}10^{19}\text{cm}^{-3}$

Hint: use eqn. 2.13

Question 3:

Plot the Fermi level separation from intrinsic energy level (Ei) as a function of temperature between -100C and +200C, for the following cases:

3a- Intrinsic Si doped with B (boron), with doping of (i) 1E15 and (ii) 1E17 cm^{-3}

3b- Si doped with As (Arsenic) with doping of (i) 1E15 and (ii) $1\text{E}17\text{cm}^{-3}$

3c- Si doped with both As (5E16cm-3) and B ($1\text{E}17\text{cm}^{-3}$)

Hint:

- Use eqn 2.20, 2.22
- Use the temperature dependence equations for $N_c(T)$ and $N_v(T)$ from question 2
- For mixed N_a & N_d, the effective $N_{doping} = N_d - N_a$.
- The plot will be something close to Fig. 2.7

Question 4:

Plot the Fermi level separation from conduction or valence band edge, as a function of doping, for:

- n-type doping, with N_d from 10^{15} - 10^{18}cm^{-3}, at T=200K, 300K and 400K
- p-type doping, with N_A from 10^{15} - 10^{18}cm^{-3}, at T=200K, 300K and 400K

Hint: This is very close to Question 3

Question 5

Calculate the effective conduction band density of states, Nc for Si, assuming that for Si, the following holds for the conduction band:

Electron density of states; $N(E)dE = K1\,(E-Ec)^{1/2}$

$K1 = (8\pi\, g\, (2mx\, my\, mz)^{1/2}) / (h^{3})$

You should use **MKS** units:
g = 6, mx = 0.92mo, mz=my= 0.19mo, mo = rest mass of electron, h = Planck's constant.

Hint:

- Use eqns. 2.3 -2.11
- Use the transformation x = (E-Ec)
- The solution of $\int x^{(1/2)} e^{(-x)} dx$ = $\pi^{1/2} / 2$