Answer to tutorial questions – 01

ME4252 Nanomaterial for Energy Engineering

1. Determine the temperature at which an energy level which is 0.3 eV below Fermi energy is 2% unoccupied by an electron.

Answer:

$$0.98 = \frac{1}{1+\exp\left(-0.3 \big/ 8.25\times10^{-5}\times T\right)}$$
$$\Rightarrow T = 894\,K$$

2. The value of p_o in Si at T = 300 K is 10^{15} cm^{-3}. Determine the following:
   (i) The position of Fermi energy below conduction band edge, and
   (ii) Equilibrium concentration of electrons

   Note that for Si at 300 K, $N_V = 1.04\times10^{19}$ cm^{-3} and $N_C = 2.8\times10^{19}$ cm^{-3}.

   Assume E_g of Si is 1.12eV.

   Solution:

   Given, $p_o = 10^{15}$ cm^{-3} and for Si, $N_v = 1.04\times10^{19}$ cm^{-3}

   i. And we know $p_0 = N_v \exp\left(-\frac{E_F - E_v}{kT}\right)$

$$10^{15} = 1.04\times10^{19}\exp\left(-\frac{E_F - E_v}{0.0259}\right)$$

$$\Rightarrow E_F - E_v = 0.24\,eV$$

$$Given, E_g = 1.12\,eV$$

$$\Rightarrow E_c - E_F = 0.88\,eV$$

Using, $E_c - E_F = 0.88\,eV$ in $n_0 = N_c\exp\left(-\frac{E_c - E_F}{kT}\right)$

We get, $n_o = 4.91\times10^{4}\ cm^{-3}$

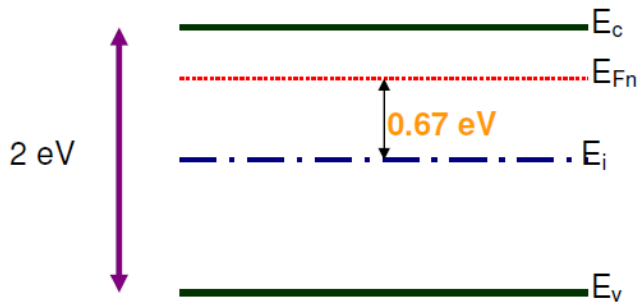
3. A semiconductor has $N_C = 10^{19}$ cm^{-3}, $N_v = 5 \times 10^{18}$ cm^{-3} and $E_g = 2$ eV doped with 10^{17} cm^{-3} donors (fully ionized)
   (a) Calculate the intrinsic, electron and hole concentrations at 627^{o}C
   (b) Where is E_F located relative to E_i?
   (c) Sketch the simplified band diagram, showing the position of E_F (assume the E_i is nearly at the midgap).

<u>Answer:</u>

(a) Intrinsic carrier concentration at 627^{o}C , $n_i = 1.77 \times 10^{13}$ cm^{-3}
Electron concentration, $n \sim N_D = 10^{17}$ cm^{-3}
Hole concentration, $p = 3.15 \times 10^{9}$ cm^{-3}

(b) $E_F - E_i = 0.67$eV

(c)



4. The Ge is now doped with Boron and with Phosphorous. Both dopants have the same concentration. Assume the Boron and Phosphorous energy levels are each 40 *meV* from the band edge. If $m_n^*/m_p^* = 0.01$, draw the band diagram of the doped Ge as accurately as you can, showing E_g, E_f and E_i. Assume E_g of Ge is 0.67eV.

<u>Answer:</u>

$$E_i = midgap + 89meV$$

5. Consider a GaAs semiconductor illuminated with photons of energy 1.65 eV.
The absorption coefficient at 1.65 eV is $10^4\ cm^{-1}$.
(a) Determine the thickness of the material so that 75% of the energy is absorbed.
(b) Determine the thickness so that 75% of the energy is transmitted.

Given: At $h\nu = 1.65\ eV$, $\alpha = 10^4\ cm^{-1}$.

<u>Answer:</u>

(a) $t = 1.39\mu m$
(b) $t = 0.29\mu m$

6. The optical properties of silicon measured at 300K are given below:

Wavelength (*nm*)	Absorption coefficient (cm^{-1})	Refraction coefficient R
400	1×10^4	0.49
700	1.90×10^3	0.34

Two monochromatic light sources at 400 *nm* and 700 *nm* are available to illuminate a silicon solar cell of 1 μm thick. Recommend the most suitable source for illumination.

Assume that the light incidents normally on the front surface of the solar cell with an intensity of 10 W/cm^2.

<u>Answer:</u>

$$At\ 400nm, R = 0.49$$
$$I(a) = 3.2W/cm^2$$
$$At\ 700nm, R = 0.34$$
$$I(a) = 1.1W/cm^2$$

Based on the intensity of absorbed light calculated above, the most suitable source for illumination is: monochromatic light source at 400 *nm*.