ELEC 321 HW #3

1. sign of effective mass depends generally on $\frac{\partial^2 E}{\partial K^2}$.

This assumption is valid at the edge of E_c & E_v however for this problem we have stretched it further!

$$A \,\&\, D : \quad \frac{\partial^2 E}{\partial K^2} < 0 \Rightarrow m_e^* < 0$$

$$B \,\&\, C : \quad \frac{\partial^2 E}{\partial K^2} > 0 \Rightarrow m_e^* > 0$$

2. $$E = E_0 - E_1 \cos[\alpha(K - K_0)]$$

K_0 : K @ min E

Close to min : $$m_e^* = \frac{\hbar^2}{\frac{\partial^2 E}{\partial K^2}} = \frac{\hbar^2}{E_1 \alpha^2}$$

3. $$g_v(E) = \frac{4\pi}{h^3}(2m_p^*)^{3/2}\sqrt{E_V - E}$$ ← Density of states (Valence band)

As the question is looking in the range of E_v to $E_v - KT$ we should pay attention to D.O.S of Valence band!

Table B.4 : @ $T = 300\,K$ $\quad m^*_{p\text{-}GaAs} = 0.45\, m_0$

$m_0 = 9.1 \times 10^{-31}$ kg

$$g_T = \int_{E_V - KT}^{E_V} g_v(E)\, dE = \frac{4\pi(2m_p^*)^{3/2}}{h^3}\int_{E_V - KT}^{E_V}\sqrt{E_V - E}\, dE$$

$$\Rightarrow g_T = \frac{4\pi(2m_p^*)^{3/2}}{h^3}\left(-\frac{2}{3}\right)(E_V - E)^{3/2}\Big|_{E_V - KT}^{E_V} \overset{@T=300K}{=\!=} 5.65 \times 10^{24}\, m^{-3} = 5.65 \times 10^{18}\, cm^{-3}$$

$KT \overset{@T=300K}{=} 25.8\, eV$ → Remember to Convert to Joule

4. $$f_F(E) = \frac{1}{1+\exp\left(\frac{E-E_F}{KT}\right)}$$

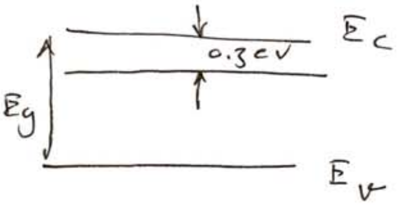
a) $E - E_F = KT \Rightarrow f_F(E) = \frac{1}{1+\exp(1)} \simeq 0.269$

b) $E - E_F = 5KT \Rightarrow f_F(E) = \frac{1}{1+\exp(5)} \simeq 6.69 \times 10^{-3}$

c) $E - E_F = 10KT \Rightarrow f_F(E) = \frac{1}{1+\exp(10)} \simeq 45.4 \times 10^{-6}$

5. $E_g = 1.12^{eV}$ for Si @ $T = 300\ K$

a) $E_c - E_F = 0.3^{eV}$



$\Rightarrow E_F - E_V = E_g - (E_c - E_F)$
$= 1.12 - 0.3$
$= 0.82^{eV}$

$T = 300^K$ $$f_F(E_c) = \frac{1}{1+\exp\left(\frac{0.3}{25.8^m}\right)} \simeq 8.9 \times 10^{-6}$$

probability of having an electron in the lower edge of ~~Valence~~ Conduction band (E_c)

$T = 300^K$ $$f_F(E_V) = \frac{1}{1+\exp\left(\frac{-0.82}{25.8^m}\right)} \simeq 1$$

chance of existing a hole at the upper edge of valence band:

$$1 - f_F(E_V) = \frac{\exp\left(-\frac{0.82}{25.8^m}\right)}{1+\exp\left(\frac{-0.82}{25.8^m}\right)} \simeq 1.57 \times 10^{-14}$$

Be careful with the math as these numbers are very small! and so calculation is prone to error when comes to divisions ...

5 Contd

b) $E_F - E_V = 0.4^{eV} \Rightarrow E_C - E_F = E_g - 0.4 = 0.72^{eV}$

$$f_F(E_c) = \frac{1}{1 + \exp\left(\frac{0.72}{25.8^m}\right)} \simeq 7.58 \times 10^{-13}$$

probab. of electron at E_c

&

$$1 - f_F(E_V) = \frac{\exp\left(-\frac{0.4}{25.8^m}\right)}{1 + \exp\left(\frac{-0.4}{25.8^m}\right)} \simeq 1.84 \times 10^{-7}$$

probab of hole at E_V

6. $$f_F(E) = \frac{1}{1 + \exp\left(\frac{E - E_I = 0.55^{eV}}{K_B T}\right)} = 10^{-6} \Rightarrow K_B T \simeq 39.81^{meV}$$

@ $T = 300 \Rightarrow K_B T = 25.8^{meV}$

$\Rightarrow T \simeq 463^{K}$