Hw2 solution

1

For $T = 100$ K,

$$E_g = 1.170 - \frac{(4.73\times10^{-4})(100)^2}{636+100} \Rightarrow$$

$$E_g = 1.164 \text{ eV}$$

$T = 200$ K, $E_g = 1.147$ eV

$T = 300$ K, $E_g = 1.125$ eV

$T = 400$ K, $E_g = 1.097$ eV

$T = 500$ K, $E_g = 1.066$ eV

$T = 600$ K, $E_g = 1.032$ eV

2

For A: $E = C_i k^2$

At $k = 0.08\times10^{+10}\ \text{m}^{-1}$, $E = 0.05$ eV

Or $E = (0.05)(1.6\times10^{-19}) = 8\times10^{-21}$ J

So $8\times10^{-21} = C_1(0.08\times10^{10})^2$

$\Rightarrow C_1 = 1.25\times10^{-38}$

$$\text{Now}\quad m^* = \frac{\hbar^2}{2C_1} = \frac{(1.054\times10^{-34})^2}{2(1.25\times10^{-38})}$$

$$= 4.44\times10^{-31}\ \text{kg}$$

$$\text{or}\quad m^* = \frac{4.4437\times10^{-31}}{9.11\times10^{-31}}\cdot m_o$$

$$m^* = 0.488\ m_o$$

For B: $E = C_i k^2$

At $k = 0.08\times10^{+10}\ \text{m}^{-1}$, $E = 0.5$ eV

Or $E = (0.5)(1.6\times10^{-19}) = 8\times10^{-20}$ J

So $8\times10^{-20} = C_1(0.08\times10^{10})^2$

$\Rightarrow C_1 = 1.25\times10^{-37}$

$$\text{Now}\quad m^* = \frac{\hbar^2}{2C_1} = \frac{(1.054\times10^{-34})^2}{2(1.25\times10^{-37})}$$

$$= 4.44\times10^{-32}\ \text{kg}$$

$$\text{or}\quad m^* = \frac{4.4437\times10^{-32}}{9.11\times10^{-31}}\cdot m_o$$

$$m^* = 0.0488\ m_o$$

3

(a) $$\frac{g_c}{g_\upsilon} = \frac{(m_n^*)^{3/2}}{(m_p^*)^{3/2}} = \left(\frac{1.08}{0.56}\right)^{3/2} = 2.68$$

(b) $$\frac{g_c}{g_\upsilon} = \frac{(m_n^*)^{3/2}}{(m_p^*)^{3/2}} = \left(\frac{0.067}{0.48}\right)^{3/2} = 0.0521$$

4

$$1 - f(E) = 1 - \frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)}$$

or

$$1 - f(E) = \frac{1}{1+\exp\left(\frac{E_F-E}{kT}\right)}$$

(a) $E_F - E = kT$, $1 - f(E) = 0.269$

(b) $E_F - E = 5kT$, $1 - f(E) = 6.69\times10^{-3}$

(c) $E_F - E = 10kT$, $1 - f(E) = 4.54\times10^{-5}$

5

(a) $$f_F \cong \exp\left[\frac{-(E-E_F)}{kT}\right]$$

$$E = E_c;\ f_F = \exp\left[\frac{-0.30}{0.0259}\right] = 9.32\times10^{-6}$$

$$E_c + \frac{kT}{2};\ f_F = \exp\left[\frac{-(0.30+0.0259/2)}{0.0259}\right]$$

$$= 5.66\times10^{-6}$$

$$E_c + kT;\ f_F = \exp\left[\frac{-(0.30+0.0259)}{0.0259}\right]$$

$$= 3.43\times10^{-6}$$

$$E_c + \frac{3kT}{2};\ f_F = \exp\left[\frac{-(0.30+3(0.0259/2))}{0.0259}\right]$$

$$= 2.08\times10^{-6}$$

$$E_c + 2kT;\ f_F = \exp\left[\frac{-(0.30+2(0.0259))}{0.0259}\right]$$

$$= 1.26\times10^{-6}$$

(b) $$1 - f_F = 1 - \frac{1}{1+\exp\left[\frac{E-E_F}{kT}\right]}$$

$$\cong \exp\left[\frac{-(E_F-E)}{kT}\right]$$

$$E = E_\upsilon;\ 1 - f_F = \exp\left[\frac{-0.25}{0.0259}\right] = 6.43\times 10^{-5}$$

$$E_\upsilon - \frac{kT}{2};\ 1 - f_F = \exp\left[\frac{-(0.25 + 0.0259/2)}{0.0259}\right]$$

$$= 3.90\times 10^{-5}$$

$$E_\upsilon - kT;\ 1 - f_F = \exp\left[\frac{-(0.25 + 0.0259)}{0.0259}\right]$$

$$= 2.36\times 10^{-5}$$

$$E_\upsilon - \frac{3kT}{2};$$

$$1 - f_F = \exp\left[\frac{-(0.25 + 3(0.0259/2))}{0.0259}\right]$$

$$= 1.43\times 10^{-5}$$

$$E_\upsilon - 2kT;$$

$$1 - f_F = \exp\left[\frac{-(0.25 + 2(0.0259))}{0.0259}\right]$$

$$= 8.70\times 10^{-6}$$

6

$$f_F = \exp\left[\frac{-(E - E_F)}{kT}\right] = \exp\left[\frac{-(E_c + kT - E_F)}{kT}\right]$$

and

$$1 - f_F = \exp\left[\frac{-(E_F - E)}{kT}\right]$$

$$= \exp\left[\frac{-(E_F - (E_\upsilon - kT))}{kT}\right]$$

So $\exp\left[\frac{-(E_c + kT - E_F)}{kT}\right]$

$$= \exp\left[\frac{-(E_F - E_\upsilon + kT)}{kT}\right]$$

Then $E_c + kT - E_F = E_F - E_\upsilon + kT$

Or $E_F = \frac{E_c + E_\upsilon}{2} = E_{midgap}$

7

(a) $f_F = \exp\left[\frac{-(E - E_F)}{kT}\right]$

$$10^{-8} = \exp\left[\frac{-0.60}{kT}\right]$$

or $\frac{0.60}{kT} = \ln(10^{+8})$

$$kT = \frac{0.60}{\ln(10^8)} = 0.032572 \text{ eV}$$

$$0.032572 = (0.0259)\left(\frac{T}{300}\right)$$

so $T = 377$ K

(b) $10^{-6} = \exp\left[\frac{-0.60}{kT}\right]$

$$\frac{0.60}{kT} = \ln(10^{+6})$$

$$kT = \frac{0.60}{\ln(10^6)} = 0.043429$$

$$0.043429 = (0.0259)\left(\frac{T}{300}\right)$$

or $T = 503$ K
