

Chapter 4

Problem Solutions

4.1

$$n_i^2 = N_c N_v \exp\left(\frac{-E_g}{kT}\right)$$

(a) Silicon		
$T(^{\circ}K)$	kT (eV)	n_i (cm ⁻³)
200	0.01727	7.68×10^4
400	0.03453	2.38×10^{12}
600	0.0518	9.74×10^{19}

	(b) Germanium	(c) GaAs
$T(^{\circ}K)$	$n_i(\text{cm}^{-3})$	$n_i(\text{cm}^{-3})$
200	2.16×10^{10}	1.38
400	8.60×10^{14}	3.28×10^6
600	3.82×10^{19}	5.72×10^{13}

4.2

$$n_i^2 = N_c N_v \exp\left(\frac{-E_g}{kT}\right)$$

$$(10^{13})^2 = (2.8 \times 10^{19})(1.04 \times 10^{19}) \left(\frac{T}{300}\right)^3 \exp\left(\frac{-1.12}{kT}\right)$$

Then

$$\exp\left(\frac{1.12}{kT}\right) = (2.912 \times 10^{-14}) \left(\frac{T}{300}\right)^3$$

By trial and error

$$T = 381K$$

4.3

Computer Plot

4.4

$$n_i^2 = N_{co} N_{cv} \cdot (T)^3 \cdot \exp\left(\frac{-E_g}{kT}\right)$$

So

$$\frac{n_i^2(T_1)}{n_i^2(T_2)} = \left(\frac{T_1}{T_2}\right)^3 \exp\left[-E_g \left(\frac{1}{kT_1} - \frac{1}{kT_2}\right)\right]$$

$$\text{At } T_1 = 300K \Rightarrow kT = 0.0259 \text{ eV}$$

$$\text{At } T_2 = 200K \Rightarrow kT = 0.01727 \text{ eV}$$

Then

$$\left(\frac{5.83 \times 10^7}{1.82 \times 10^7}\right)^2 = \left(\frac{300}{200}\right)^3 \exp\left[-E_g \left(\frac{1}{0.0259} - \frac{1}{0.01727}\right)\right]$$

or

$$1.026 \times 10^{11} = 3.375 \exp\left[(19.29)E_g\right]$$

which yields

$$E_g = 1.25 \text{ eV}$$

For $T = 300K$,

$$(5.83 \times 10^7)^2 = (N_{co} N_{cv})(300)^3 \exp\left(\frac{-1.25}{0.0259}\right)$$

or

$$N_{co} N_{cv} = 1.15 \times 10^{20}$$

4.5

$$\begin{aligned} (a) \quad g_c f_c &= \sqrt{E - E_c} \exp\left[\frac{-(E - E_c)}{kT}\right] \\ &= \sqrt{E - E_c} \exp\left[\frac{-(E - E_c)}{kT}\right] \exp\left[\frac{-(E_c - E_c)}{kT}\right] \end{aligned}$$

Let $E - E_c = x$

Then

$$g_c f_c = \sqrt{x} \exp\left(\frac{-x}{kT}\right)$$

Now, to find the maximum value

$$\begin{aligned} \frac{d(g_c f_c)}{dx} &= \frac{1}{2} x^{-1/2} \exp\left(\frac{-x}{kT}\right) \\ &\quad - \frac{1}{kT} \cdot x^{1/2} \exp\left(\frac{-x}{kT}\right) = 0 \end{aligned}$$

This yields

$$\frac{1}{2x^{1/2}} = \frac{x^{1/2}}{kT} \Rightarrow x = \frac{kT}{2}$$

Then the maximum value occurs at

$$E = E_c + \frac{kT}{2}$$

(b)

$$\begin{aligned} g_v (1 - f_v) &= \sqrt{E_v - E} \exp\left[\frac{-(E_v - E)}{kT}\right] \\ &= \sqrt{E_v - E} \exp\left[\frac{-(E_v - E_c)}{kT}\right] \exp\left[\frac{-(E_c - E)}{kT}\right] \end{aligned}$$

Let $E_v - E = x$

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