Chapter 5

Exercise Solutions

E5.1

$n_o = 10^{15} - 10^{14} = 9x10^{14}\ cm^{-3}$

so

$$p_o = \frac{n_i^2}{n_o} = \frac{\left(1.5x10^{10}\right)^2}{9x10^{14}} = 2.5x10^5\ cm^{-3}$$

Now

$$J_{drf} = e\left(\mu_n n_o + \mu_p p_o\right)\mathrm{E} \approx e\mu_n n_o \mathrm{E}$$
$$= \left(1.6x10^{-19}\right)(1350)\left(9x10^{14}\right)(35)$$

or

$$\underline{J_{drf} = 6.80\ A/cm^2}$$

E5.2

$$J_{drf} \cong e\mu_p p_o \mathrm{E}$$

Then

$$120 = \left(1.6x10^{-19}\right)(480)p_o(20)$$

so

$$\underline{p_o = 7.81x10^{16}\ cm^{-3} = N_a}$$

E5.3

Use Figure 5.2

(a)

(i) $\mu_n \cong 500\ cm^2/V-s$, (ii) $\cong 1500\ cm^2/V-s$

(b)

(i) $\mu_p \cong 380\ cm^2/V-s$, (ii) $\cong 200\ cm^2/V-s$

E5.4

Use Figure 5.3 [Units of $cm^2/V-s$]

(a) For $N_I = 10^{15}\ cm^{-3}$; $\mu_n \cong 1350$, $\mu_p \cong 480$:

(b) $N_I = 1.5x10^{17}\ cm^{-3}$; $\mu_n \cong 700$, $\mu_p \cong 300$:

(c) $N_I = 1.1x10^{17}\ cm^{-3}$; $\mu_n \cong 800$, $\mu_p \cong 310$:

(d) $N_I = 2x10^{17}\ cm^{-3}$; $\mu_n \cong 4500$, $\mu_p \cong 220$

E5.5

(a) For

$N_I = 7x10^{16}\ cm^{-3}$; $\mu_n \cong 1000\ cm^2/V-s$,

$\mu_p \cong 350\ cm^2/V-s$

(b) $\sigma \cong e\mu_n\left(N_d - N_a\right)$

$$= \left(1.6x10^{-19}\right)(1000)\left(3x10^{16}\right) \Rightarrow$$

$$\underline{\sigma = 4.8\ (\Omega - cm)^{-1}}$$

$$\rho = \frac{1}{\sigma} = \frac{1}{4.8} \Rightarrow \underline{\rho = 0.208\ \Omega - cm}$$

E5.6

$$\sigma = e\mu_n N_d = \frac{1}{\rho}$$

so

$$\left(1.6x10^{-19}\right)\mu_n N_d = \frac{1}{0.1} = 10$$

Then

$$\mu_n N_d = 6.25x10^{19}$$

Using Figure 5.4a, $\underline{N_d \cong 9x10^{16}\ cm^{-3}}$

Then

$$\underline{\mu_n \approx 695\ cm^2/V-s}$$

E5.7

(a) $R = \frac{V}{I} = \frac{5}{2} = 2.5\ k\Omega$

(b) $R = 2.5x10^3 = \frac{\rho\left(1.2x10^{-3}\right)}{10^{-6}} \Rightarrow$

$$\underline{\rho = 2.08\ \Omega - cm}$$

(c) From Figure 5.4a, $\underline{N_a \cong 7x10^{15}\ cm^{-3}}$

E5.8

$$J_{diff} = eD_n\frac{dn}{dx} = -eD_n\left(\frac{10^{15}}{10^{-4}}\right)\exp\left(\frac{-x}{L_n}\right)$$

$$D_n = 25\ cm^2/s,\quad L_n = 10^{-4}\ cm = 1\ \mu m$$

Then

$$J_{diff} = -40\exp\left(\frac{-x}{1}\right)\ A/cm^2$$

(a) $x = 0$; $\underline{J_{diff} = -40\ A/cm^2}$

(b) $x = 1\ \mu m$; $\underline{J_{diff} = -14.7\ A/cm^2}$

(c) $x = \infty$; $\underline{J_{diff} = 0}$

E5.9

$$J_{diff} = -eD_p \frac{dp}{dx}$$

so

$$20 = -(1.6x10^{-19})(10)\frac{\Delta p}{(0-0.010)}$$

Then

$$\Delta p = 1.25x10^{17} = 4x10^{17} - p$$

or

$$\underline{p(x=0.01) = 2.75x10^{17}\ cm^{-3}}$$

E5.10

At $x = 0$,

$$J_{diff} = -eD_p \frac{dp}{dx} = -eD_p\left(\frac{2x10^{15}}{-L_p}\right)$$

Then

$$6.4 = (1.6x10^{-19})(10)\left(\frac{2x10^{15}}{L_p}\right)$$

Which yields

$$\underline{L_P = 5x10^{-4}\ cm}$$