Chapter 6

Exercise Solutions

E6.1

$$\delta n(t) = \delta n(0)\exp\left(\frac{-t}{\tau_{no}}\right)$$

so

$$\delta n(t) = 10^{15}\exp\left(\frac{-t}{1\ \mu s}\right)$$

(a) $t = 0$; $\underline{\delta n = 10^{15}\ cm^{-3}}$

(b) $t = 1\ \mu s$; $\underline{\delta n = 3.68x10^{14}\ cm^{-3}}$

(c) $t = 4\ \mu s$; $\underline{\delta n = 1.83x10^{13}\ cm^{-3}}$

E6.2

$$R = \frac{\delta n}{\tau_{no}}$$

Then

(a) $R = \frac{10^{15}}{10^{-6}} \Rightarrow \underline{R = 10^{21}\ cm^{-3}s^{-1}}$

(b) $R = \frac{3.68x10^{14}}{10^{-6}} \Rightarrow \underline{R = 3.68x10^{20}\ cm^{-3}s^{-1}}$

(c) $R = \frac{1.83x10^{13}}{10^{-6}} \Rightarrow \underline{R = 1.83x10^{19}\ cm^{-3}s^{-1}}$

E6.3

(a) p-type $\Rightarrow$ Minority carrier = electrons

(b) $\delta n(t) = \delta n(0)\exp\left(\frac{-t}{\tau_{no}}\right)$

Then

$$\underline{\delta n(t) = 10^{15}\exp\left(\frac{-t}{5\ \mu s}\right)\quad cm^{-3}}$$

E6.4

(a) p-type $\Rightarrow$ Minority carrier = electrons

(b) $\delta n(t) = g'\tau_{no}\left[1 - \exp\left(\frac{-t}{\tau_{no}}\right)\right]$

or

$$\delta n(t) = \left(10^{20}\right)\left(5x10^{-6}\right)\left[1 - \exp\left(\frac{-t}{5\ \mu s}\right)\right]$$

Then

$$\underline{\delta n(t) = 5x10^{14}\left[1 - \exp\left(\frac{t}{5\ \mu s}\right)\right]}$$

(c) As $t \to \infty$, $\underline{\delta n(\infty) = 5x10^{14}\ cm^{-3}}$

E6.5

$$\delta n(x) = \delta p(x) = \delta n(0)\exp\left(\frac{-x}{L_p}\right)$$

$$L_P = \sqrt{D_P\tau_{po}} = \sqrt{(10)\left(10^{-6}\right)} = 31.6\ \mu m$$

Then

$$\underline{\delta n(x) = \delta p(x) = 10^{15}\exp\left(\frac{-x}{31.6\ \mu m}\right)\quad cm^{-3}}$$

E6.6

n-type $\Rightarrow$ Minority carrier = hole

$$J_{diff} = -eD_p\frac{dp}{dx} = -eD_p\frac{d(\delta p(x))}{dx}$$

$$J_{diff} = \frac{-\left(1.6x10^{-19}\right)(10)\left(10^{15}\right)}{-\left(3.16x10^{-3}\right)}\exp\left(\frac{-10}{31.6}\right)$$

or

$\underline{J_{diff} = +0.369\ A/cm^2}$ Hole diffusion current

$$J_{diff}(electrons) = -J_{diff}(holes)$$

so

$\underline{J_{diff} = -0.369\ A/cm^2}$ Electron diffusion current

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E6.7

$$\delta p = \frac{\exp\left(-t/\tau_{po}\right)}{\left(4\pi D_p t\right)^{1/2}}$$

(a) $\frac{\exp(-1/5)}{\left[(4\pi)(10)\left(10^{-6}\right)\right]^{1/2}} \Rightarrow \underline{\delta p = 73.0}$

(b) $\frac{\exp(-5/5)}{\left[(4\pi)(10)\left(5x10^{-6}\right)\right]^{1/2}} \Rightarrow \underline{\delta p = 14.7}$

(c) $\frac{\exp(-15/5)}{\left[(4\pi)(10)\left(15x10^{-6}\right)\right]^{1/2}} \Rightarrow \underline{\delta p = 1.15}$

(d) $\frac{\exp(-25/5)}{\left[(4\pi)(10)\left(25x10^{-6}\right)\right]^{1/2}} \Rightarrow \underline{\delta p = 0.120}$

$x = \mu_p \mathrm{E}_o t = (386)(10)t$

(a) $\underline{x = 38.6\ \mu m}$; (b) $\underline{x = 193\ \mu m}$

(b) $\underline{x = 579\ \mu m}$; (d) $\underline{x = 965 \mu m}$

E6.8

$$\delta p = \frac{\exp(-t/\tau_{po})}{(4\pi D_p t)^{1/2}} \cdot \exp\left[\frac{-(x-\mu_p \mathrm{E}_o t)^2}{4D_p t}\right]$$

(a) (i) $x - \mu_p \mathrm{E}_o t$

$= 1.093x10^{-2} - (386)(10)(10^{-6}) = 7.07x10^{-3}$

$$\delta p = \frac{\exp(-1/5)}{[(4\pi)(10)(10^{-6})]^{1/2}} \cdot \exp\left[\frac{-(7.07x10^{-3})^2}{4(10)(10^{-6})}\right]$$

or

$$\delta p = 73.0 \exp\left[\frac{-(7.07x10^{-3})^2}{4(10)(10^{-6})}\right]$$

Then

$\underline{\delta p = 20.9}$

(ii) $x - \mu_p \mathrm{E}_o t$

$-3.21x10^{-3} - (386)(10)(10^{-6}) = -7.07x10^{-3}$

$$\delta p = 73.0 \exp\left[\frac{-(-7.07x10^{-3})^2}{4(10)(10^{-6})}\right]$$

or

$\underline{\delta p = 20.9}$

(b) (i) $x - \mu_p \mathrm{E}_o t$

$= 2.64x10^{-2} - (386)(10)(5x10^{-6}) = 7.1x10^{-3}$

$$\delta p = 14.7 \exp\left[\frac{-(7.1x10^{-3})^2}{4(10)(5x10^{-6})}\right]$$

Then

$\underline{\delta p = 11.4}$

(ii) $x - \mu_p \mathrm{E}_o t$

$= 1.22x10^{-2} - (386)(10)(5x10^{-6}) = -7.1x10^{-3}$

Then

$\underline{\delta p = 11.4}$

(c) (i) $x - \mu_p \mathrm{E}_o t$

$= 6.50x10^{-2} - (386)(10)(15x10^{-6}) = 7.1x10^{-3}$

$$\delta p = 1.15 \exp\left[\frac{-(7.1x10^{-3})^2}{4(10)(15x10^{-6})}\right] \quad \underline{\delta p = 1.05}$$

(ii) $x - \mu_p \mathrm{E}_o t$

$= 5.08x10^{-2} - (386)(10)(15x10^{-6}) = -7.1x10^{-3}$

Then

$\underline{\delta p = 1.05}$

E6.9 Computer Plot

E6.10

(a) $E_F - E_{Fi} = (0.0259)\ln\left(\frac{10^{16}}{1.5x10^{10}}\right) \Rightarrow$

$\underline{E_F - E_{Fi} = 0.3473\ eV}$

(b) $E_{Fn} - E_{Fi} = (0.0259)\ln\left(\frac{10^{16} + 5x10^{14}}{1.5x10^{10}}\right) \Rightarrow$

$\underline{E_{Fn} - E_{Fi} = 0.3486\ eV}$

$E_{Fi} - E_{Fp} = (0.0259)\ln\left(\frac{5x10^{14}}{1.5x10^{10}}\right) \Rightarrow$

$\underline{E_{Fi} - E_{Fp} = 0.2697\ eV}$

E6.11

(a) p-type

$E_{Fi} - E_F = (0.0259)\ln\left(\frac{6x10^{15} - 10^{15}}{1.5x10^{10}}\right)$

$\underline{E_{Fi} - E_F = 0.3294\ eV}$

(b) $E_{Fn} - E_{Fi} = (0.0259)\ln\left(\frac{2x10^{14}}{1.5x10^{10}}\right) \Rightarrow$

$\underline{E_{Fn} - E_{Fi} = 0.2460\ eV}$

$E_{Fi} - E_{Fp} = (0.0259)\ln\left(\frac{5x10^{15} + 2x10^{14}}{1.5x10^{10}}\right)$

$\underline{E_{Fi} - E_{Fp} = 0.3304\ eV}$

E6.12

n-type; $n_o = 10^{15}\ cm^{-3}$; $p_o = 2.25x10^{5}\ cm^{-3}$

$$R = \frac{[(n_o + \delta n)(p_o + \delta p) - n_i^2]}{\tau_{po}(n_o + \delta n + n_i) + \tau_{no}(p_o + \delta p + n_i)}$$

Then

$\underline{R = 1.83x10^{20}\ cm^{-3} s^{-1}}$
