8.1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 14, 15, 16, 19

8.1

In forward bias

$$I_f = I_S \exp\left(\frac{eV}{kT}\right)$$

Then

$$\frac{I_{f1}}{I_{f2}} = \frac{I_S \exp\left(\frac{eV_1}{kT}\right)}{I_S \exp\left(\frac{eV_2}{kT}\right)} = \exp\left[\left(\frac{e}{kT}\right)(V_1 - V_2)\right]$$

or

$$V_1 - V_2 = \left(\frac{kT}{e}\right)\ln\left(\frac{I_{f1}}{I_{f2}}\right)$$

(a)

For $\frac{I_{f1}}{I_{f2}} = 10$, then

$$V_1 - V_2 = (0.0259)\ln(10)$$

or

$$V_1 - V_2 = 59.6 \text{ mV} \cong 60 \text{ mV}$$

(b)

For $\frac{I_{f1}}{I_{f2}} = 100$, then

$$V_1 - V_2 = (0.0259)\ln(100)$$

or

$$V_1 - V_2 = 119.3 \text{ mV} \cong 120 \text{ mV}$$

8.2

$$n_{po} = \frac{n_i^2}{N_a} = \frac{(1.5\times10^{10})^2}{8\times10^{15}} = 2.8125\times10^4 \text{ cm}^{-3}$$

$$p_{no} = \frac{n_i^2}{N_d} = \frac{(1.5\times10^{10})^2}{2\times10^{15}} = 1.125\times10^5 \text{ cm}^{-3}$$

$$p_n(x_n) = p_{no}\exp\left(\frac{V_a}{V_t}\right)$$

$$n_p(-x_p) = n_{po}\exp\left(\frac{V_a}{V_t}\right)$$

(a) $V_a = 0.45$ V,

$$p_n(x_n) = (1.125\times10^5)\exp\left(\frac{0.45}{0.0259}\right)$$

$$= 3.95\times10^{12} \text{ cm}^{-3}$$

$$n_p(-x_p) = (2.8125\times10^4)\exp\left(\frac{0.45}{0.0259}\right)$$

or

$$n_p(-x_p) = 9.88\times10^{11} \text{ cm}^{-3}$$

(b) $V_a = 0.55$ V,

$$p_n(x_n) = (1.125\times10^5)\exp\left(\frac{0.55}{0.0259}\right)$$

$$= 1.88\times10^{14} \text{ cm}^{-3}$$

$$n_p(-x_p) = (2.8125\times10^4)\exp\left(\frac{0.55}{0.0259}\right)$$

$$= 4.69\times10^{13} \text{ cm}^{-3}$$

(c) $V_a = -0.55$ V

$$p_n(x_n) = (1.125\times10^5)\exp\left(\frac{-0.55}{0.0259}\right)$$

$$\cong 0$$

$$n_p(-x_p) = (2.8125\times10^4)\exp\left(\frac{-0.55}{0.0259}\right)$$

$$\cong 0$$

8.3

$$n_{po} = \frac{n_i^2}{N_a} = \frac{(1.8\times10^6)^2}{4\times10^{16}} = 8.1\times10^{-5} \text{ cm}^{-3}$$

$$p_{no} = \frac{n_i^2}{N_d} = \frac{(1.8\times10^6)^2}{10^{16}} = 3.24\times10^{-4} \text{ cm}^{-3}$$

(a) $V_a = 0.90$ V,

$$p_n(x_n) = (3.24\times10^{-4})\exp\left(\frac{0.90}{0.0259}\right)$$

$$= 4.0\times10^{11} \text{ cm}^{-3}$$

$$n_p(-x_p) = (8.1\times10^{-5})\exp\left(\frac{0.90}{0.0259}\right)$$

$$= 10.0\times10^{10} \text{ cm}^{-3}$$

(b) $V_a = 1.10$ V

$$p_n(x_n) = (3.24\times10^{-4})\exp\left(\frac{1.10}{0.0259}\right)$$

$$= 9.03\times10^{14} \text{ cm}^{-3}$$

$$n_p(-x_p) = (8.1\times10^{-5})\exp\left(\frac{1.10}{0.0259}\right)$$

$$= 2.26\times10^{14} \text{ cm}^{-3}$$

(c) $p_n(x_n) \cong 0$

$n_p(-x_p) \cong 0$

8.4

(a) $n_{po} = \frac{n_i^2}{N_a} = \frac{(1.5\times10^{10})^2}{5\times10^{16}}$

$$= 4.5\times10^3 \text{ cm}^{-3}$$

$$p_{no} = \frac{n_i^2}{N_d} = \frac{(1.5\times10^{10})^2}{5\times10^{15}}$$

$$= 4.5\times10^4 \text{ cm}^{-3}$$

(i) $p_n(x_n) = p_{no}\exp\left(\frac{V_a}{V_t}\right)$

or $V_a = V_t \ln\left[\frac{p_n(x_n)}{p_{no}}\right]$

$$= (0.0259)\ln\left[\frac{(0.1)(5\times10^{15})}{4.5\times10^4}\right]$$

$$= 0.599 \text{ V}$$

(ii) n-region - lower doped side

(b) $n_{po} = \frac{n_i^2}{N_a} = \frac{(1.5\times10^{10})^2}{7\times10^{15}}$

$$= 3.214\times10^4 \text{ cm}^{-3}$$

$$p_{no} = \frac{n_i^2}{N_d} = \frac{(1.5\times10^{10})^2}{3\times10^{16}}$$

$$= 7.5\times10^3 \text{ cm}^{-3}$$

(i) $V_a = V_t \ln\left[\frac{(0.1)N_a}{n_{po}}\right]$

$$= (0.0259)\ln\left[\frac{(0.1)(7\times10^{15})}{3.214\times10^4}\right]$$

$$= 0.6165 \text{ V}$$

(ii) p-region - lower doped side

8.5

(a) $J_n(-x_p) = \frac{eD_n n_{p0}}{L_n} \exp\left(\frac{V_a}{V_t}\right)$

$= \frac{en_i^2}{N_a}\sqrt{\frac{D_n}{\tau_{n0}}} \cdot \exp\left(\frac{V_a}{V_t}\right)$

$= \frac{(1.6\times10^{-19})(1.8\times10^{6})^2}{5\times10^{16}}\sqrt{\frac{205}{5\times10^{-8}}}$

$\times \exp\left(\frac{1.10}{0.0259}\right)$

$= 1.849\ \text{A/cm}^2$

$I_n = AJ_n(-x_p) = (10^{-3})(1.849)\ \text{A}$

or $I_n = 1.85\ \text{mA}$

(b) $J_p(x_n) = \frac{eD_p p_{n0}}{L_p} \exp\left(\frac{V_a}{V_t}\right)$

$= \frac{en_i^2}{N_d}\sqrt{\frac{D_p}{\tau_{p0}}} \cdot \exp\left(\frac{V_a}{V_t}\right)$

$= \frac{(1.6\times10^{-19})(1.8\times10^{6})^2}{10^{16}}\sqrt{\frac{9.80}{10^{-8}}}$

$\times \exp\left(\frac{1.10}{0.0259}\right)$

$= 4.521\ \text{A/cm}^2$

$I_p = AJ_p(x_n) = (10^{-3})(4.521)\ \text{A}$

or $I_p = 4.52\ \text{mA}$

(c) $I = I_n + I_p = 1.85 + 4.52 = 6.37\ \text{mA}$

8.6

For an n^+p silicon diode

$I_S = Aen_i^2 \cdot \frac{1}{N_a}\sqrt{\frac{D_n}{\tau_{nO}}}$

$= \frac{(10^{-4})(1.6\times10^{-19})(1.5\times10^{10})^2}{10^{16}}\sqrt{\frac{25}{10^{-6}}}$

or

$I_S = 1.8\times10^{-15}\ \text{A}$

(a) For $V_a = 0.5\ \text{V}$,

$I_D \cong I_S \exp\left(\frac{V_a}{V_t}\right)$

$= (1.8\times10^{-15})\exp\left(\frac{0.5}{0.0259}\right)$

or

$I_D = 4.36\times10^{-7}\ \text{A}$

(b) For $V_a = -0.5\ \text{V}$,

$I_D = (1.8\times10^{-15})\left[\exp\left(\frac{-0.5}{0.0259}\right) - 1\right]$

or

$I_D \cong -I_S = -1.8\times10^{-15}\ \text{A}$

8.7

$J_s = en_i^2\left[\frac{1}{N_a}\sqrt{\frac{D_n}{\tau_{n0}}} + \frac{1}{N_d}\sqrt{\frac{D_p}{\tau_{p0}}}\right]$

$= (1.6\times10^{-19})(2.4\times10^{13})^2$

$\times\left[\frac{1}{4\times10^{15}}\sqrt{\frac{90}{2\times10^{-6}}} + \frac{1}{2\times10^{17}}\sqrt{\frac{48}{2\times10^{-6}}}\right]$

$J_s = 1.568\times10^{-4}\ \text{A/cm}^2$

(a) $I = AJ_s \exp\left(\frac{V_a}{V_t}\right)$

$= (10^{-4})(1.568\times10^{-4})\exp\left(\frac{0.25}{0.0259}\right)$

$= 2.44\times10^{-4}\ \text{A}$

or $I = 0.244\ \text{mA}$

(b) $I = -I_s = -AJ_s = -(10^{-4})(1.568\times10^{-4})$

$= -1.568\times10^{-8}\ \text{A}$

8.8

(a) $J_s = en_i^2\left[\frac{1}{N_a}\sqrt{\frac{D_n}{\tau_{n0}}} + \frac{1}{N_d}\sqrt{\frac{D_p}{\tau_{p0}}}\right]$

$= (1.6\times10^{-19})(1.5\times10^{10})^2$

$\times\left[\frac{1}{5\times10^{17}}\sqrt{\frac{25}{10^{-7}}} + \frac{1}{8\times10^{15}}\sqrt{\frac{10}{8\times10^{-8}}}\right]$

$J_s = 5.145\times10^{-11}\ \text{A/cm}^2$

$I_s = AJ_s = (2\times10^{-4})(5.145\times10^{-11})$

$= 1.029\times10^{-14}\ \text{A}$

(b) $I = I_s \exp\left(\frac{V_a}{V_t}\right)$

(i) $I = (1.029\times10^{-14})\exp\left(\frac{0.45}{0.0259}\right)$

$= 3.61\times10^{-7}\ \text{A}$

(ii) $I = (1.029\times10^{-14})\exp\left(\frac{0.55}{0.0259}\right)$

$= 1.72\times10^{-5}\ \text{A}$

(iii) $I = (1.029\times10^{-14})\exp\left(\frac{0.65}{0.0259}\right)$

$= 8.16\times10^{-4}\ \text{A}$

8.10

Case 1: $I = I_s \exp\left(\frac{V_a}{V_t}\right)$

$$0.50\times10^{-3} = I_s \exp\left(\frac{0.65}{0.0259}\right)$$

$$\Rightarrow I_s = 6.305\times10^{-15}\ \text{A} = 6.305\times10^{-12}\ \text{mA}$$

$$J_s = \frac{I_s}{A} = \frac{6.305\times10^{-12}}{2\times10^{-4}}$$

$$= 3.153\times10^{-8}\ \text{mA/cm}^2$$

Case 2: $I = I_s \exp\left(\frac{V_a}{V_t}\right)$

$$= \left(2\times10^{-12}\right)\exp\left(\frac{0.70}{0.0259}\right)$$

or $I = 1.093$ mA

$$J_s = \frac{I_s}{A} = \frac{2\times10^{-12}}{1\times10^{-3}}$$

$$= 2\times10^{-9}\ \text{mA/cm}^2$$

Case 3: $I = AJ_s \exp\left(\frac{V_a}{V_t}\right)$

So $V_a = V_t \ln\left[\frac{I}{AJ_s}\right]$

$$= (0.0259)\ln\left[\frac{0.80}{\left(10^{-4}\right)\left(10^{-7}\right)}\right]$$

$$V_a = 0.6502\ \text{V}$$

Then

$$I_s = AJ_s = \left(10^{-4}\right)\left(10^{-7}\right) = 10^{-11}\ \text{mA}$$

Case 4: $I_s = \frac{I}{\exp\left(\frac{V_a}{V_t}\right)} = \frac{1.20}{\exp\left(\frac{0.72}{0.0259}\right)}$

$$I_s = 1.014\times10^{-12}\ \text{mA}$$

$$A = \frac{I_s}{J_s} = \frac{1.014\times10^{-12}}{2\times10^{-8}}$$

$$= 5.07\times10^{-5}\ \text{cm}^2$$

8.11

(a) $$\frac{J_n}{J_n + J_p} = \frac{\frac{eD_n n_{po}}{L_n}}{\frac{eD_n n_{po}}{L_n} + \frac{eD_p p_{no}}{L_p}}$$

$$= \frac{\sqrt{\frac{D_n}{\tau_{no}}}\cdot\frac{n_i^2}{N_a}}{\sqrt{\frac{D_n}{\tau_{no}}}\cdot\frac{n_i^2}{N_a} + \sqrt{\frac{D_p}{\tau_{po}}}\cdot\frac{n_i^2}{N_d}}$$

$$0.90 = \frac{1}{1 + \sqrt{\frac{D_p\tau_{no}}{D_n\tau_{po}}}\cdot\left(\frac{N_a}{N_d}\right)}$$

$$\sqrt{\frac{D_p\tau_{no}}{D_n\tau_{po}}}\cdot\left(\frac{N_a}{N_d}\right) = \frac{1}{0.90} - 1$$

$$\frac{N_a}{N_d} = \sqrt{\frac{D_n\tau_{po}}{D_p\tau_{no}}}\left(\frac{1}{0.90} - 1\right)$$

$$= \sqrt{\frac{(25)\left(10^{-7}\right)}{(10)\left(5\times10^{-7}\right)}}(0.1111)$$

$$\frac{N_a}{N_d} = 0.07857 \text{ or } \frac{N_d}{N_a} = 12.73$$

(b) From part (a),

$$\frac{N_a}{N_d} = \sqrt{\frac{D_n\tau_{po}}{D_p\tau_{no}}}\left(\frac{1}{0.20} - 1\right)$$

$$= \sqrt{\frac{(25)\left(10^{-7}\right)}{(10)\left(5\times10^{-7}\right)}}(4)$$

$$\frac{N_a}{N_d} = 2.828 \text{ or } \frac{N_d}{N_a} = 0.354$$

8.12

The cross-sectional area is

$$A = \frac{I}{J} = \frac{10\times10^{-3}}{20} = 5\times10^{-4}\ \text{cm}^2$$

We have

$$J \cong J_S \exp\left(\frac{V_D}{V_t}\right) \Rightarrow 20 = J_S \exp\left(\frac{0.65}{0.0259}\right)$$

which yields

$$J_S = 2.522\times10^{-10}\ \text{A/cm}^2$$

We can write

$$J_S = en_i^2\left[\frac{1}{N_a}\sqrt{\frac{D_n}{\tau_{nO}}} + \frac{1}{N_d}\sqrt{\frac{D_p}{\tau_{pO}}}\right]$$

We want

$$\frac{\frac{1}{N_a}\cdot\sqrt{\frac{D_n}{\tau_{nO}}}}{\frac{1}{N_a}\cdot\sqrt{\frac{D_n}{\tau_{nO}}} + \frac{1}{N_d}\cdot\sqrt{\frac{D_p}{\tau_{pO}}}} = 0.10$$

or

$$\frac{\frac{1}{N_a}\cdot\sqrt{\frac{25}{5\times10^{-7}}}}{\frac{1}{N_a}\sqrt{\frac{25}{5\times10^{-7}}} + \frac{1}{N_d}\cdot\sqrt{\frac{10}{5\times10^{-7}}}}$$

$$= \frac{7.071\times10^3}{7.071\times10^3 + \frac{N_a}{N_d}\left(4.472\times10^3\right)} = 0.10$$

which yields

$$\frac{N_a}{N_d} = 14.23$$

Now

$$J_S = 2.522\times10^{-10} = \left(1.6\times10^{-19}\right)\left(1.5\times10^{10}\right)^2$$

$$\times\left[\frac{1}{(14.23)N_d}\cdot\sqrt{\frac{25}{5\times10^{-7}}} + \frac{1}{N_d}\cdot\sqrt{\frac{10}{5\times10^{-7}}}\right]$$

We find

$$N_d = 7.09\times10^{14}\ \text{cm}^{-3}$$

and

$$N_a = 1.01\times10^{16}\ \text{cm}^{-3}$$

8.14

(a)

$$\frac{J_n}{J_n + J_p} = \frac{\frac{eD_n n_{po}}{L_n}}{\frac{eD_n n_{po}}{L_n} + \frac{eD_p p_{no}}{L_p}}$$

$$= \frac{\sqrt{\frac{D_n}{\tau_{no}}}\cdot\frac{n_i^2}{N_a}}{\sqrt{\frac{D_n}{\tau_{no}}}\cdot\frac{n_i^2}{N_a} + \sqrt{\frac{D_p}{\tau_{po}}}\cdot\frac{n_i^2}{N_d}}$$

$$= \frac{1}{1 + \sqrt{\frac{D_p\tau_{no}}{\ldots}}\left(\frac{N_a}{\ldots}\right)}$$

8.14

(a)

$$\frac{J_n}{J_n+J_p}=\frac{\dfrac{eD_n n_{po}}{L_n}}{\dfrac{eD_n n_{po}}{L_n}+\dfrac{eD_p p_{no}}{L_p}}$$

$$=\frac{\sqrt{\dfrac{D_n}{\tau_{no}}}\cdot\dfrac{n_i^2}{N_a}}{\sqrt{\dfrac{D_n}{\tau_{no}}}\cdot\dfrac{n_i^2}{N_a}+\sqrt{\dfrac{D_p}{\tau_{po}}}\cdot\dfrac{n_i^2}{N_d}}$$

$$=\frac{1}{1+\sqrt{\dfrac{D_p\tau_{no}}{D_n\tau_{po}}}\cdot\left(\dfrac{N_a}{N_d}\right)}$$

We have

$$\frac{D_p}{D_n}=\frac{\mu_p}{\mu_n}=\frac{1}{2.4}\quad\text{and}\quad\frac{\tau_{no}}{\tau_{po}}=\frac{1}{0.1}$$

so

$$\frac{J_n}{J_n+J_p}=\frac{1}{1+\sqrt{\dfrac{1}{2.4}\cdot\dfrac{1}{0.1}}\cdot\left(\dfrac{N_a}{N_d}\right)}$$

or

$$\frac{J_n}{J_n+J_p}=\frac{1}{1+(2.04)\left(\dfrac{N_a}{N_d}\right)}$$

(b) Using Einstein's relation, we can write

$$\frac{J_n}{J_n+J_p}=\frac{\dfrac{e\mu_n}{L_n}\cdot\dfrac{n_i^2}{N_a}}{\dfrac{e\mu_n}{L_n}\cdot\dfrac{n_i^2}{N_a}+\dfrac{e\mu_p}{L_p}\cdot\dfrac{n_i^2}{N_d}}$$

$$=\frac{e\mu_n N_d}{e\mu_n N_d+\dfrac{L_n}{L_p}\cdot e\mu_p N_a}$$

We have

$$\sigma_n=e\mu_n N_d\quad\text{and}\quad\sigma_p=e\mu_p N_a$$

Also

$$\frac{L_n}{L_p}=\sqrt{\frac{D_n\tau_{no}}{D_p\tau_{po}}}=\sqrt{\frac{2.4}{0.1}}=4.90$$

Then

$$\frac{J_n}{J_n+J_p}=\frac{(\sigma_n/\sigma_p)}{(\sigma_n/\sigma_p)+4.90}$$

8.15

(a) p-side;

$$E_{Fi}-E_F=kT\ln\left(\frac{N_a}{n_i}\right)$$

$$=(0.0259)\ln\left(\frac{5\times10^{15}}{1.5\times10^{10}}\right)$$

or

$$E_{Fi}-E_F=0.329\,\text{eV}$$

Also on the n-side;

$$E_F-E_{Fi}=kT\ln\left(\frac{N_d}{n_i}\right)$$

$$=(0.0259)\ln\left(\frac{10^{17}}{1.5\times10^{10}}\right)$$

or

$$E_F-E_{Fi}=0.407\,\text{eV}$$

(b) We can find

$$D_n=(1250)(0.0259)=32.4\text{ cm}^2/\text{s}$$

$$D_p=(320)(0.0259)=8.29\text{ cm}^2/\text{s}$$

Now

$$J_S=en_i^2\left[\frac{1}{N_a}\sqrt{\frac{D_n}{\tau_{nO}}}+\frac{1}{N_d}\sqrt{\frac{D_p}{\tau_{pO}}}\right]$$

$$=(1.6\times10^{-19})(1.5\times10^{10})^2$$

$$\times\left[\frac{1}{5\times10^{15}}\sqrt{\frac{32.4}{10^{-6}}}+\frac{1}{10^{17}}\sqrt{\frac{8.29}{10^{-7}}}\right]$$

or

$$J_S=4.426\times10^{-11}\text{ A/cm}^2$$

Then

$$I_S=AJ_S=(10^{-4})(4.426\times10^{-11})$$

or

$$I_S=4.426\times10^{-15}\text{ A}$$

We find

$$I=I_S\exp\left(\frac{V_D}{V_t}\right)$$

$$=(4.426\times10^{-15})\exp\left(\frac{0.5}{0.0259}\right)$$

or

$$I=1.07\times10^{-6}\text{ A}=1.07\,\mu\text{A}$$

(c) The hole current is

$$I_p=en_i^2A\cdot\frac{1}{N_d}\sqrt{\frac{D_p}{\tau_{po}}}\exp\left(\frac{V_D}{V_t}\right)$$

$$=(1.6\times10^{-19})(1.5\times10^{10})^2(10^{-4})\left(\frac{1}{10^{17}}\right)$$

$$\times\sqrt{\frac{8.29}{10^{-7}}}\exp\left(\frac{V_D}{V_t}\right)$$

or

$$I_p=3.278\times10^{-16}\exp\left(\frac{V_D}{V_t}\right)\text{ (A)}$$

Then

$$\frac{I_p}{I}=\frac{J_p}{J_S}=\frac{3.278\times10^{-16}}{4.426\times10^{-15}}=0.0741$$

8.16

(a) $$I_{sp}=A\left(\frac{eD_p p_{no}}{L_p}\right)=eA\sqrt{\frac{D_p}{\tau_{po}}}\cdot\frac{n_i^2}{N_d}$$

$$=(1.6\times10^{-19})(5\times10^{-4})\sqrt{\frac{10}{8\times10^{-8}}}\cdot\frac{(1.5\times10^{10})^2}{1.5\times10^{16}}$$

$$I_{sp}=1.342\times10^{-14}\text{ A}$$

(b) $$I_{sn}=A\left(\frac{eD_n n_{po}}{L_n}\right)=eA\sqrt{\frac{D_n}{\tau_{no}}}\cdot\frac{n_i^2}{N_a}$$

$$=(1.6\times10^{-19})(5\times10^{-4})\sqrt{\frac{25}{2\times10^{-7}}}\cdot\frac{(1.5\times10^{10})^2}{5\times10^{16}}$$

$$I_{sn}=4.025\times10^{-15}\text{ A}$$

(c) $$V_{bi}=(0.0259)\ln\left[\frac{(5\times10^{16})(1.5\times10^{16})}{(1.5\times10^{10})^2}\right]$$

$$=0.746826\,\text{V}$$

$$V_a=(0.8)V_{bi}=(0.8)(0.746826)=0.59746\,\text{V}$$

$$p_n(x_n)=p_{no}\exp\left(\frac{V_a}{V_t}\right)=\frac{n_i^2}{N_d}\exp\left(\frac{V_a}{V_t}\right)$$

$$=\frac{(1.5\times10^{10})^2}{1.5\times10^{16}}\exp\left(\frac{0.59746}{0.0259}\right)$$

$$=1.56\times10^{14}\text{ cm}^{-3}$$

(d) $$I_n(-x_p)=I_n(x_n)=I_{sn}\exp\left(\frac{V_a}{V_t}\right)$$

$$=(4.025\times10^{-15})\exp\left(\frac{0.59746}{0.0259}\right)$$

$$=4.1981\times10^{-5}\text{ A}$$

(e) $$I_p(x_n)=I_{sp}\exp\left(\frac{V_a}{V_t}\right)$$

$$=(1.342\times10^{-14})\exp\left(\frac{0.59746}{0.0259}\right)$$

$$=1.3997\times10^{-4}\text{ A}$$

$$I_{Total}=I_n+I_p$$

$$=4.1981\times10^{-5}+1.3997\times10^{-4}$$

$$=1.820\times10^{-4}\text{ A}$$

Now

$$I_p\left(x_n+\frac{1}{2}L_p\right)=I_p(x_n)\exp\left(\frac{-(1/2)L_p}{L_p}\right)$$

$$=(1.3997\times10^{-4})\exp\left(\frac{-1}{2}\right)$$

$$=8.4896\times10^{-5}\text{ A}$$

Then

$$I_n\left(x_n+\frac{1}{2}L_p\right)=I_{Total}-I_p\left(x_n+\frac{1}{2}L_p\right)$$

$$=1.820\times10^{-4}-8.4896\times10^{-5}$$

$$=9.710\times10^{-5}\text{ A}$$

8.19

The excess electron concentration is given by

$$\delta n_p = n_p - n_{po}$$

$$= n_{po}\left[\exp\left(\frac{V_a}{V_t}\right) - 1\right] \cdot \exp\left(\frac{-x}{L_n}\right)$$

The total number of excess electrons is

$$N_p = A\int_0^\infty \delta n_p \, dx$$

We may note that

$$\int_0^\infty \exp\left(\frac{-x}{L_n}\right) dx = -L_n \exp\left(\frac{-x}{L_n}\right)\Bigg|_0^\infty = L_n$$

Then

$$N_p = AL_n n_{po}\left[\exp\left(\frac{V_a}{V_t}\right) - 1\right]$$

We find that

$D_n = 25\ \text{cm}^2/\text{s}$ and $L_n = 50.0\ \mu\text{m}$

Also

$$n_{po} = \frac{n_i^2}{N_a} = \frac{(1.5\times10^{10})^2}{8\times10^{15}} = 2.81\times10^4\ \text{cm}^{-3}$$

Then

$$N_p = (10^{-3})(50.0\times10^{-4})(2.8125\times10^4) \times\left[\exp\left(\frac{V_a}{V_t}\right) - 1\right]$$

or

$$N_p = (0.1406)\left[\exp\left(\frac{V_a}{V_t}\right) - 1\right]$$

Then, we find the total number of excess electrons in the p-region to be:

(a) $V_a = 0.3\ \text{V}$, $N_p = 1.51\times10^4$

(b) $V_a = 0.4\ \text{V}$, $N_p = 7.17\times10^5$

(c) $V_a = 0.5\ \text{V}$, $N_p = 3.40\times10^7$

Similarly, the total number of excess holes in the n-region is found to be

$$P_n = AL_p p_{no}\left[\exp\left(\frac{V_a}{V_t}\right) - 1\right]$$

We find that

$D_p = 10.0\ \text{cm}^2/\text{s}$ and $L_p = 10.0\ \mu\text{m}$

Also

$$p_{no} = \frac{n_i^2}{N_d} = \frac{(1.5\times10^{10})^2}{10^{16}} = 2.25\times10^4\ \text{cm}^{-3}$$

Then

$$P_n = (2.25\times10^{-2})\left[\exp\left(\frac{V_a}{V_t}\right) - 1\right]$$

So

(a) $V_a = 0.3\ \text{V}$, $P_n = 2.41\times10^3$

(b) $V_a = 0.4\ \text{V}$, $P_n = 1.15\times10^5$

(c) $V_a = 0.5\ \text{V}$, $P_n = 5.45\times10^6$