Hw7 solution

1.

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

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

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

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

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

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

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

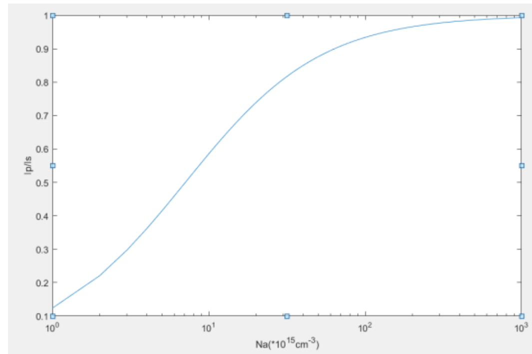
(b) From part (a),

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

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

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

2.



3.

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

$$= (10^{-4})(1.6\times 10^{-19})(1.5\times 10^{10})^2$$

$$\times\left[\frac{1}{4\times 10^{16}}\sqrt{\frac{25}{10^{-7}}} + \frac{1}{4\times 10^{16}}\sqrt{\frac{10}{10^{-7}}}\right]$$

$$I_s = 2.323\times 10^{-15}\text{ A}$$

(b)
$$I_{gen} = \frac{Aen_i W}{2\tau_0}$$

We find

$$V_{bi} = (0.0259)\ln\left[\frac{(4\times 10^{16})(4\times 10^{16})}{(1.5\times 10^{10})^2}\right]$$

$$= 0.7665 \text{ V}$$

and

$$W = \left\{\frac{2\in_s (V_{bi} + V_R)}{e}\left(\frac{N_a + N_d}{N_a N_d}\right)\right\}^{1/2}$$

$$= \left\{\frac{2(11.7)(8.85\times 10^{-14})(0.7665 + 5)}{1.6\times 10^{-19}}\right.$$

$$\left.\times\left[\frac{4\times 10^{16} + 4\times 10^{16}}{(4\times 10^{16})(4\times 10^{16})}\right]\right\}^{1/2}$$

$$W = 6.109\times 10^{-5}\text{ cm}$$

Then

$$I_{gen} = \frac{(10^{-4})(1.6\times 10^{-19})(1.5\times 10^{10})(6.109\times 10^{-5})}{2(10^{-7})}$$

$$= 7.331\times 10^{-11}\text{ A}$$

(c) $\dfrac{I_{gen}}{I_s} = \dfrac{7.331\times 10^{-11}}{2.323\times 10^{-15}} = 3.16\times 10^{4}$

4.

$$D_n = \left(\frac{kT}{e}\right)\cdot \mu_n = (0.0259)(5500)$$
$$= 142.5 \text{ cm}^2/\text{s}$$
$$D_p = (0.0259)(220) = 5.70 \text{ cm}^2/\text{s}$$

(a)

(i) $$I_s = Aen_i^2\left[\frac{1}{N_a}\sqrt{\frac{D_n}{\tau_{n0}}} + \frac{1}{N_d}\sqrt{\frac{D_p}{\tau_{p0}}}\right]$$
$$= \left(2\times 10^{-4}\right)\left(1.6\times 10^{-19}\right)\left(1.8\times 10^{6}\right)^2$$
$$\times\left[\frac{1}{7\times 10^{16}}\sqrt{\frac{142.5}{2\times 10^{-8}}} + \frac{1}{7\times 10^{16}}\sqrt{\frac{5.70}{2\times 10^{-8}}}\right]$$
$$I_s = 1.50\times 10^{-22}\text{ A}$$

(ii) $$I_D = I_s \exp\left(\frac{V_a}{V_t}\right)$$
$$= \left(1.50\times 10^{-22}\right)\exp\left(\frac{0.6}{0.0259}\right)$$
$$= 1.726\times 10^{-12}\text{ A}$$

(iii) $$I_D = \left(1.50\times 10^{-22}\right)\exp\left(\frac{0.8}{0.0259}\right)$$
$$= 3.896\times 10^{-9}\text{ A}$$

(iv) $$I_D = \left(1.50\times 10^{-22}\right)\exp\left(\frac{1.0}{0.0259}\right)$$
$$= 8.795\times 10^{-6}\text{ A}$$

(b) $$I_{gen} = \frac{Aen_iW}{2\tau_0}$$

$$V_{bi} = (0.0259)\ln\left[\frac{\left(7\times 10^{16}\right)\left(7\times 10^{16}\right)}{\left(1.8\times 10^{6}\right)^2}\right]$$
$$= 1.263\text{ V}$$

$$W = \left\{\frac{2(13.1)\left(8.85\times 10^{-14}\right)(1.263+3)}{1.6\times 10^{-19}}\right.$$
$$\left.\times\left[\frac{7\times 10^{16}+7\times 10^{16}}{\left(7\times 10^{16}\right)\left(7\times 10^{16}\right)}\right]\right\}^{1/2}$$
$$= 4.201\times 10^{-5}\text{ cm}$$

(i)Then

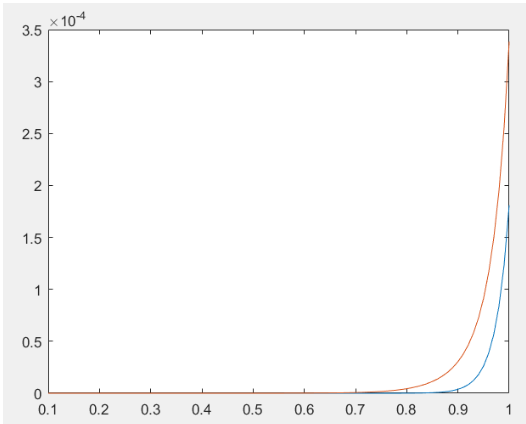
$$I_{gen} = \frac{\left(2\times 10^{-4}\right)\left(1.6\times 10^{-19}\right)\left(1.8\times 10^{6}\right)\left(4.201\times 10^{-5}\right)}{2\left(2\times 10^{-8}\right)}$$
$$= 6.049\times 10^{-14}\text{ A}$$

(ii) $$I_{rec} = I_{ro}\exp\left(\frac{V_a}{2V_t}\right)$$
$$= \left(6\times 10^{-14}\right)\exp\left(\frac{0.6}{2(0.0259)}\right)$$
$$= 6.436\times 10^{-9}\text{ A}$$

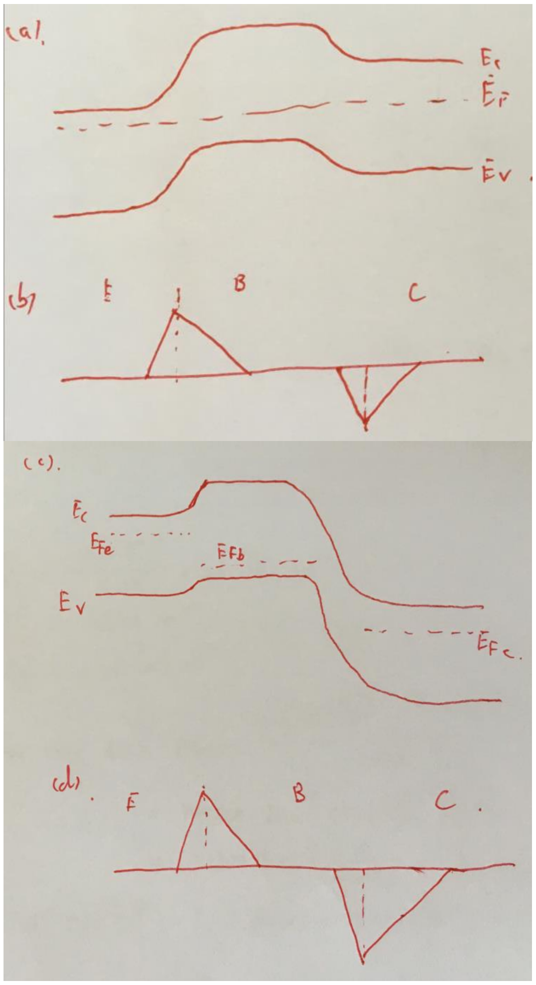
(iii) $$I_{rec} = \left(6\times 10^{-14}\right)\exp\left(\frac{0.8}{2(0.0259)}\right)$$
$$= 3.058\times 10^{-7}\text{ A}$$

(iv) $$I_{rec} = \left(6\times 10^{-14}\right)\exp\left(\frac{1.0}{2(0.0259)}\right)$$
$$= 1.453\times 10^{-5}\text{ A}$$

5.



6.



7.

(a) $p_{E0} = \dfrac{n_i^2}{N_E} = \dfrac{\left(1.5\times10^{10}\right)^2}{8\times10^{17}}$

$= 2.8125\times10^{2}\ \text{cm}^{-3}$

$n_{B0} = \dfrac{n_i^2}{N_B} = \dfrac{\left(1.5\times10^{10}\right)^2}{2\times10^{16}}$

$= \cancel{1.125}\times10^{4}\ \text{cm}^{-3}$

$p_{C0} = \dfrac{n_i^2}{N_C} = \dfrac{\left(1.5\times10^{10}\right)^2}{10^{15}}$

$= 2.25\times10^{5}\ \text{cm}^{-3}$

(b) $n_B(0) = n_{B0}\exp\left(\dfrac{V_{BE}}{V_t}\right)$

$= \left(\cancel{1.125}\times10^{4}\right)\exp\left(\dfrac{0.640}{0.0259}\right)$

$= \cancel{6.064\times10}^{14}\ \text{cm}^{-3}$

$p_E(0) = p_{E0}\exp\left(\dfrac{V_{BE}}{V_t}\right)$

$= \left(2.8125\times10^{2}\right)\exp\left(\dfrac{0.640}{0.0259}\right)$

$= 1.516\times10^{13}\ \text{cm}^{-3}$

8.

(a)

(i) $\gamma = \dfrac{1}{1+\dfrac{I_{pE}}{I_{nE}}} = \dfrac{1}{1+\dfrac{0.0035}{0.50}} = 0.99305$

(ii) $\alpha_T = \dfrac{I_{nC}}{I_{nE}} = \dfrac{0.495}{0.50} = 0.990$

(iii) $\delta = \dfrac{I_{nE}+I_{pE}}{I_{nE}+I_R+I_{pE}}$

$= \dfrac{0.50+0.0035}{0.50+0.005+0.0035} = 0.990167$

(iv) $\alpha = \delta\alpha_T\delta = (0.99305)(0.990)(0.990167)$

$= 0.97345$

(v) $\beta = \dfrac{\alpha}{1-\alpha} = \dfrac{0.97345}{1-0.97345} = 36.7$

(b) For $\beta = 120 \Rightarrow \alpha = \dfrac{\beta}{1+\beta} = \dfrac{120}{121}$

$\alpha = 0.991736$

Then $\gamma = \alpha_T = \delta = 0.997238$

$\alpha_T = 0.997238 = \dfrac{I_{nC}}{I_{nE}} = \dfrac{I_{nC}}{0.50}$

$\Rightarrow I_{nC} = 0.4986\ \text{mA}$

$\gamma = 0.997238 = \dfrac{1}{1+\dfrac{I_{pE}}{I_{nE}}} = \dfrac{1}{1+\dfrac{I_{pE}}{0.50}}$

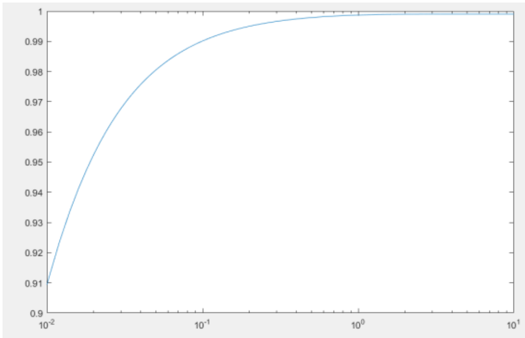
$\Rightarrow I_{pE} = 0.00138\ \text{mA} = 1.38\ \mu\text{A}$

$\delta = \dfrac{I_{nE}+I_{pE}}{I_{nE}+I_R+I_{pE}}$

$0.997238 = \dfrac{0.50+0.00138}{0.50+I_R+0.00138}$

$\Rightarrow I_R = 0.00139\ \text{mA} = 1.39\ \mu\text{A}$

9.



When X_E/L_E increaase, the gain will increase rapidly.