EE105 Spring 2001 Homework 8 solution by Xuesong Jiang

8.1 (a) $I_o = q n_i^2 A \left(\frac{D_p}{N_d W_n} + \frac{D_n}{N_a W_p} \right)$

$= 1.6 \times 10^{-19} \times 10^{20} \times (20 \times 10^{-4})^2 \times \left(\frac{5}{2 \times 10^{16} \times 10^{-4}} + \frac{5}{5 \times 10^{17} \times 0.5 \times 10^{-4}} \right)$

$= \boxed{1.728 \times 10^{-16}\ A}$

(b) $I_D = I_o \cdot (e^{V_D/V_{th}} - 1) = 1.728 \times 10^{-16} A \cdot (e^{(0.7V/0.026V)} - 1)$

$\doteq \boxed{85.13\ \mu A = 8.513 \times 10^{-5} A}$

(c). $r_d = \frac{V_{th}}{I_D} = \frac{0.026V}{8.513 \times 10^{-5} A} = \boxed{305.4\ \Omega}$

(d). $\Phi_B = \phi_n - \phi_p = 60 mV \cdot \log \frac{N_a \cdot N_d}{n_i^2} = 60 mV \cdot \log \frac{5 \times 10^{17} \times 2 \times 10^{16}}{10^{20}}$

$= 840 mV$

$C_{jo} = A \cdot \sqrt{\frac{q \varepsilon_s \cdot N_a \cdot N_d}{2 \cdot (N_a + N_d) \cdot \Phi_B}} = (20 \times 10^{-4})^2 \cdot \sqrt{\frac{1.6 \times 10^{-19} \times 11.7 \times 8.85 \times 10^{-14} \times 10^{34}}{2 \times 5.2 \times 10^{17} \times 0.84}}$

$= 0.174\ PF$

$C_j = \sqrt{2}\, C_{jo} = \boxed{0.246\ PF}$

(e). $C_d = \frac{qA}{2V_{th}} (W_p \cdot n_{po} + W_n \cdot p_{no})\, e^{V_D/V_{th}}$

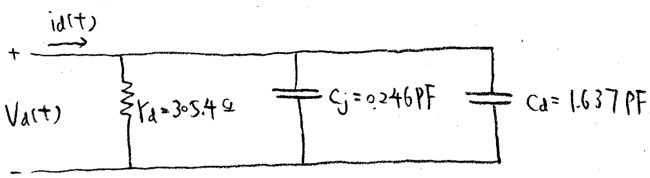
$n_{po} = n_i^2 / N_d = 10^{20} / (2 \times 10^{16}) = 5 \times 10^3\ cm^{-3}$

$p_{no} = n_i^2 / N_a = 10^{20} / (5 \times 10^{17}) = 2 \times 10^2\ cm^{-3}$

$C_d = \frac{1.6 \times 10^{-19} \times (20 \times 10^{-4})^2}{2 \times 0.026} \times (0.5 \times 10^{-4} \times 5 \times 10^3 + 10^{-4} \times 2 \times 10^2) \cdot e^{0.7/0.026}$

$= \boxed{1.637\ PF}$

(f)



8.2 $I_{D1} \doteq q \cdot n_i^2 \cdot A \left(\frac{D_{p1}}{N_{d1} \cdot W_{n1}} \right) \cdot \left(e^{V_D/V_{th}} - 1 \right)$

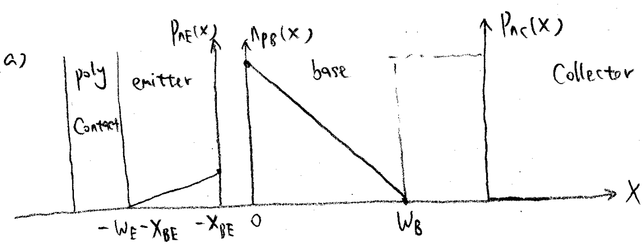
$I_{D2} \doteq q n_i^2 \cdot A \left(\frac{D_{p2}}{N_{d2} \cdot W_{n2}} \right) \cdot \left(e^{V_D/V_{th}} - 1 \right)$

Since $D_{p1} = D_{p2}$, $W_{n1} = W_{n2}$

$\therefore \frac{I_{D1}}{I_{D2}} = \frac{N_{d2}}{N_{d1}} = \frac{10^{15}}{10^{15}} = 1$

$\therefore I_{D1} = I_{D2} = \frac{1}{2}\,mA = 0.5\,mA$

8.3. (a)



(b). $\alpha_F = \frac{1}{1 + \left(\frac{D_p N_{aB} W_B}{D_n N_{aE} W_E} \right)} = \frac{1}{1 + \left(\frac{5 \times 10^{17} \times 0.5 \times 10^{-4}}{5 \times 8 \times 10^{18} \times 10^{-4}} \right)} = \boxed{0.9938}$

(C). $\beta_F = \frac{\alpha_F}{1 - \alpha_F} = \frac{D_n N_{aE} \cdot W_E}{D_p \cdot N_{aB} \cdot W_B} = \boxed{160}$

8.4 (a) Reverse active or saturation : $V_{BC} > 0.7V \Rightarrow I_B > 0$, $V_{BE} < 0V$

(b) Saturation $I_C / I_B < \beta_F$, $I_B > 0$

(C). Saturation : $I_B \cdot \beta_F \cdot 20\,k\Omega = 10V > 5V \Rightarrow I_C < I_B \cdot \beta_F$

(d) Open Circuit. $I_B = 0$