

Problem Set #7 1/9/00

1) a) In Base $n_{pB} = n_{pB}(0) \left(1 - \frac{x}{W_B}\right)$

$$I_C = -q A E D_n \frac{n_{pB}(0)}{W_B}$$

$$D_n = \mu_n \frac{kT}{q} = 14.375 \text{ cm}^2/\text{s}$$

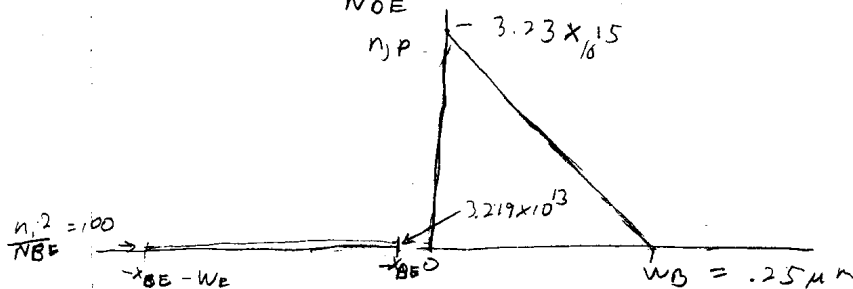
$$n_{pB}(0) = \frac{W_B I_C}{q A E D_n} = 3.2258 \times 10^{15} \text{ cm}^{-3}$$

$$p_{nE}(-x_{BE}) = p_{nE0} e^{\left(\frac{qV_{BE}}{kT}\right)} \quad p_{nE0} = \frac{n_i^2}{N_{OE}}$$

$$n_{pB}(0) = \frac{n_i^2}{N_{AB}} e^{\frac{qV_{BE}}{kT}}$$

$$V_{BE} = \frac{kT}{q} \ln \left(\frac{n_{pB}(0) N_{AB}}{n_i^2} \right) = .72 \text{ V}$$

$$p_{nE}(-x_{BE}) = \frac{n_i^2}{N_{OE}} e^{\left(\frac{qV_{BE}}{kT}\right)} = 3.2187 \times 10^{13} \text{ cm}^{-3}$$



b) $V_{BE} = .72 \text{ V}$

c) $I_B = \frac{I_C}{\beta_F}$

$$\beta_F = \frac{N_{DE} D_n W_E}{N_{AB} D_p W_B}$$

$$D_p = \mu_p \frac{kT}{q} = 1.75 \text{ cm}^2/\text{s}$$

$$\beta_F = 1328.57 \frac{A}{A}$$

$$I_B = 18.8 \text{ nA}$$

$$2 \quad V_{An} = 25 \text{ V}$$

$$a) \quad g_m = \frac{q}{kT} I_C = 1 \times 10^{-3} \text{ A/V}$$

$$b) \quad r_{\pi} = \frac{\beta_0}{g_m} = \frac{\beta_F}{g_m} = 1.329 \text{ M}\Omega$$

$$c) \quad r_o = \frac{V_{AN}}{I_C} = 1 \text{ M}\Omega$$

$$3) \quad a) \quad Q_{NB}(V_{BE}) = -\left(\frac{W_B^2}{2D_{NB}}\right) i_c = -4.03 \times 10^{-16} \text{ C}$$

$$\tau_F = \frac{W_B^2}{2D_{NB}} = \frac{(0.25 \times 10^{-4})^2}{2(19.375)} = 1.61 \times 10^{-11}$$

$$C_b = \tau_F g_m = 1.61 \times 10^{-14} \text{ F}$$

$$C_{jE0} = A_E \sqrt{\frac{q \epsilon_s N_A N_D}{2 \phi_B (N_A + N_D)}} = (2.5 \times 10^{-4})^2 \sqrt{\frac{(1.6 \times 10^{-19})(8.854 \times 10^{-14})(11.8)(10^{17})(10^{19})}{2(0.96)(1.01 \times 10^{19})}}$$

$$= 5.80 \times 10^{-15} \text{ F}$$

$$C_{je} = \frac{C_{jE0}}{\sqrt{1 - \frac{V_{BE}}{\phi_B}}} = \frac{5.8 \times 10^{-15}}{\sqrt{1 - \frac{0.72}{0.96}}} = 1.16 \times 10^{-14} \approx \sqrt{2} C_{jE0}$$

$$C_{\pi} = C_{je} + C_b = 27.7 \text{ fF}$$

$$r_{\pi} = \frac{\beta_F}{g_m} = 1.329 \text{ M}\Omega$$

$$\omega = \frac{1}{r_{\pi} C_{\pi}} = 27.2 \frac{\text{Mrads}}{s}$$

4)

$$\beta_F = \frac{I_C}{I_B} = \frac{-qAE \frac{n_i^2}{N_{AB}} \frac{D_n}{W_B}}{-qAE \frac{n_i^2}{N_{DE}} \frac{D_p}{W_E}}$$

$$\beta_F = \frac{n_i^2 N_{DE} D_n W_E}{n_i^2 N_{AB} D_p W_B}$$

$$\beta_F = 5314.29 \frac{A}{A}$$

$$b. \beta_F = \frac{n_i^2 N_{DE} D_n W_E}{n_i^2 N_{AB} D_p W_B} = \frac{N_{DE} D_n W_E}{N_{AB} D_p W_B}$$

$$\frac{N_{AB}}{D_n} = \frac{N_{DE} W_E}{D_p W_B \beta_F} \quad D_n = m_n \frac{kT}{q}$$

$$\frac{N_{AB}}{m_n} = \frac{kT}{q} \frac{N_{DE} W_E}{D_p W_B \beta_F} = 3.2258 \times 10^{13}$$

solve iteratively $N_{AB, new} < N_{AB} = 10^{17}$

choose 10^{16} $\frac{N_{AB}}{m_n} = \frac{10^{16}}{1190} = 8.4 \times 10^{12}$

choose 4×10^{16} $\frac{N_{AB}}{m_n} = \frac{4 \times 10^{16}}{950} = 4.2 \times 10^{13}$

choose 2×10^{16} $\frac{N_{AB}}{m_n} = \frac{2 \times 10^{16}}{1050} = 1.9 \times 10^{13}$

choose 3×10^{16} $\frac{N_{AB}}{m_n} = \frac{3 \times 10^{16}}{975} = 3.07 \times 10^{13}$

$$N_{AB} \approx 3 \times 10^{16}$$