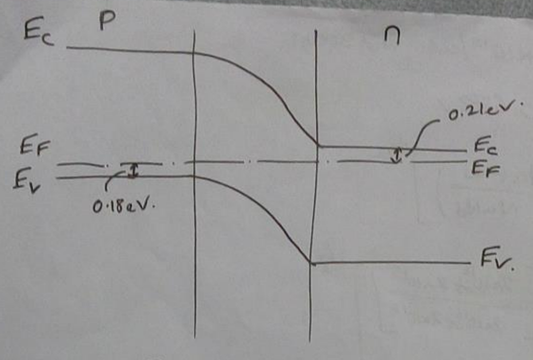
1.



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$$n_o = N_c \exp\left[-\frac{(E_c-E_F)}{KT}\right]$$

$N_c = 2.8\times10^{19}/cm^3$, $N_V = 1.04\times10^{19}/cm^3$, $KT = 26\,meV$.

$$n_o = 2.8\times10^{19}\left[\frac{-(0.21)eV}{0.026\ eV}\right]$$

$$n_o = N_d = 8.69\times10^{15}/cm^3 \quad \text{(n-region)}$$

$$p_o = N_v \exp\left[-\frac{(E_F-E_v)}{KT}\right]$$

$$= 1.04\times10^{19}\exp\left[\frac{-0.18\,eV}{0.026\,eV}\right]$$

$$p_o = N_a = 1.02\times10^{16}/cm^3 \quad \text{(p-region)}$$

$$V_{bi} = V_t \ln\left[\frac{N_a N_d}{n_i^2}\right] = 26mV\times\ln\left[\frac{1.02\times10^{16}\times8.69\times10^{15}}{2.25\times10^{20}}\right]$$

$$= 0.694V.$$

2. $N_a = 2\times10^{16}/cm^3$, $N_d = 2\times10^{15}/cm^3$, $T = 300K$

$$V_{bi} = V_t \ln\left[\frac{N_a N_d}{n_i^2}\right] = 0.673V$$

$$W = \left[\frac{2\epsilon_s(V_{bi}+V_R)}{q}\left(\frac{N_a+N_d}{N_aN_d}\right)\right]^{1/2}$$

$$= \left[\frac{2\times10^{-12}\times(V_{bi}+V_R)}{1.6\times10^{-19}}\left[\frac{2\times10^{16}+2\times10^{15}}{2\times10^{16}\times2\times10^{15}}\right]\right]^{1/2}$$

$$W = \left[6.875\times10^{-9}\,(V_{bi}+V_R)\right]^{1/2}$$

For $V_R = 0$, $W = 68.02\times10^{-6}cm$ ~~= 68.02 µm~~ $= 0.68\times10^{-4}cm$

For $V_R = 8V$, $W = 2.44\times10^{-4}cm = 244.18\times10^{-6}cm = 2.44\times10^{-4}cm$

$$E_m = \left|\frac{2(V_{bi}+V_R)}{W}\right| \rightarrow$$

For $V_R = 0$, $E_m = -19.79\times10^4\ V/cm$

For $V_R = 8V$, $E_m = -71.09\times10^3 V/cm$

3. $N_a = 5\times10^{17}/cm^3$, $N_d = 10^{17}/cm^3$, $A = 10^{-4}\ cm^2$, $V_R = 5V$.

V_{bi}, x_n, x_p, W, E_m,

$$\rightarrow V_{bi} = \frac{KT}{q}\ln\left[\frac{N_aN_d}{n_i^2}\right] = 0.858V$$

$$W = \sqrt{\frac{2\epsilon_s(V_{bi}+V_R)}{q}\left(\frac{N_a+N_d}{N_aN_d}\right)} = \sqrt{\frac{2\times10^{-12}\times(0.858+5)}{1.6\times10^{-19}}\left(\frac{5\times10^{17}+10^{17}}{5\times10^{17}\times10^{17}}\right)}$$

$W = 29.64\times10^{-6}\ cm$

$$|x_n| = \left(\frac{N_a}{N_a+N_d}\right)W = 24.7\times10^{-6}cm\ ;\quad |x_p| = \left(\frac{N_d}{N_a+N_d}\right)W = 4.94\times10^{-6}cm$$

$$E_m = -\frac{2(V_{bi}+V_R)}{W} = -3.95\times10^5\ V/cm$$

$$C_j = \frac{\epsilon_s A}{W} = \frac{(11.7)\times(8.854\times10^{-14})\times10^{-4}}{29.64\times10^{-6}} = 3.37\times10^{-12}F = 3.37pF$$

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4. $T = 300K$, $N_a = 5\times10^{15}/cm^3$, $N_d = 10^{14}/cm^3$

$$V_{bi} = V_T \ln\left[\frac{N_a N_d}{n_i^2}\right] = 0.559V$$

$$W = \left[\frac{2\epsilon_s (V_{bi})}{q}\left(\frac{N_a + N_d}{N_a N_d}\right)\right]^{1/2}$$

$$= \left[\frac{2\times10^{-12}\times 0.559}{1.6\times10^{-19}}\left[\frac{5\times10^{15}+10^{14}}{5\times10^{15}\times10^{14}}\right]\right]^{1/2} = 266.96\times10^{-6}cm$$

$$|x_n| = \left(\frac{N_a}{N_a+N_d}\right)W = 261.72\times10^{-6}cm, \quad |x_p| = \left(\frac{N_d}{N_a+N_d}\right)W = 5.23\times10^{-6}cm$$

5. pn junction diode (Si) at $T = 300K$.

In forward-bias,

$$I_f = I_s \exp\left(\frac{V_a}{K_T}\right) \quad \text{(Neglecting (-1))}$$

Then,

$$\frac{I_{f1}}{I_{f2}} = \frac{I_s \exp\left(\frac{qV_{a1}}{KT}\right)}{I_s \exp\left(\frac{qV_{a2}}{KT}\right)} = \exp\left[\frac{1}{V_T}(V_1 - V_2)\right]$$

$$V_{a_1} - V_{a_2} = (V_T)\ln\left(\frac{I_{f1}}{I_{f2}}\right)$$

a) For $\frac{I_{f1}}{I_{f2}} = 10 \Rightarrow V_{a_1} - V_{a_2} = 26\times10^{-3}\ln[10]$

$\therefore$ Change in diode vtg $(V_{a_1} - V_{a_2}) = 59.86\ mV$

6. p^+n Si diode, $T = 300K$, $N_a = 10^{18}/cm^3$, $N_d = 10^{16}/cm^3$,
$D_p = 12 cm^2/s$, $\tau_{po} = 10^{-7}s$, $A = 10^{-4}s$, $V_a = 0.5V$

Soln:

$$I_S = \frac{q D_n n_{po}}{L_n} + \frac{q D_p p_{no}}{L_p}$$

$$I_s = Aqn_i^2 \left[\cancel{\frac{1}{N_a}\sqrt{\frac{D_n}{\tau_{no}}}} + \frac{1}{N_d}\sqrt{\frac{D_p}{\tau_{po}}} \right]$$

For a p^+n J^n

$$I_s = Aqn_i^2 \left[\frac{1}{N_d}\sqrt{\frac{D_p}{\tau_{po}}} \right]$$

$$I_s = 10^{-4} \times 1.6\times10^{-19} \times 2.25\times10^{20} \left[\frac{1}{10^{16}}\sqrt{\frac{12}{10^{-7}}} \right]$$

$$I_s = 3.943 \times 10^{-15} A$$

$$I_D = I_s \exp\left(\frac{V_D}{V_T} - 1\right)$$

$$= 3.94\times10^{-15} \exp\left[\frac{0.5}{26mV} - 1\right]$$

$$I_D = 8.85\times10^{-7} A$$

7. $L_p = 0.2cm$, $L_n = 0.1cm$, $A = 10^{-2}cm^2$, $N_d = 10^{15}/cm^3$, $N_a = 10^{16}/cm^3$; $\mu_p = 480$, $\mu_n = 1350 cm^2/v\text{-}s$

a) p-region:

$$R_p = \frac{\rho_p L}{A} = \frac{L}{\sigma_p A} = \frac{L}{A(q\mu_p N_a)}$$

$$R_p = \frac{0.2}{10^{-12}(1.6\times10^{-19} \times 480 \times 10^{16})} = 26\Omega$$

b) n-region:

$$R_n = \frac{\rho_n L}{A} = \frac{L}{\sigma_n A} = \frac{L}{A(q\mu_n N_d)} = \frac{0.1}{10^{-2}(1.6\times10^{-19} \times 1350 \times 10^{15})} = 46.30\Omega$$

Total series resistance is $R = R_p + R_n = 26 + 46.3 = 72.3\Omega$

8. $V_a = 20\,mV$, $I_s = 10^{-13} A$

$$\Rightarrow \frac{1}{r_d} = \frac{dI_D}{dV_a} = I_s\left[\frac{1}{V_T}\right) \exp\left(\frac{V_a}{V_T}\right)$$

$$\frac{1}{r_d} = \frac{10^{-13}}{26\,mV} \exp\left(\frac{20\,mV}{26\,mV}\right)$$

$$\Rightarrow r_d = 1.2\times10^{11}\,\Omega$$

$$I_D = I_s \exp\left(\frac{V_a}{V_T}\right)$$

$$\frac{dI_D}{dV_a} = \frac{I_s}{V_T} \exp\left(\frac{V_a}{V_T}\right)$$

9. $$V_B = \frac{\epsilon_s E_{crit}^2}{2q N_B}$$; $E_{crit} = 4\times10^5\,V/cm$, $V_B = 30V$

$$\rightarrow N_B = \frac{\epsilon_s E_{crit}^2}{V_B\, 2q}$$

$$\therefore N_B = \frac{11.7\times8.854\times10^{-14}\times(4\times10^5)^2}{30\times2\times1.6\times10^{-19}}$$

$$\boxed{N_d = N_B = 1.73\times10^{16}/cm^3}$$

10. Find cut-off freq^n of a BJT, for $\tau_{ec} = \tau_D = 104\times10^{-12}\,sec$, $\beta = 100$ & Beta cut-off freq?

$$f_T = \frac{1}{2\pi\,\tau_D} = 1.53\,GHz$$

$$f_\beta = \frac{f_T}{\beta} = 15.3\,MHz.$$

11] $P_{E0} = \frac{n_i^2}{N_E} = 4.5\times10^2/cm^3$; $n_B(0) = n_{B0}\exp\left(\frac{V_{BE}}{V_T}\right)$

$n_{B0} = \frac{n_i^2}{N_B} = 2.25\times10^4/cm^3$ $= 2.25\times10^4 \exp\left(\frac{0.625}{26mV}\right)$

$P_{C0} = \frac{n_i^2}{N_C} = 2.25\times10^5/cm^3$ $= 6.2\times10^{14}/cm^3$

12] $I_{nE} = 1.2mA$, $I_{pE} = 0.1mA$ $I_G = 0.001mA$

$I_{nC} = 1.18mA$, $I_R = 0.2mA$ $I_{pco} = 0.001mA$

Find a) α b) γ c) $b(\alpha_T)$ d) δ & β.

$\rightarrow \gamma = \frac{I_{nE}}{I_{nE}+I_{pE}} = 0.923$

$\rightarrow b$ or $\alpha_T = \frac{I_{nC}}{I_{nE}} = 0.983$

$\rightarrow \delta = \frac{I_{nE}+I_{pE}}{I_{nE}+I_R+I_{pE}} = 0.867$

$\rightarrow \alpha = \gamma b \delta = 0.7867$

$\rightarrow \beta = \frac{\alpha}{1-\alpha} = 3.68$

13) $W_B = 0.5\mu m = 0.5\times10^{-4}cm$, $D_B = 20cm^2/s$

$\tau_b = 0.2\ \tau_0$ or (τ_{ec})

$\tau_b = \frac{W_B^2}{2D_B} = 6.25\times10^{-11}sec$

$\tau_b = 0.2\tau_{ec} \Rightarrow \tau_{ec} = 3.125\times10^{-10}sec$

$f_T = \frac{1}{2\pi\tau_{ec}} = 509\ mHz$