EECS-130

Integrated Circuit Devices

Midterm Exam #2, part one Solutions

(35% total point weighting)

March 14, 1996

1.

a.
$$Q_p = \int_{x_n}^{\infty} q\, p'(x)dx = \int_{x_n}^{\infty} q\, p_{no}(e^{\frac{qV}{kt}} - 1)(e^{\frac{-(x-x_n)}{Lp}})dx$$
$$Q_p = q\frac{n_i^2}{N_d}(e^{\frac{qV_A}{kt}} - 1)L_p$$
$$Q_n = \int_{-x_p}^{\infty} qn'(x)dx = \int_{-x_p}^{\infty} qn_{po}(e^{\frac{qV}{kt}} - 1)(e^{\frac{x+x_p}{L_n}})dx$$
$$Q_n = q\frac{n_i^2}{N_a}(e^{\frac{qV_A}{kt}} - 1)L_n$$

b.
$$J_n = \frac{Q_n}{\tau_n} \qquad J_p = \frac{Q_p}{\tau_p}$$
$$J_n = \frac{qn_i^2}{\tau_n N_d}(e^{\frac{qV_A}{kt}} - 1)L_n \qquad J_p = \frac{qn_i^2}{\tau_p N_d}(e^{\frac{qV_A}{kt}} - 1)L_p$$
$$J_{total} = J_n + j_p = \frac{Q_n}{\tau_n} + \frac{Q_p}{\tau_p}$$

c. The current supplied by forward biasing the p_n is that needed to replenish minority charge being lost due to recombination.

d. $J_{total} \propto n_i^2 \quad \rightarrow \quad J_{total} \propto T^3$

$L_p \propto T^{\frac{1}{2}} \quad D_p \propto T^{\frac{1}{2}}$

Current increases as temperature increases

2.

a.
$$I_{op} = qAD_p\frac{P_{no}}{L_p} = qA \cdot \frac{D_p}{\sqrt{D_p \tau_p}} \cdot \frac{n_i^2}{N_D} = 8.76 \times 10^{-15} A$$

b.
$$I_{on} = qAD_N\frac{n_{pi}}{L_N} = qA \cdot \frac{D_N}{\sqrt{D_N \tau_N}} \cdot \frac{n_i^2}{N_A} = 5.9 \times 10^{-15} A$$

c. $I_o = I_{on} + I_{op} = 14.66 \times 10^{-15} A$

d.

i.

$$V_a = \frac{1}{2} \cdot \frac{kt}{q} \ln(\frac{N_D N_A}{n_i^2}) = .3204\,V$$

$$P_n'(x_n) = P_{no}(e^{\frac{qV_A}{kt}} - 1) = n_i^2 / N_D (e^{qV_A/kt} - 1) = 2.24 \times 10^{10}\,cm^{-3} \quad (injected)$$

$$p_n(x_n) = p_{no} + p_n'(x_n) \approx p_n'(x_n) = 2.24 \times 10^{10}\,cm^{-3}$$

ii.

iii.

iv.

$$n_p(\frac{L_n}{2}) = n_{po} + n_{po}(e^{\frac{qV_A}{kt}} - 1)e^{\frac{-x_n''}{L_n}}$$

$$n_p(\frac{L_n}{2}) = 2.72 \times 10^9\,cm^{-3}$$

e.

$$Q_p = QA\int_0^\infty p_n'(x')\,dx' = qA\int_0^\infty p_{no}(e^{qV_A/kt} - 1)e^{\frac{-x'}{L_p}}\,dx'$$

$$Q_p = qAp_o'(x_n)L_p$$

$$V_A = .3203\,V\; Q_p = 7.98 \times 10^{-16}\,C$$