

7.17 Consider the pn junction described in Problem 7.10 for $T = 300$ K. The cross-sectional area of the junction is $2 \times 10^{-4} \text{ cm}^2$ and the applied reverse-biased voltage is $V_R = 2.5$ V. Calculate (a) V_{bi} , (b) x_n, x_p, W , (c) $|E_{\max}|$, and (d) the junction capacitance.

7.10 Consider a uniformly doped silicon pn junction with doping concentrations $N_a = 2 \times 10^{17} \text{ cm}^{-3}$ and $N_d = 4 \times 10^{16} \text{ cm}^{-3}$.

From Table B.4, $\epsilon_r = 11.7$, $n_i = 1.5 \times 10^{10} \text{ cm}^{-3} = 1.5 \times 10^{16} \text{ m}^{-3}$ for silicon at 300 K.

a) Per (7.10), the built-in voltage is $V_{bi} = \frac{k_B T}{e} \ln\left(\frac{N_a N_d}{n_i^2}\right) = V_t \ln\left(\frac{N_a N_d}{n_i^2}\right)$.

At 300 K, the thermal voltage $V_t = \frac{k_B T}{e} = \frac{8.617333 \times 10^{-5} \text{ eV/K} (300 \text{ K})}{e} = 0.025852 \text{ V}$.

Here, $V_{bi} = 0.025852 \ln\left(\frac{2 \times 10^{17} (4 \times 10^{16})}{(1.5 \times 10^{10})^2}\right) \Rightarrow \underline{V_{bi} = 0.806637 \text{ V}}$.

b) Replace V_{bi} w/ $V_{\text{tot}} = V_{bi} + V_R = 0.806637 + 2.5 = 3.306637 \text{ V}$ in equations. Per (7.28),

$$x_n = \left\{ \frac{2\epsilon_s V_{\text{tot}}}{e} \left(\frac{N_a}{N_d} \right) \frac{1}{N_a + N_d} \right\}^{1/2} = \left\{ \frac{2(11.7)8.854 \times 10^{-12} (3.30664)}{1.602176634 \times 10^{-19}} \left(\frac{20}{4} \right) \frac{1}{2 \times 10^{23} + 4 \times 10^{22}} \right\}^{1/2}$$

$\Rightarrow \underline{x_n = 2.984694 \times 10^{-7} \text{ m} = 298.469 \text{ nm}}$.

Per (7.29),

$$x_p = \left\{ \frac{2\epsilon_s V_{\text{tot}}}{e} \left(\frac{N_d}{N_a} \right) \frac{1}{N_a + N_d} \right\}^{1/2} = \left\{ \frac{2(11.7)8.854 \times 10^{-12} (3.30664)}{1.602176634 \times 10^{-19}} \left(\frac{4}{20} \right) \frac{1}{2 \times 10^{23} + 4 \times 10^{22}} \right\}^{1/2}$$

$\Rightarrow \underline{x_p = 5.969387 \times 10^{-8} \text{ m} = 59.694 \text{ nm}}$.

Per (7.30), $W = x_n + x_p = 298.469 + 59.694 \Rightarrow \underline{W = 3.58163 \times 10^{-7} \text{ m} = 358.163 \text{ nm}}$.

c) Per (7.37),

$$|E_{\max}| = \left| \frac{-2(V_{bi} + V_R)}{W} \right| = \frac{2(3.306637)}{3.581632 \times 10^{-7}} \Rightarrow \underline{|E_{\max}| = 1.84644 \times 10^7 \text{ V/m} = 18.4644 \text{ MV/m}}$$

d) Per (7.43), $C' = \frac{\epsilon_s}{W} = \frac{11.7(8.8541878 \times 10^{-12})}{3.581632 \times 10^{-7}} = 2.89237 \times 10^{-4} \text{ F/m}^2$.

$C = C' A = 2.89237 \times 10^{-4} \text{ F/m}^2 (2 \times 10^{-8} \text{ m}^2) \Rightarrow \underline{C = 5.78474 \times 10^{-11} \text{ F} = 5.7847 \text{ pF}}$.