

7.8 (a) Consider a uniformly doped silicon pn junction at $T = 300$ K. At zero bias, a **third** of the total space charge region is in the n-region. The built-in potential barrier is $V_{bi} = 0.710$ V. Determine (i) N_a , (ii) N_d , (iii) x_n , (iv) x_p , and (v) $|E_{max}|$.

a) From Table B.4, $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$ @ 300K
 $\epsilon_r = 11.7$

Per (7.30), $W = x_n + x_p$

Given: $x_n = \frac{1}{3}W = \frac{1}{3}(x_n + x_p)$
 $\hookrightarrow (1 - \frac{1}{3})x_n = \frac{1}{3}x_p \Rightarrow \frac{x_p}{x_n} = 2$

Per (7.17) $N_a x_p = N_d x_n \Rightarrow \frac{x_p}{x_n} = \frac{N_d}{N_a} = 2$

(i) Per (7.10), $V_{bi} = \frac{k_B T}{e} \ln\left(\frac{N_a N_d}{n_i^2}\right) = V_t \ln\left(\frac{N_a N_d}{n_i^2}\right)$

$$V_t = \frac{8.617333 \times 10^{-5} \text{ eV/K} (300\text{K})}{e} = 0.025852 \text{ V}$$

$$V_{bi} = 0.710 \text{ V} = (0.025852 \text{ V}) \ln\left(\frac{N_a (2N_a)}{n_i^2}\right)$$

$$N_a = \left\{ \frac{n_i^2}{2} e^{0.71/0.025852} \right\}^{1/2}$$

$$= \left\{ \frac{(1.5 \times 10^{10})^2}{2} e^{0.71/0.025852} \right\}^{1/2}$$

$$\underline{\underline{N_a = 9.7569 \times 10^{15} \text{ cm}^{-3}}}$$

(ii) $\underline{\underline{N_d = 2N_a = 1.9514 \times 10^{16} \text{ cm}^{-3}}}$

$$(iii) \quad x_n = \left\{ \frac{2\epsilon_s V_{bi}}{e} \left[\frac{N_a}{N_d} \right] \left[\frac{1}{N_a + N_d} \right] \right\}^{1/2} \quad (7.28)$$

$$= \left\{ \frac{2(11.7)8.8542 \times 10^{-12} (0.71) \left(\frac{1}{2} \right)}{1.602176634 \times 10^{-19}} \frac{1}{9.7569 \times 10^{21} + 1.9514 \times 10^{22}} \right\}^{1/2}$$

$$\underline{\underline{x_n = 1.4863 \times 10^{-7} \text{ m} = 148.63 \text{ nm}}}$$

$$(iv) \quad x_p = 2x_n = 2(1.4863 \times 10^{-7})$$

$$\underline{\underline{x_p = 2.9725 \times 10^{-7} \text{ m} = 297.25 \text{ nm}}}$$

$$\text{Bonus: } w = x_n + x_p = 445.9 \text{ nm}$$

$$(v) \quad \text{Per (7.14), } |E_{\max}| = \left| -\frac{eN_a}{\epsilon_s} x_p \right|$$

$$|E_{\max}| = \left| \frac{1.602176634 \times 10^{-19} (9.7569 \times 10^{21})}{(11.7)8.8541878 \times 10^{-12}} 2.9725 \times 10^{-7} \right|$$

$$\underline{\underline{|E_{\max}| = 4.414 \times 10^6 \text{ V/m} = 4.414 \frac{\text{MV}}{\text{m}}}}$$