For a uniformly doped ($N_a = 6 \times 10^{15}$ cm^{-3} on the p-side and $N_d = 4 \times 10^{16}$ cm^{-3} on the n-side) silicon pn junction at 300 K with cross-sectional area 30×10^{-9} m^2, calculate x_n, x_p, W, $|E_{max}|$, C', and C when: a) $V_R = 0$ and b) $V_R = 1.8$ V.

Table B.4, $\epsilon_r = 11.7$ & $n_i = 1.5 \times 10^{10}$ #/cm^3 $= 1.5 \times 10^{16}$ m^{-3} @ 300K

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

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

$V_{bi} = 0.025852 \ln\left(\frac{6 \times 10^{15}(4 \times 10^{16})}{(1.5 \times 10^{10})^2}\right) = 0.71599\ V$

a) $V_R = 0$

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

$= \left\{\frac{2(11.7)8.8542 \times 10^{-12}(0.716)}{1.6021766 \times 10^{-19}}\left(\frac{6}{40}\right)\frac{1}{6 \times 10^{21} + 4 \times 10^{22}}\right\}^{1/2}$

$x_n = 5.49472 \times 10^{-8}\ m = 54.947\ nm$

(7.29) $x_p = \left\{\frac{2\epsilon_s V_{bi}}{e}\left(\frac{N_d}{N_a}\right)\frac{1}{N_a + N_d}\right\}^{1/2}$

$= \left\{\frac{2(11.7)8.8542 \times 10^{-12}(0.716)}{1.6021766 \times 10^{-19}}\left(\frac{40}{6}\right)\frac{1}{6 \times 10^{21} + 4 \times 10^{22}}\right\}^{1/2}$

$x_p = 3.66315 \times 10^{-7}\ m = 366.315\ nm$

(7.30) $W = x_n + x_p = 5.4947 \times 10^{-8} + 3.66315 \times 10^{-7}$

$W = 421.262\ nm$

a) cont.

(7.37) $E_{max} = \frac{-2(V_{bi}+V_R)}{W} = \frac{-2(0.71599)}{4.21262\times10^{-7}}$

$|E_{max}| = 3.39924\times10^{6}\ V/m = 3.399\ \frac{MV}{m}$

(7.43) $C' = \epsilon_s/W = \frac{11.7(8.8542\times10^{-12})}{4.21262\times10^{-7}} = 2.45913\times10^{-4}\ F/m^2$

$C = C'A = 2.459\times10^{-4}(30\times10^{-9}) = 7.3774\ pF$

b) $V_R = 1.8V \Rightarrow$ Replace V_{bi} w/ $V_{tot} = 0.71599 + 1.8 = 2.51599V$ in prior eq'ns to scale answers

$x_n = 5.49472\times10^{-8}\left\{\frac{2.516}{0.716}\right\}^{1/2}$

$x_n = 1.03003\times10^{-7}m = 103.003\ nm$

$x_p = 3.66315\times10^{-7}\left(\frac{2.516}{0.716}\right)^{1/2}$

$x_p = 6.86684\times10^{-7}m = 686.684\ nm$

$W = 103.003 + 686.684 \Rightarrow W = 789.686\ nm$

$|E_{max}| = \frac{2(2.516)}{789.686\times10^{-9}} \Rightarrow |E_{max}| = 6.372\ MV/m$

$C' = \frac{\epsilon_s}{W} = \frac{11.7(8.8542\times10^{-12})}{789.686\times10^{-9}} \Rightarrow C' = 1.3118\times10^{-4}\ F/m^2$

$C = C'A = 1.3118\times10^{-4}(30\times10^{-9}) \Rightarrow C = 3.9355\ pF$