For a uniformly doped ($N_a = 4 \times 10^{16}$ cm^{-3} on p-side and $N_d = 6 \times 10^{15}$ cm^{-3} on n-side) GaAs pn junction at 300 K with cross-sectional area 40×10^{-9} m^2, calculate x_n, x_p, W, $|E_{\max}|$, C', and C when: a) $V_R = 0$ and b) $V_R = 2.4$ V.

Table B.4 – $\epsilon_r = 13.1$ and $n_i = 1.8 \times 10^6 \text{ cm}^{-3} = 1.8 \times 10^{12} \text{ m}^{-3}$

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

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

$$V_{bi} = 0.025852 \ln\left(\frac{4 \times 10^{16} (6 \times 10^{15})}{(1.8 \times 10^6)^2}\right) = 1.18277 \text{ V}$$

a) $V_R = 0$

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

$$= \left\{\frac{2(13.1) 8.8542 \times 10^{-12} (1.183)}{1.602176634 \times 10^{-19}}\left(\frac{40}{6}\right)\frac{1}{4 \times 10^{22} + 6 \times 10^{21}}\right\}^{1/2}$$

$$x_n = 4.98191 \times 10^{-7} \text{ m} = 498.191 \text{ nm}$$

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

$$= \left\{\frac{2(13.1) 8.8542 \times 10^{-12} (1.18277)}{1.602176634 \times 10^{-19}}\left(\frac{6}{40}\right)\frac{1}{4.6 \times 10^{22}}\right\}^{1/2}$$

$$x_p = 7.47286 \times 10^{-8} \text{ m} = 74.7286 \text{ nm}$$

(7.30) $W = x_n + x_a = 4.98191 \times 10^{-7} + 7.47286 \times 10^{-8}$

$$W = 5.7292 \times 10^{-7} \text{ m} = 572.92 \text{ nm}$$

a) cont. (7.37) $E_{max} = -\frac{2(V_{bi} + \cancel{V_R})}{W}$

$$|E_{max}| = \frac{2(1.18277)}{5.7292 \times 10^{-7}} = 4.1289 \times 10^{6}\ V/m$$

(7.43) $C' = \frac{\epsilon_s}{W} = \frac{13.1(8.8542 \times 10^{-12})}{5.7292 \times 10^{-7}} = 2.02454 \times 10^{-4}\ F/m^2$

$$C = C'A = 2.02454 \times 10^{-4}(40 \times 10^{-9}) = 8.09817 \times 10^{-12}\ F$$

b) $V_R = 2.4\,V \Rightarrow$ replace V_{bi} w/ $V_{tot} = V_{bi} + V_R = 3.58277\,V$ in prior equations

$x_n = 4.98191 \times 10^{-7}\left(\frac{3.58277}{1.18277}\right)^{1/2}$ ← scale part a) answer

$$x_n = 8.67071 \times 10^{-7}\,m = 867.071\,nm$$

$x_p = 7.47286 \times 10^{-8}\left(\frac{3.58277}{1.18277}\right)^{1/2}$

$$x_p = 1.30061 \times 10^{-7}\,m = 130.061\,nm$$

$W = 8.67071 \times 10^{-7} + 1.30061 \times 10^{-7}$

$$W = 9.97132 \times 10^{-7}\,m = 997.132\,nm$$

$$|E_{max}| = \frac{2(3.58277)}{9.97132 \times 10^{-7}} = 7.18615 \times 10^{6}\ V/m$$

$$C' = \frac{13.1(8.8542 \times 10^{-12})}{9.97132 \times 10^{-7}} = 1.16323 \times 10^{-4}\ F/m^2$$

$$C = C'A = 1.16323 \times 10^{-4}(40 \times 10^{-9}) = 4.65294 \times 10^{-12}\ F$$