EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 6 (Spring 2026)

Name __**KEY A**__

Instructions: Open book/notes. Place answers in indicated spaces and **show all** work for credit. Carry *at least* **6** significant figures on constants/parameters in calculations. Give answers with **3-4** significant figures.

At 400 K, a semiconductor has an intrinsic carrier concentration 6×10^{11} #/cm^3 and a relative permittivity of 11.5. Determine the thermal and built-in voltages for a pn junction in this semiconductor when the acceptor concentration is 7×10^{17} #/cm^3 and the donor concentration is 6×10^{16} #/cm^3. With no bias voltage applied, find the width of the depletion layer (m), magnitude of the maximum electric field (V/m), and the junction capacitance (assume cross-sectional area of pn junction is 56×10^{-9} m^2).

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 400 K, the thermal voltage $V_t = \frac{k_B T}{e} = \frac{8.617333 \times 10^{-5}\,\text{eV/K}\,(400\,\text{K})}{e}$

$\Rightarrow$ $\underline{\boldsymbol{V_t = 0.034469\ \text{V}}}$.

Here, $V_{bi} = 0.034469 \ln\left(\frac{6\times10^{16}(7\times10^{17})}{(6\times10^{11})^2}\right)$ $\Rightarrow$ $\underline{\boldsymbol{V_{bi} = 0.878368\ \text{V}}}$.

Per (7.31),

$$W = \left\{\frac{2\varepsilon_s V_{bi}}{e}\left(\frac{N_a + N_d}{N_a N_d}\right)\right\}^{1/2} = \left\{\frac{2(11.5)8.8542\times10^{-12}(0.878368)}{1.602176634\times10^{-19}}\left(\frac{7\times10^{23}+6\times10^{22}}{7\times10^{23}(6\times10^{22})}\right)\right\}^{1/2}$$

$\Rightarrow$ $\underline{\boldsymbol{W = 1.42136 \times 10^{-7}\ \text{m} = 142.136\ \text{nm}}}$.

Per (7.37),

$$|E_{\max}| = \left|\frac{-2(V_{bi}+V_R)}{W}\right| = \frac{2(0.878368+0)}{1.42136\times10^{-7}}$$

$\Rightarrow$ $\underline{\boldsymbol{|E_{\max}| = 1.23596 \times 10^{7}\ \text{V/m} = 12.36\ \text{MV/m}}}$.

Per (7.43), $C' = \frac{\varepsilon_s}{W} = \frac{11.5(8.8541878\times10^{-12})}{1.42136\times10^{-7}}$ $\Rightarrow$ $\boldsymbol{C' = 7.16379 \times 10^{-4}\ \text{F/m}^2}$.

$C = C'A = 7.16379 \times 10^{-4}\ \text{F/m}^2\,(56 \times 10^{-9}\ \text{m}^2)$ $\Rightarrow$ $\underline{\boldsymbol{C = 4.01173 \times 10^{-11}\ \text{F} = 40.117\ \text{pF}}}$.

V_t = **0.034469 V** V_{bi} = **0.878368 V** W = **142.136 nm**

$|E_{\max}|$ = **12.36 MV/m** C = **40.117 pF**

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Name _KEY B_

Instructions: Open book/notes. Place answers in indicated spaces and **show all** work for credit. Carry *at least* **6** significant figures on constants/parameters in calculations. Give answers with **3-4** significant figures.

At 200 K, a semiconductor has an intrinsic carrier concentration 3×10^9 #/cm^3 and a relative permittivity of 12.2. Determine the thermal and built-in voltages for a pn junction in this semiconductor when the acceptor concentration is 3×10^{16} #/cm^3 and the donor concentration is 4×10^{17} #/cm^3. With no bias voltage applied, find the width of the depletion layer (m), magnitude of the maximum electric field (V/m), and the junction capacitance (assume cross-sectional area of pn junction is 65×10^{-9} m^2).

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 200 K, the thermal voltage $V_t = \frac{k_B T}{e} = \frac{8.617333\times10^{-5}\,\text{eV/K}\,(200\,\text{K})}{e}$

$\Rightarrow$ **$V_t = 0.017235$ V**.

Here, $V_{bi} = 0.017235\ln\left(\frac{3\times10^{16}(4\times10^{17})}{(3\times10^{9})^2}\right)$ $\Rightarrow$ **$V_{bi} = 0.600222$ V**.

Per (7.31),

$$W = \left\{\frac{2\varepsilon_s V_{bi}}{e}\left(\frac{N_a+N_d}{N_a N_d}\right)\right\}^{1/2} = \left\{\frac{2(12.2)8.8542\times10^{-12}(0.600222)}{1.602176634\times10^{-19}}\left(\frac{3\times10^{22}+4\times10^{23}}{3\times10^{22}(4\times10^{23})}\right)\right\}^{1/2}$$

$\Rightarrow$ **$W = 1.702997 \times 10^{-7}$ m = 170.30 nm**.

Per (7.37),

$$|E_{max}| = \left|\frac{-2(V_{bi}+V_R)}{W}\right| = \frac{2(0.600222+0)}{1.702997\times10^{-7}}$$ $\Rightarrow$ **$|E_{max}| = 70.4901 \times 10^6$ V/m = 7.049 MV/m**.

Per (7.43), $C' = \frac{\varepsilon_s}{W} = \frac{12.2(8.8541878\times10^{-12})}{1.702997\times10^{-7}}$ $\Rightarrow$ **$C' = 6.3430 \times 10^{-4}$ F/m^2**.

$C = C'A = 6.343 \times 10^{-4}$ F/m^2 $(65 \times 10^{-9}$ m$^2)$ $\Rightarrow$ **$C = 4.12295 \times 10^{-11}$ F = 41.23 pF**.

V_t = **0.017235 V** V_{bi} = **0.60022 V** W = **170.30 nm**

$|E_{max}|$ = **7.049 MV/m** C = **41.23 pF**