10.2 (*a*) Calculate the maximum space charge width x_{dT} and the maximum space charge density $|Q'_{SD}(\max)|$ in a MOS capacitor with a p-type silicon substrate at ~~$T = 300$ K~~ for doping concentrations of (*i*) $N_a = 7 \times 10^{15}$ cm^{-3} and (*ii*) $N_a = 3 \times 10^{16}$ cm^{-3}. (*b*) Repeat part (*a*) for $T = 350$ K.

➢ Also, find V_t and ϕ_{fp}. Let $n_i = 5 \times 10^{11}$ cm^{-3} at 350 K, other properties same.

b)

$$\text{Per (7.10)},\ V_t = \frac{8.617333 \bullet 10^{-7}\ \text{eV/K}\,(350\,\text{K})}{e} \quad \Rightarrow \quad \underline{\mathbf{V_t = 0.0301607\ V}}$$

(i) $N_a = 7 \times 10^{15}\ \text{cm}^{-3} = 7 \times 10^{21}\ \text{m}^{-3}$

$$\text{Per (10.4)},\ \phi_{fp} = V_t \ln\left(\frac{N_a}{n_i}\right) = 0.0301607 \ln\left(\frac{7\times10^{15}}{5\times10^{11}}\right) \quad \Rightarrow \quad \underline{\boldsymbol{\phi_{fp} = 0.287938\ \text{V}}}$$

$$\text{Per (10.6)},\ x_{dT} = \sqrt{\frac{4\varepsilon_s \phi_{fp}}{e\,N_a}} = \sqrt{\frac{4(11.7)8.8541878\times10^{-12}\,(0.287938)}{1.602176634\times10^{-19}\,(7\times10^{21})}}$$

$$\Rightarrow \quad \underline{\boldsymbol{x_{dT} = 326.169\ \text{nm}}}$$

$$\text{Per (10.27)},\ |Q'_{SD}(\max)| = e\,N_a\,x_{dT} = 1.602176634 \times 10^{-19}\,(7 \times 10^{21})\ 326.169 \times 10^{-9}$$

$$\Rightarrow \quad \underline{\boldsymbol{|Q'_{SD}(\max)| = 3.65806 \times 10^{-4}\ \text{C/m}^2 = 3.65806 \times 10^{-8}\ \text{C/cm}^2}}$$

(ii) $N_a = 3 \times 10^{16}\ \text{cm}^{-3} = 3 \times 10^{22}\ \text{m}^{-3}$

$$\text{Per (10.4)},\ \phi_{fp} = V_t \ln\left(\frac{N_a}{n_i}\right) = 0.0301607 \ln\left(\frac{3\times10^{16}}{5\times10^{11}}\right) \quad \Rightarrow \quad \underline{\boldsymbol{\phi_{fp} = 0.331831\ \text{V}}}$$

$$\text{Per (10.6)},\ x_{dT} = \sqrt{\frac{4\varepsilon_s \phi_{fp}}{e\,N_a}} = \sqrt{\frac{4(11.7)8.8541878\times10^{-12}\,(0.331831)}{1.602176634\times10^{-19}\,(3\times10^{22})}}$$

$$\Rightarrow \quad \underline{\boldsymbol{x_{dT} = 169.137\ \text{nm}}}$$

$$\text{Per (10.27)},\ |Q'_{SD}(\max)| = e\,N_a\,x_{dT} = 1.602176634 \times 10^{-19}\,(3 \times 10^{22})\ 169.137 \times 10^{-9}$$

$$\Rightarrow \quad \underline{\boldsymbol{|Q'_{SD}(\max)| = 8.12964 \times 10^{-4}\ \text{C/m}^2 = 8.12964 \times 10^{-8}\ \text{C/cm}^2}}$$