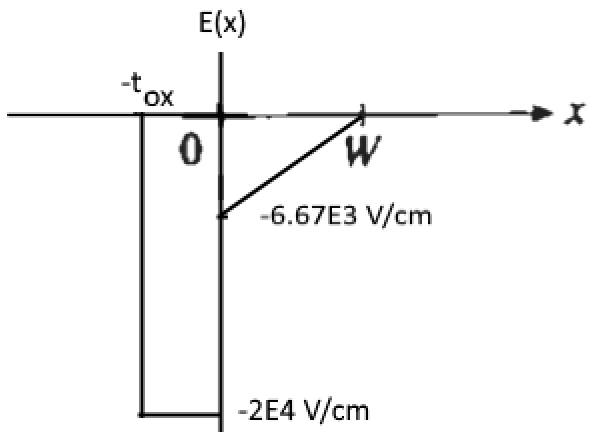
ECE 305 – Spring 2018

Homework 9 Solution

1.

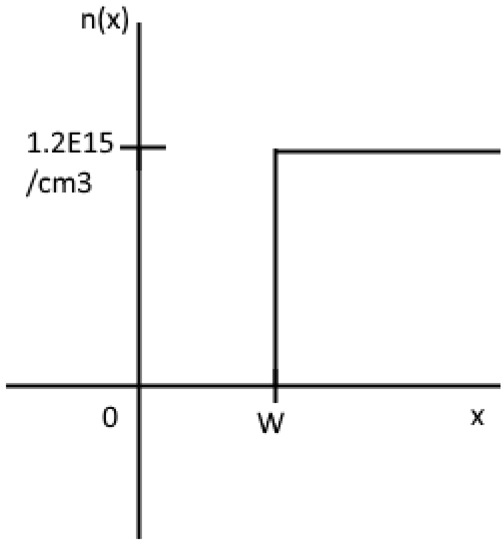


E(0+)=K_{ox}/K_{Si}×E(0-)=4/12× $-2 \times 10^4 = -6.67 \times 10^3\ V/cm$

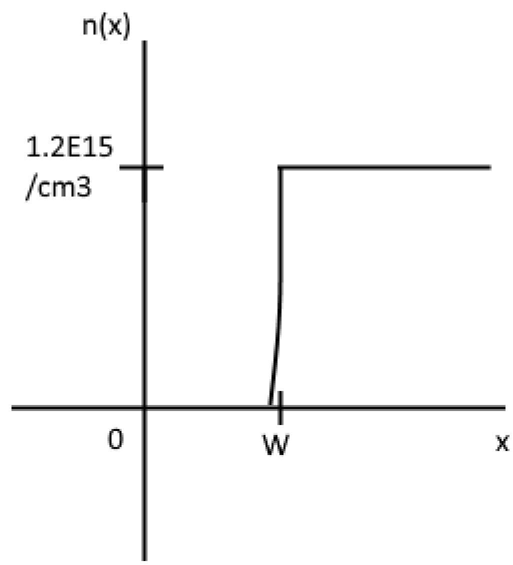
b.

n_i=1.1× $10^{10} cm^{-3}$

n at x=W: n= $n_i\, e^{(E_F-E_i)/kT}$ =$n_i\, e^{0.29\times 40} = 1.2 \times 10^{15} cm^{-3}$



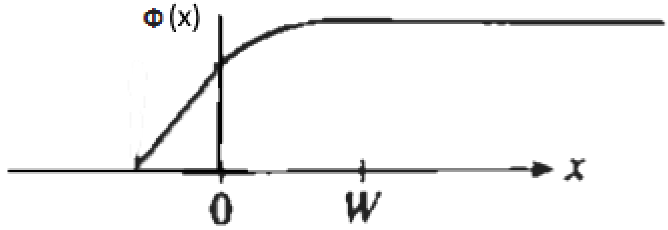
or



c.

n $at\ W \approx N_D \approx 1.2 \times 10^{15} cm^{-3}$

d.



Φ_S= change in potential from bulk to surface=(E_{FS}-E_i)/q=0.29 V (As E_i=E_{FS} at x=0)
Or,

$E_S = \sqrt{\frac{2qN_D\varphi_S}{K_S\varepsilon_0}}$ where $E_S = 6.67 \times 10^3\ V, N_D \approx 1.2 \times 10^{15} cm^{-3}$

Φ_S=0.12 V

e.

Voltage drop across oxide= $2 \times 10^4\ V/cm \times 2 \times 10^{-5}\ cm = 0.4\ V$

f.

$V_G' = -(0.29 + 0.4) = -0.69\ V$

Or

$V_G' = -(0.12 + 0.4) = -0.52\ V$

2.

a. $W = \sqrt{\frac{2K_{si}\varepsilon_0}{qN_A}\phi_s}$

$\Rightarrow \phi_s = \frac{qN_A}{2K_{si}\varepsilon_0} W^2$

$V_a' = \phi_s + \frac{K_{si}}{K_{ox}} t_{ox} \sqrt{\frac{2qN_A}{K_{si}\varepsilon_0}\phi_s}$

$\Rightarrow 0 = \frac{qN_A}{2K_{si}\varepsilon_0} W^2 + \frac{K_{si}}{K_{ox}} t_{ox} \frac{qN_A}{K_{si}\varepsilon_0} W - V_a'$

This is a quadratic equation:

$aW^2 + bW + c = 0$

$W = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$$= \frac{-\frac{qN_A t_{ox}}{K_{ox}\varepsilon_0} \pm \sqrt{\frac{q^2 N_A^2 t_{ox}^2}{K_{ox}^2 \varepsilon_0^2} - 4\,\frac{qN_A}{2K_{si}\varepsilon_0} \cdots V_a}}{2 \cdot \frac{qN_A}{2K_{si}\varepsilon_0}}$$

$$= \frac{-\frac{qN_A t_{ox}}{K_{ox}\varepsilon_0} \pm \sqrt{\frac{q^2 N_A^2 t_{ox}^2}{K_{ox}^2 \varepsilon_0^2} + \frac{2qN_A}{K_{si}\varepsilon_0} V_a'}}{\frac{qN_A}{K_{si}\varepsilon_0}}$$

$$= -\frac{K_{si}}{K_{ox}} t_{ox} \pm \sqrt{\frac{K_{si}^2}{K_{ox}^2} t_{ox}^2 + \frac{2K_{si}\varepsilon_0}{qN_A} V_a'}$$

$$W \geq 0$$

$$\therefore W = -\frac{K_{si}}{K_{ox}} t_{ox} + \sqrt{\frac{K_{si}^2}{K_{ox}} t_{ox}^2 + \frac{2K_{si}\varepsilon_0}{qN_A} V_a'}$$

$$= \frac{K_{si}}{K_{ox}} t_{ox} \left(-1 + \sqrt{1 + \frac{V_a'}{\left(\frac{qN_A K_{si} t_{ox}^2}{2K_{ox}^2 \varepsilon_0}\right)}}\right)$$

$$= \frac{K_{si}}{K_{ox}} t_{ox} \left(-1 + \sqrt{1 + \frac{V_a'}{V_\delta}}\right)$$

where $V_\delta = \frac{qN_A K_{si} t_{ox}^2}{2K_{ox}^2 \varepsilon_0}$

b.

$$V'_T = 2\phi_f + \Delta\phi_{ox}$$

$$where\ 2\phi_f = \frac{2kT}{q}\ln(\frac{N_A}{n_i})$$

$$= 0.6\ V$$

$$\Delta\phi_{ox} = \mathcal{E}_{ox}t_{ox}$$

$$\mathcal{E}_{ox} = \frac{K_{Si}}{K_{ox}}\mathcal{E}_{Si}$$

$$\mathcal{E}_{si} = \sqrt{\frac{2qN_A 2\phi_f}{K_s\epsilon_o}}$$

Therefore,

$V'_T = 2\phi_f + \frac{K_{Si}}{K_{ox}}\sqrt{\frac{2qN_A 2\phi_f}{K_s\epsilon_o}}t_{ox}$=0.6+1.8=2.4 V

From equation derived in a., depletion width at $V'_G = 0\ is\ 0$

Depletion width at $V'_G = V'_T\ is$: $\sqrt{\frac{2K_s\epsilon_o 2\phi_f}{qN_A}} = 2 \times 10^{-5}cm$

For capacitance:

$$C = \frac{C_0}{\sqrt{1 + V'_G/V'_\delta}}$$

Capacitance at $V'_G = 0$ is C_0.

Capacitance at $V'_G = V'_T$ is 0.47 C_0 , as $V'_\delta = 0.678$.