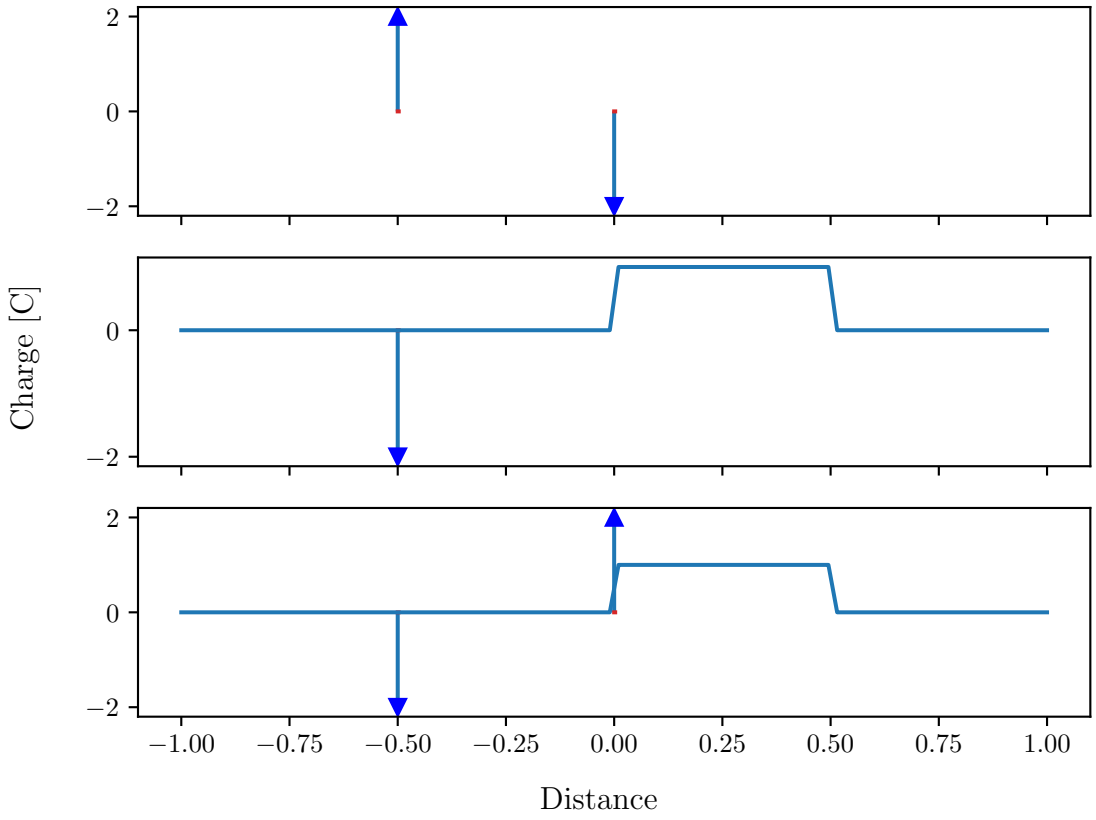
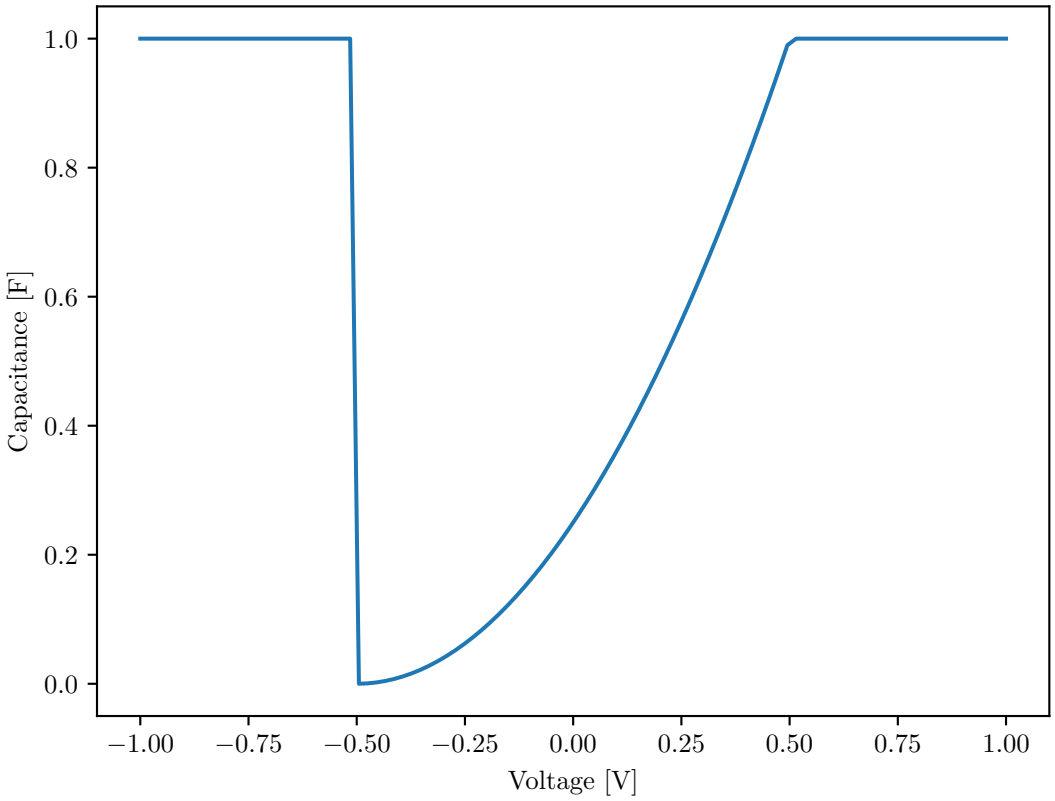
EE 105 HW 08

1


2
0
−2
0
−2
2
0
−2
Charge [C]
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
Distance



2

$$T = 300\,\mathrm{K} \tag{1}$$
$$\phi_M = 4.5\,\mathrm{eV} \tag{2}$$
$$\epsilon_{\mathrm{Si}} = 11.7\epsilon_0 \tag{3}$$
$$\chi = 4.05\,\mathrm{eV} \tag{4}$$
$$E_g = 1.12\,\mathrm{eV} \tag{5}$$
$$n_i = 1 \times 10^{10}\,\mathrm{cm}^{-3} \tag{6}$$
$$N_a = 1 \times 10^{16}\,\mathrm{cm}^{-3} \tag{7}$$
$$\epsilon_{\mathrm{ox}} = 3.9\epsilon_0 \tag{8}$$
$$t_{\mathrm{ox}} = 5\,\mathrm{nm} \tag{9}$$
$$\tag{10}$$

(a)

$$\phi_{\mathrm{Si}} = \chi + \frac{kT}{q}\ln\left(\frac{N_a}{n_i}\right) + \frac{E_g}{2} = 4.967\,\mathrm{eV} \tag{11}$$
$$V_{fb} = \frac{\phi_M - \phi_{\mathrm{Si}}}{q} = -0.467\,\mathrm{V} \tag{12}$$

(b)

$$V_t = V_{fb} + \gamma\sqrt{2|\phi_p|} - 2|\phi_p| \tag{13}$$

$$= V_{fb} + \frac{t_{\text{ox}}}{\epsilon_{\text{ox}}}\sqrt{2\epsilon_s q N_a}\sqrt{2\frac{kT}{q}\ln\left(\frac{N_a}{N_i}\right)} + 2\frac{kT}{q}\ln\left(\frac{N_a}{N_i}\right) \tag{14}$$

$$= 0.318\,\text{V} \tag{15}$$

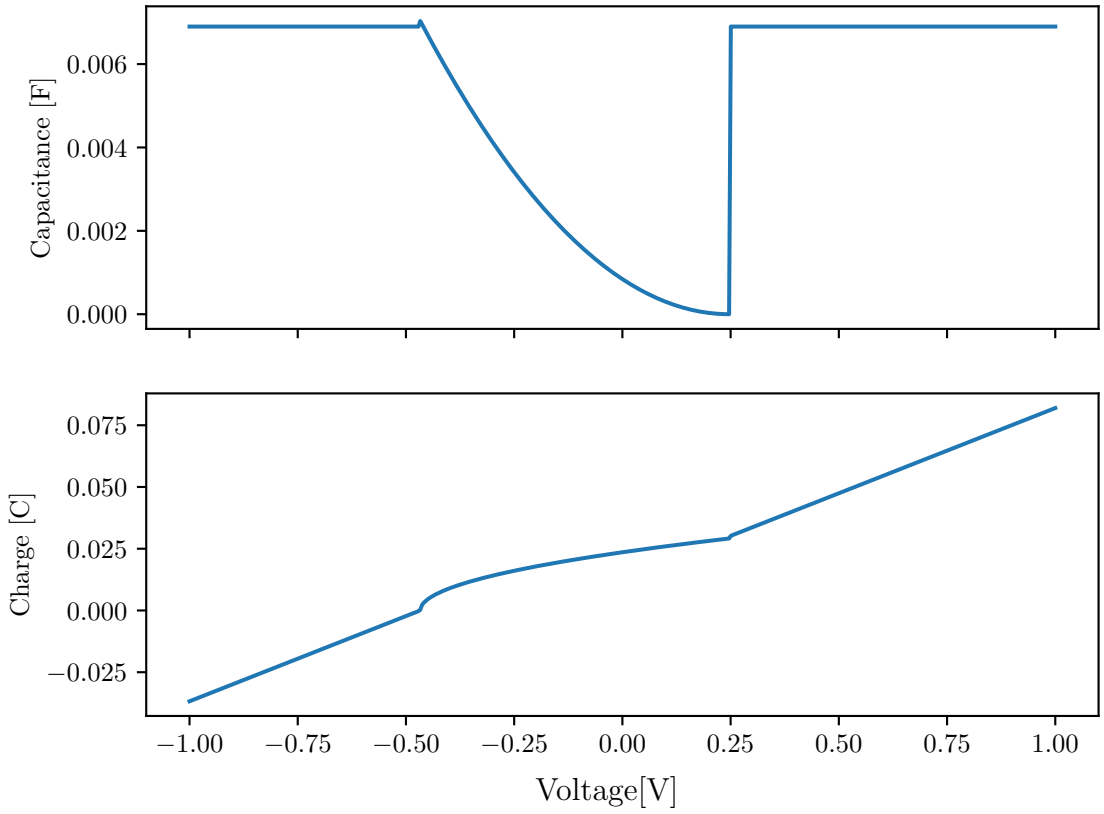
(c)

$$C_{\text{acc}} = C_{\text{ox}} = \frac{\epsilon_{\text{ox}}}{t_{\text{ox}}} = 6.91\,\text{mF m}^{-2} \tag{16}$$

(d)

$$C_{\text{inv}} = C_{\text{ox}} = \frac{\epsilon_{\text{ox}}}{t_{\text{ox}}} = 6.91\,\text{mF m}^{-2} \tag{17}$$

(e)



3

$$W = 50\,\mu\text{m} \tag{18}$$
$$L = 1\,\mu\text{m} \tag{19}$$
$$T_{\text{ox}} = 10\,\text{nm} \tag{20}$$
$$\epsilon_{\text{ox}} = 4\epsilon_0 \tag{21}$$
$$\epsilon_{\text{Si}} = 12\epsilon_0 \tag{22}$$
$$N_a = 1 \times 10^{15}\,\text{cm}^{-3} \tag{23}$$
$$n_i = 1 \times 10^{10}\,\text{cm}^{-3} \tag{24}$$
$$V_{fb} = 0\,\text{V} \tag{25}$$
$$\mu_n = 800\,\text{cm}^2\,\text{V}^{-1}\,\text{s}^{-1} = 0.08\,\text{m}^2\,\text{V}^{-1}\,\text{s}^{-1} \tag{26}$$
$$T = 300\,\text{K} \tag{27}$$

(a)

$$V_T = \frac{T_{\text{ox}}}{\epsilon_{\text{ox}}}\sqrt{2\epsilon_s q N_a}\sqrt{2\frac{kT}{q}\ln\left(\frac{N_a}{N_i}\right)} + 2\frac{kT}{q}\ln\left(\frac{N_a}{N_i}\right) = 0.635\,\text{V} \tag{28}$$

(b) Since $V_{GS} > V_T$ and $V_{DS} < V_{GS} - V_T$, the MOSFET is in linear/triode mode,

$$I_{DS} = \frac{W}{L}\mu_n C_{ox}\left(V_{GS} - V_T - \frac{V_{DS}}{2}\right) = 12.25\,\text{mA} \tag{29}$$

(c)

$$Q_{N,S} = C_{\text{ox}}(V_{GS} - V_T - \cancelto{0}{V(0)}) = 4.83\,\text{mC}\,\text{m}^{-2} \tag{30}$$
$$Q_{N,D} = C_{\text{ox}}(V_{GS} - V_T - \cancelto{V_{DS}}{V(0)}) = 1.29\,\text{mC}\,\text{m}^{-2} \tag{31}$$
$$\tag{32}$$

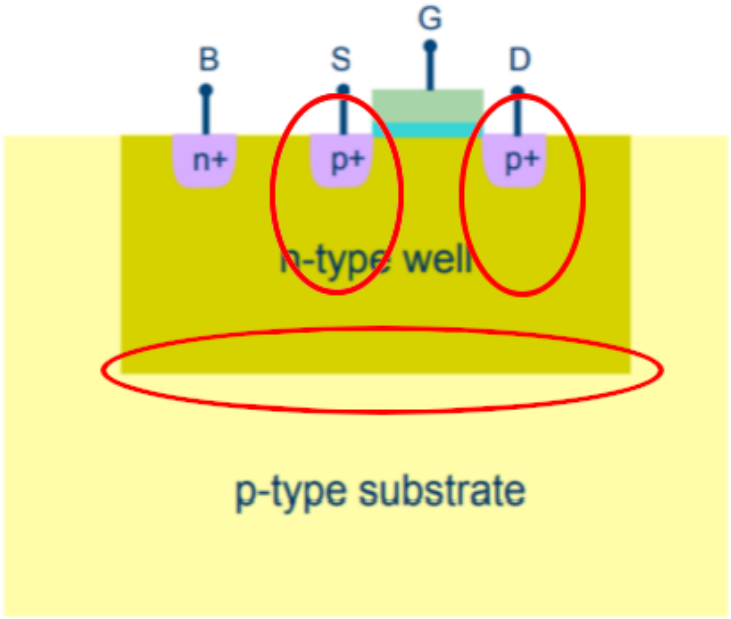
(d) Since $V_{GS} > V_T$ and $V_{DS} > V_{GS} - V_T$, the MOSFET is in saturation mode,

$$I_{DS} = \frac{W}{L}\frac{\mu_n C_{ox}}{2}(V_{GS} - V_T)^2(1 + \cancelto{0}{\lambda V_{DS}}) = 13.19\,\text{mA} \tag{33}$$

4

(a)

Transistor	Mode
i	Linear/Triode
ii	Saturation
iii	Linear/Triode
iv	Linear/Triode
v	Saturation
vi	Cutoff



(b)