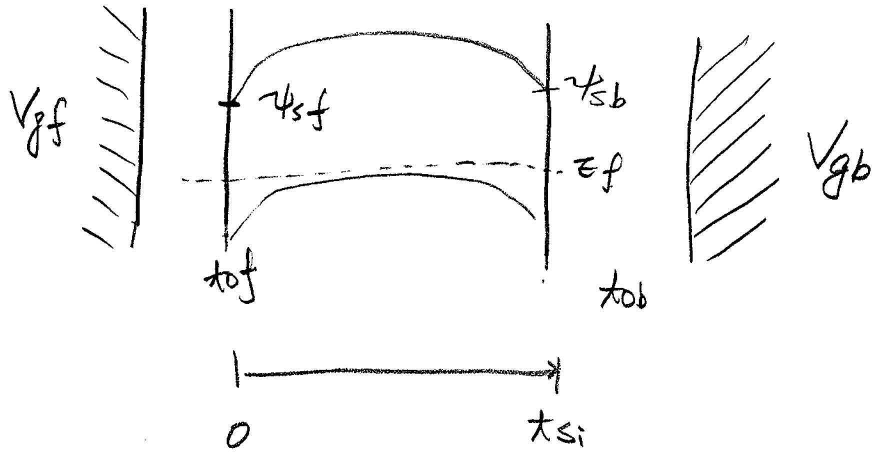
EE 612. HW # 11.

1)	10
2)	20
3)	20
4)	20
5)	10
6)	20
	100.

1)



$$C_{of} = \frac{\varepsilon_{ox}}{t_{of}} \qquad C_{ob} = \frac{\varepsilon_{ox}}{t_{ob}}$$

$$-\frac{d^2\psi}{dx^2} = \frac{dE}{dx} = -q\frac{N_A}{\epsilon_{si}}$$

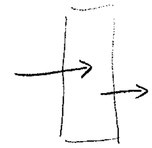
$$\int_{E(0^+)}^{E(t_{si})} dE = -q\frac{N_A}{\epsilon_{si}}\int_0^{t_{si}} dx.$$

$$E(t_{si}) - E(0^+) = -q\frac{N_A}{\epsilon_{si}} t_{si} \qquad -(1)$$

$$\psi_{sf} - \psi_{sb} = \frac{1}{2} q \frac{N_A}{\epsilon_{si}} t_{si}^2 \qquad -(2)$$

$$= -\frac{t_{si}}{2}\left(E(0^+) - E(t_{si})\right)$$

$$E_{of} = \frac{V_{Gf} - \psi_{sf}}{t_{of}}$$



$$V_{Gf} = \psi_{sf} + t_{of} \cdot E_{of}$$

$$\because \varepsilon_{ox} E_{of} = \epsilon_{si} E(0^+) - Q_{nf}$$

$$\therefore V_{Gf} = \psi_{sf} + t_{of} \cdot \frac{1}{\varepsilon_{ox}} (\epsilon_{si} E(0^+) - Q_{nf})$$

$$= \psi_{sf} + \frac{1}{C_{of}} (\epsilon_{si} E(0^+) - Q_{nf})$$

From (1) and (2)

$$E(0^+) = E(t_{si}) + \frac{q N_A}{\epsilon_{si}} t_{si}$$

$$= \frac{2}{t_{si}} (\psi_{sf} - \psi_{sb}) + E(0^+) + \frac{q N_A t_{si}}{\epsilon_{si}}$$

$$E(0^+) = \frac{1}{t_{si}} (\psi_{sf} - \psi_{sb}) + \frac{q N_A t_{si}}{2 \epsilon_{si}}$$

$$\Rightarrow V_{Gf} = \psi_{sf} + \frac{1}{C_{of}} [\epsilon_{si} \cdot \frac{1}{t_{si}} (\psi_{sf} - \psi_{sb}) - \frac{Q_B}{2} - Q_{nf})$$

$$= \psi_{sf} - \frac{1}{C_{of}} [0.5 Q_B + Q_{nf}] + \frac{C_{si}}{C_{of}} (\psi_{si} - \psi_{sb})$$

Similarly

$$V_{gb} = \psi_{sb} - \frac{(0.5\,Q_B + Q_{nb})}{C_{ob}} + \frac{C_{si}}{C_{ob}}(\psi_{sb} - \psi_{sf})$$

2.)

$$C_{of} = C_{ob} \qquad V_{gf} = V_{gb}$$

$$S \equiv 2.3\frac{k_B T}{q}\left(\frac{\partial V_{gf}}{\partial \psi_{sf}}\right)$$

For idea double gate

$$\psi_{sf} = \psi_{sb}.$$

$$V_{gf}' = \psi_{sf} - \frac{0.5\,Q_B + Q_{nf}}{C_{of}}$$

$$\Rightarrow \quad S = 2.3\,\frac{k_B T}{q}$$

3) $V_{gf} = V_{gb} \quad C_{of} \neq C_{ob}$

① $$V_{gf} = \psi_{sf} - \frac{0.5Q_B + Q_{nf}}{C_{of}} + \frac{C_{si}}{C_{of}}(\psi_{sf} - \psi_{sb})$$

$\parallel$

② $$V_{gb} = \psi_{sb} - \frac{0.5Q_B + Q_{nb}}{C_{of}} + \frac{C_{si}}{C_{ob}}(\psi_{sb} - \psi_{sf})$$

$\parallel$

V_g

$$[V_g \cdot C_{ob} + C_{si}\psi_{sf} + \text{Const}A] = (C_{ob} + C_{si})\psi_{sb}$$

$$\Rightarrow \psi_{sb} = \frac{C_{ob}V_g + C_{si}\psi_{sf} + \text{Const}A}{(C_{ob} + C_{si})}$$

$\Rightarrow$ ①'

$$C_{of}V_{gf} = C_{of}\psi_{sf} - \text{Const}B + C_{si}\psi_{sf} - \frac{C_{si}C_{ob}V_g + C_{si}^2\psi_{sf} + \text{Const}A''}{C_{ob} + C_{si}}$$

$$C_{of}(C_{ob} + C_{si})V_{gf} + C_{si}C_{ob}V_g = (C_{of} + C_{si})(C_{ob} + C_{si})\psi_{sf} - C_{si}^2\psi_{sf} + \text{Const}C$$

$$(C_{of}C_{ob} + C_{si}\cancel{C_{of}} + C_{si}C_{ob})V_{gf} = (C_{of}C_{ob} \cancel{+ C_{si}C_{ob}} + C_{of}C_{si})\psi_{sf} + \text{Const}$$

$$V_{gf} = \psi_{sf} + \text{Const}$$

$$\frac{\partial V_{gf}}{\partial \psi_{sf}} = 1.$$

$$\Rightarrow S = 2.3 \frac{k_B T}{q} \#.$$

4) V_{gb}' is const.

$$\frac{\partial V_{gb}'}{\partial \psi_{sf}} = 0 = \frac{\partial \psi_{sb}}{\partial \psi_{sf}} + \frac{C_{si}}{C_{ob}}\left(\frac{\psi_{sb}}{\partial \psi_{sf}} - 1\right)$$

$$\frac{C_{si}}{C_{ob}} = \left(\frac{C_{si}+C_{ob}}{C_{ob}}\right)\frac{\partial \psi_{sb}}{\partial \psi_{sf}}$$

$$\frac{\partial V_{gf}}{\partial \psi_{sf}} = 1 + \frac{C_{si}}{C_{of}}\left(1 - \frac{C_{si}}{C_{si}+C_{ob}}\right)$$

$$= 1 + \frac{C_{si}}{C_{of}}\left(\frac{C_{ob}}{C_{si}+C_{ob}}\right)$$

$$S = 2.3\, k_B T/q \left[1 + \frac{C_{si}}{C_{of}} \cdot \frac{C_{ob}}{C_{si}+C_{ob}}\right]$$ #

5.) Symmetry DG MOSFET

$\Rightarrow \psi_{sb} = \psi_{sf} \quad V_{FB,f} = V_{FB,B} \quad Q_{nf} = Q_{nB}$

$\Rightarrow (1) + (2)$

$$2V_{gf} = 2V_{FB,f} + 2\psi_{sb} - \frac{Q_B + 2Q_{nf}}{C_{ob}}$$

$\psi_{sb} = 2\psi_{B,f}$ (inversion)

$$Q_{nf} = -C_{ox}(V_g - V_T)$$

$$V_T = V_{FB} + 2\psi_{B,f} - \frac{0.5 Q_B}{C_{ob}}$$

$$Q_n = Q_{nf} + Q_{nB} = -2 \cdot C_{ox}(V_g - V_T)$$

6) assume $\psi_{S,b} \approx 0$. $Q_{nb} \approx 0$.

$\Rightarrow$ (1) + (2)

$$2V_g = \psi_{sf} - \frac{Q_B + Q_{nf}}{C_{of}} + V_{FB,f} + V_{FB,B}.$$

$$\Rightarrow \frac{Q_{nf}}{C_{of}} = -2V_g + (V_{FB,f} + V_{FB,B}) + 2\psi_B - \frac{Q_B}{C_{of}}$$

$$V_{FB,f} = -\frac{E_g}{2} - \psi_B$$

$$V_{FB,B} = \frac{E_g}{2} - \psi_B.$$

$$Q_{nf} = -2C_{ox}\left(V_g - \left(\underbrace{\frac{Q_B}{2 \cdot C_{of}}}_{V_T}\right)\right)$$

$$\therefore Q_{nf} = -2C_{ox}(V_g - V_T)$$