

prob) 2.9.

• using shockley model

$$I_D = \begin{cases} 0 & V_{GS} < V_{TH} \\ \mu_n C_{ox} \frac{W}{L} \cdot (V_{GS} - V_{TH}) V_{DS} - \frac{1}{2} V_{DS}^2 & V_{DS} < V_{GS} - V_{TH} \\ \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2 & V_{DS} > V_{GS} - V_{TH} \end{cases}$$

$$\mu_n = 350 \text{ cm}^2/\text{V}\cdot\text{s}$$

$$\kappa_{ox} \cdot \epsilon_0 = (3.9) \cdot (8.85) \cdot 10^{-14} \text{ F/cm}$$

$$L_{ox} = 100 \cdot 10^{-8} \text{ cm}$$

$$\text{let } \mu_n C_{ox} \frac{W}{L} = \beta = 350 \cdot \text{cm}^2/\text{V}\cdot\text{s} \cdot \frac{(3.9) \cdot 8.85 \cdot 10^{-14} \text{ (F/cm)}}{100 \cdot 10^{-8} \text{ cm}} \cdot 2$$

$$= 2.416 \cdot 10^{-4} \text{ (A/V}^2\text{)}$$

• graph plotted in another file.

# DI HW 3.

prob) 2.2.2

the shockley model, let's assume  $\mu n C_{ox} \frac{W}{L} = \beta$ ,  $V_{gs} - V_{th} = V_{over}$ .

$$I_D = \begin{cases} 0 & V_{DS} < V_{over} \\ \beta (V_{over} V_{DS} - \frac{1}{2} V_{DS}^2) & V_{DS} < V_{over} \\ \frac{1}{2} \beta (V_{over})^2 & V_{DS} > V_{over} \end{cases}$$

for this problem, we assume the linear region

where  $V_{gs} > V_{th}$ ,  $V_{DS} \ll V_{over}$ ,

hence, for a

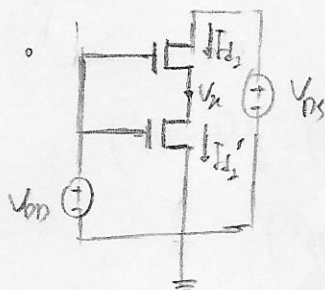
$$V_{gs} - V_{th} = V_{DD} - V_{th} = V_{over}$$

$$I_D = \beta \cdot \frac{1}{2} \cdot (V_{over} \cdot V_{DS} - \frac{1}{2} V_{DS}^2)$$

$$I_D \approx \beta \cdot \frac{1}{2} (V_{over} \cdot V_{DS})$$

$$(\because V_{DS} \ll V_{gs} - V_{th})$$

for b)



$$\text{by KCL} \quad -I_{D2} + I_{D2}' = 0$$

$$I_{D2} = \beta \cdot (V_{over} \cdot (V_{DS} - V_{th}) - \frac{1}{2} (V_{DS} - V_{th})^2)$$

$$I_{D2}' = \beta \cdot (V_{over} \cdot V_{th} - \frac{1}{2} V_{th}^2)$$

$$\text{hence, } \beta (V_{over} (V_{DS} - V_{th}) - \frac{1}{2} (V_{DS} - V_{th})^2) = \beta (V_{over} V_{th} - \frac{1}{2} V_{th}^2)$$

$$\begin{aligned} V_{over} (V_{DS} - 2V_{th}) &= \frac{1}{2} \cdot (V_{DS} - V_{th} - V_{th}) (V_{DS}) \\ &= \frac{1}{2} (V_{DS} - 2V_{th}) V_{DS} \end{aligned}$$

$$\text{hence, } (V_{over} - \frac{1}{2} V_{DS}) \cdot (V_{DS} - 2V_{th}) = 0$$

$$\therefore \boxed{V_{th} = \frac{1}{2} V_{DS}}$$

$$I_{D2} = \beta (V_{over} \cdot \frac{1}{2} V_{DS} - \frac{1}{2} \cdot (\frac{1}{4} V_{DS}^2))$$

$$I_{D2} \approx \beta (V_{over} \cdot \frac{1}{2} V_{DS}) \quad (\because V_{DS} - V_{th} \gg V_{DS})$$

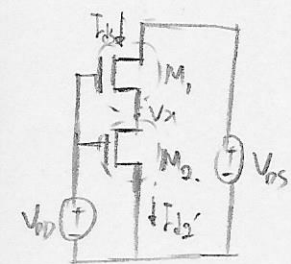
$$I_{D2} \approx \frac{1}{2} \beta (V_{over}) \cdot V_{DS}$$

finally,  $I_{D1} \approx I_{D2}$

prob 2.3)

by the body effect

$$V_T = V_{T0} + \gamma (\sqrt{\phi_s + V_{sb}} - \sqrt{\phi_s})$$



(considering previous prob. 2.2,

the threshold voltage of  $M_1$  will be increased. ( $V_{th1} = V_{th} + \delta$ )

but still, the circuit obeys KCL

$$\text{hence, } -I_{d2} + I_{d2'} = 0$$

$$\text{also, } I_{d2} = \beta (V_{over} - \delta)(V_{os} - V_{x1}) - \frac{1}{2} (V_{os} - V_{x1})^2$$

$$I_{d2'} = \beta ((V_{over}) V_{x1} - \frac{1}{2} V_{x1}^2)$$

( $\because$  body effect affect the  $V_{th}$  of  $M_1$ , as  $V_{th} + \delta$ )

but,  $M_2$ 's source voltage is gnd. as body.

$$\text{So } I_{d2} = I_{d2'} \rightarrow V_{over}(V_{os} - V_{x1}) - \delta(V_{os} - V_{x1}) - \frac{1}{2} (V_{os} - V_{x1})^2 = V_{over}(V_{x1}) - \frac{1}{2} V_{x1}^2$$

$$V_{over}(V_{os} - 2V_{x1}) - \delta(V_{os} - V_{x1}) = \frac{1}{2} (V_{os}) \cdot (V_{os} - 2V_{x1})$$

$$-\delta(V_{os} - V_{x1}) = (\frac{1}{2} V_{os} - V_{over})(V_{os} - 2V_{x1})$$

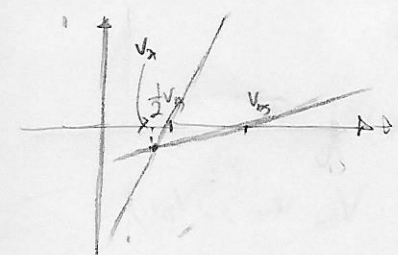
$$-\delta(V_{x1} - V_{os}) = (2V_{over} - V_{os})(V_{x1} - \frac{1}{2} V_{os})$$

we assumed linear region hence,  $V_{over} \gg V_{os}$ , therefore,  $2V_{over} - V_{os} > 0$ ,  $\delta > 0$

finally, we can know that new  $V_{x1} < \frac{1}{2} V_{os}$

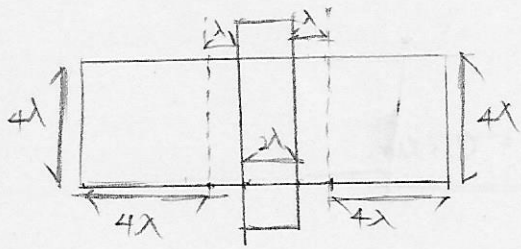
it means that  $I_{d2'}$  is smaller than previous prob 2.2

by KCL, we can know that the  $I_{ns2}$  will be smaller than  $I_{ns1}$ .



prob) 2.4

assume MOSFET,



for 90nm process,  $\lambda = 45 \text{ nm}$

and the capacitance of gate  $C_g = k_{ox} \cdot \frac{\epsilon_0}{t_{ox}} \cdot WL$

hence,  $C_{\text{per micron}} = k_{ox} \cdot \frac{\epsilon_{ox}}{t_{ox}} \cdot L$

$$= 3.9 \cdot \frac{8.85 \cdot 10^{-12} \text{ F/m}}{16 \cdot 10^{-10} \text{ m}} \cdot 90 \cdot 10^{-9} \text{ m}$$

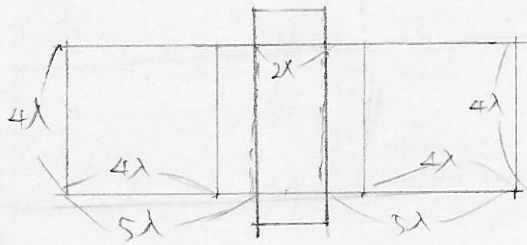
$$= 3.9 \cdot (8.85) \cdot \frac{90 \cdot 10^{-9}}{16 \cdot 10^{-10}} \cdot 10^{-12} \cdot \left[ \frac{10^6 \text{ fF}}{10^6 \mu\text{m}} \right]$$

$$= 3.9 \cdot (8.85) \cdot \frac{90 \cdot 10^{-9}}{16 \cdot 10^{-10}} \cdot 10^{-12} \cdot 10^6 \text{ fF}/\mu\text{m}$$

$$= 1.941 \text{ fF}/\mu\text{m}$$



Prob) 2.5.



for 0.6 μm process,  $\lambda = 0.3 \mu m$

for diffusion capacitance

$$C_{db} = A S \cdot C_{jbs} + P S \cdot C_{jbsw} (*)$$

$$\begin{cases} \cdot C_{jbs} = C_j \cdot \left(1 + \frac{V_{db}}{\phi_0}\right)^{-M_j} \\ \cdot \phi_0 = V_t \ln \frac{N_A N_D}{n_i^2} \end{cases} \quad \begin{cases} \cdot C_{jbsw} = C_{jsw} \left(1 + \frac{V_{db}}{\phi_{sw}}\right)^{-M_{jsw}} \\ \cdot C_{jbswg} = C_{jsw} \left(1 + \frac{V_{db}}{\phi_{swg}}\right)^{-M_{jswg}} \end{cases}$$

- $C_j = 0.42 \text{ fF}/\mu m^2$ ,  $M_j = 0.44$
- $C_{jsw} = 0.33 \text{ fF}/\mu m$ ,  $M_{jsw} = 0.12$
- $\phi_0 = 0.98 \text{ V}$  at room temp.

• since no constant are defined for  $C_{jbswg}$ , we'll use (\*) equation, and define  $V_{db}$  as  $x$  ( $x$  will be 0 or 5V)

$$\begin{aligned} \text{hence, } C_{db} &= 20\lambda^2 \cdot 0.42 \text{ fF}/\mu m^2 \cdot \left(1 + \frac{x}{0.98}\right)^{-0.44} \\ &\quad + 18\lambda \cdot 0.33 \text{ fF}/\mu m \cdot \left(1 + \frac{x}{0.98}\right)^{-0.12} \\ &= 20 \cdot (0.3 \mu m)^2 \cdot 0.42 \text{ fF}/\mu m^2 \cdot \left(1 + \frac{x}{0.98}\right)^{-0.44} \\ &\quad + 18 \cdot (0.3 \mu m) \cdot 0.33 \text{ fF}/\mu m \cdot \left(1 + \frac{x}{0.98}\right)^{-0.12} \\ &= \end{aligned}$$

$$\text{hence, } C_{db}(V_d = 0V) = 2.538 \text{ fF}$$

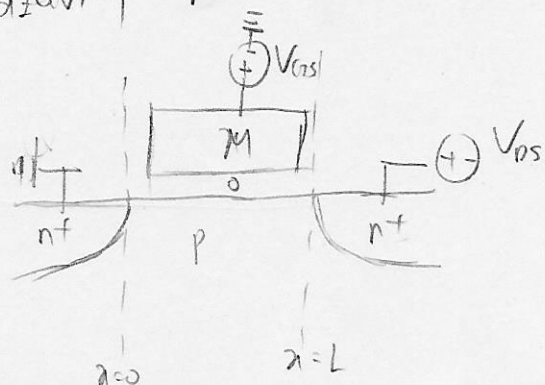
$$C_{db}(V_d = 5V) = 1.775 \text{ fF}$$

prob) 대문자 2.

•  $V_g = 1.8V$ ,  $V_t = 0.4$  •  $L = 180nm$  이.

NMOS 이 대문자,

Razavi 의 microelectronics 2 에 대하여,



channel 의 양의 이온이 이온이 대문자

$e^-$  의 양도, Q(n) 이 대문자

•  $Q(n) = W C_{ox} (V_{GS} - V_{th} - V(x))$

• drain current  $I_D$  이

$I_D = Q \cdot v$  이 대문자

• 이 때  $v = -\mu_n \cdot E$  이 대문자

voltage 이 대문자  $v = +\mu_n \cdot \frac{dV}{dx}$  이 대문자

•  $I_D = W C_{ox} (V_{GS} - V_{th} - V(x)) \cdot \mu_n \cdot \frac{dV}{dx}$  이 대문자

$I_D$  이 대문자 이 대문자 이 대문자

이 대문자,  $\frac{I_D}{\mu_n C_{ox} W} = (V_{GS} - V_{th} - V(x)) \cdot \frac{dV}{dx}$  이 대문자,  $\frac{I_D}{\mu_n C_{ox} W} = k$  이 대문자

then,  $k = (1.4 - V) \cdot V'$   
differential equation 이 대문자

$h x + C_0 = (1.4 - V) \cdot V + \int V dV$

$h x + C_0 = 1.4V - \frac{1}{2} V^2$

$V^2 - 2.8V + (2hx + 2C_0) = 0$

hence,  $V = 1.4 \pm \sqrt{(1.4)^2 - 2hx - 2C_0}$

boundary condition  $V(0) = 0V$  이 대문자

이 대문자  $V_{DS}$  이 대문자,

$V = 1.4 - \sqrt{(1.4)^2 - 2hx}$  이 대문자

(\*)

(\*) 이 대문자 이 대문자

0 부터 1.4V 까지  $V_{DS}$  이 대문자

graph 이 대문자

graph plotted in another file