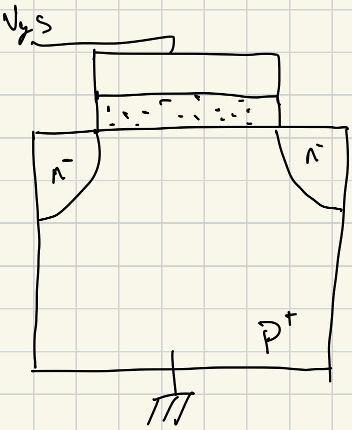
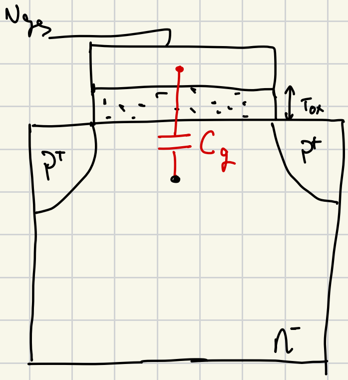
ECE 3150
Homework 2

1. With the knowledge that $\mu_p = 0.4\mu_n$, what must be the relative width of the n-channel and p-channel MOS devices if they are to have equal drain currents when operated in the saturation mode with overdrive and drain-to-source voltages of the same magnitude. Also assume that the device lengths and oxide capacitances are equal.





The width of the n channel MOSFET must be $\frac{4}{10}$ the width of the P-channel MOS device if they are to have same ID @ saturation

When in saturation

$$I_{Dsat} = \frac{\beta V_{gt}^2}{2} \Rightarrow \beta = \frac{\varepsilon_{ox}\,\mu}{t_{ox}}\left(\frac{W}{L}\right)$$

for both in overdrive voltage

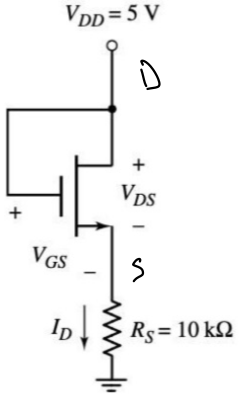
The oxide capacitances are equal

$$\Rightarrow \beta_{nmos} = \beta_{pmos} \Rightarrow \frac{\cancel{\varepsilon_{ox}}}{\cancel{t_{ox}}}\mu_n\left(W/\cancel{L}\right) = \frac{\cancel{\varepsilon_{ox}}}{\cancel{t_{ox}}}\mu_p\left(W_p/\cancel{L}\right)$$

$$\cancel{\mu_n}(W_n) = .4\cancel{\mu_n}W_p$$

$$W_n = .4W_p$$

2. Consider the MOS device shown in the picture below.
    a) Consider that $V_{GS} > V_T$ of the transistor. In which region of operation is the MOSFET operating?
    b) Given transistor parameters $V_T = 0.8V$ and β=0.1mA/V^2, find out V_{GS} and I_D.



$V_{gs} > V_t$

$V_{gs} - V_D$

V_{DS} $\quad$ $V_{gs} - V_T$

a) Since $V_{gS} = V_{DD}$ and $V_{DS} = V_{DD}$

$\therefore$ $V_{DS} > V_{gs} - V_T$ since $V_{gs} > V_T$

$\Rightarrow$ V_{DS} is $> V_{gs} - V_T \Rightarrow$ Device is in Saturation Region

b) $I_D = \beta \dfrac{V_{gT}^2}{2} \Rightarrow \dfrac{V_S}{R_S} = I_D = \beta \dfrac{(V_g - V_S - V_t)^2}{2}$

$$\frac{V_S}{10e3} = \frac{.1e3}{2}(4.2 - V_S)^2$$

$$= \frac{1}{10} V_S = .05(4.2 - V_S)^2$$

$$V_S = .5(4.2 - V_S)^2$$

$V_S = 2.134V$ ✓ $\longrightarrow$ $V_g = 5$

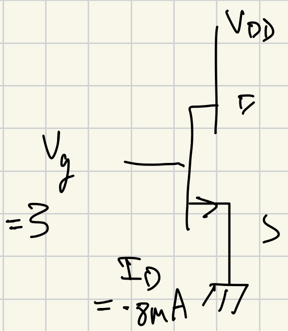
$V_S = 8.266$ X $\qquad$ $V_S = 2.134$

$$\boxed{V_{gS} = 2.866V}$$

$$I_D = \frac{V_S}{10e3} \Rightarrow \frac{2.134}{10e3} = \boxed{.2134 mA}$$

Made with Goodnotes

3. An NMOS transistor with $V_T = 1V$ has a drain current of 0.8mA when $V_{GS} = 3V$ and $V_{DS} = 4.5V$. Calculate the drain current when (a) $V_{GS} = 2V$ and $V_{DS} = 4.5V$ and (b) $V_{GS} = 3V$ and $V_{DS} = 1V$.



$V_t = 1V$

$V_{DS} = 4.5 \geq V_{gs} - V_t$

$V_{DD} = 4.5V$

$I_D = \dfrac{\beta V_{gt}^2}{2} \Rightarrow$

$V_{gt} = 3 - 1 = 2$

$.8 = \beta \dfrac{4}{2}$

$\boxed{.4 = \beta}$

a) $V_{gs} - V_T = 1 = V_{gt}$

$V_{DS} > 2 - 1 \Rightarrow$

Saturation Region

$I_{DS} = \beta\left(\dfrac{1^2}{2}\right) = \boxed{.2mA}$

b) $V_{gs} - V_T = 2$

$V_{DS} < V_{gs} - V_T$

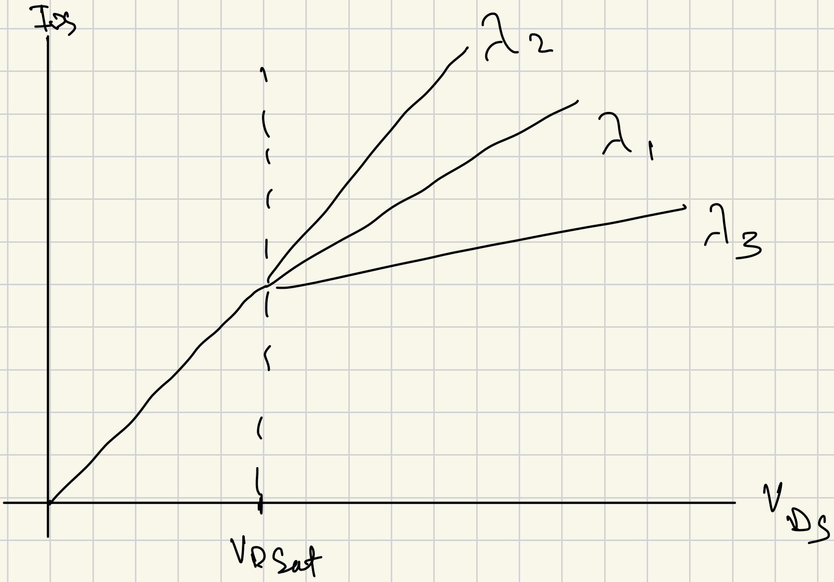
$1 < 2 \Rightarrow$ linear Region

$I_D = \beta\left(V_{gT} - \dfrac{V_{DS}}{2}\right) V_{DS}$

$= .4\left(2 - \dfrac{1}{2}\right)(1) \Rightarrow .4(1.5)$

$\boxed{I_D \Rightarrow .6 mA}$

4. If the saturation current of an NMOS device is given by: $I_{DS} = \frac{\beta}{2}(V_{GS}-V_T)^2 \cdot (1 + \lambda \cdot V_{DS})$. Draw the output characteristics of the device. What does λ signify? Assume $\lambda << 1/V_{DS}$.



$$I_{DS} = \frac{\beta}{2}(V_{GS}-V_t)^2 + \frac{\beta}{2}(V_{GS}-V_t)^2 \lambda V_{DS}$$

following the most recently saturation stage ($V_{DS} > V_{GS} - V_t$) λ is the slope on I_{DS} for this Region.

Given that V_{DS} in saturation is of second order, I_{DS} still Rises linearly (λ)