HW #7

3.1 Circuit 1:

$$V_{GS} = \left[\frac{2}{2+8}\right] \times 10 = 2\,V$$

$V_{DS} \geq V_{GS} - V_{tn}$ $\Rightarrow$ transistor in Saturation

$$I_D = k_n\left(\frac{W}{L}\right)(V_{GS} - V_{tn})^2 = \frac{200}{2} \times 2 \times (2 - 0.4)^2 = 0.512 \text{ mA}$$

Circuit 2:

$$V_{GS} = \left[\frac{2}{2+18}\right] \times 2 = 0.2\,V$$

$V_{GS} < V_{tn}$ $\Rightarrow$ transistor in cut off

$I_D = 0$

Circuit 3:

$$V_{GS} = \left[\frac{8}{8+12}\right] \times 2 = 0.8\,V$$

$V_{DS} \geq V_{GS} - V_{tn}$ $\Rightarrow$ transistor in Saturation

$$I_D = k_n\left(\frac{W}{L}\right)(V_{GS} - V_{tn})^2 = \frac{200}{2} \times 2 \times (0.8 - 0.9)^2 = 32\ \mu A$$

3.2

$V_{DS} < V_{GS} - V_{tn}$

a) $0.8 < 3 - 0.5$ $\Rightarrow$ Nonsaturated (linear region)

$$I_D = k_n\left(\frac{W}{L}\right)\left[2(V_{GS} - V_{tn})V_{DS} - V_{DS}^2\right]$$

$$I_D = \frac{200}{2} \times 4 \left[2(3-0.5)10.8 - 0.8^2 \right] = 1.344 \text{ mA}$$

b) $$R_d = \frac{1.5 - V_D}{I_D} = \frac{1.5 - 0.8}{1.344} = 520.83\ \Omega$$

3.5.

$$I_D = \frac{V_o}{100k}$$

$$I_D = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{tn})^2 = \frac{75}{2} \times 3 \times (1.5 - V_o - 0.6)^2$$

$$\frac{V_o}{100k} = \frac{75}{2} \times 3 \times (1.5 - V_o - 0.6)^2$$

$$V_o = 0.658 \text{ V}$$

$$I_D = \frac{V_o}{100k} = \frac{0.658}{100k} = 6.58\ \mu A$$

3.6. $V_{GS} = 6 - V_o$, $V_{DS} = V_D - V_S = 5 - V_o$

$V_{GS} - V_{tn} > V_{DS} \Rightarrow 6 - V_o - 0.8 > 5 - V_o$ $\quad 5.2 > 5$ Non Saturated State

$$I_D = \frac{k_n'}{2}\left(\frac{W}{L}\right)\left[2(V_{GS} - V_{tn})V_{DS} - V_{DS}^2\right]$$

$$I_D = \frac{V_o}{5} = \frac{200}{2} \times 4 \times \left[2(6 - V_o - 0.8)(5 - V_o) - (5 - V_o)^2\right]$$

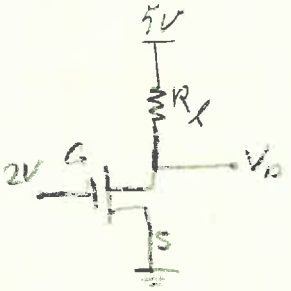
$$V_o = 3.806 \text{ V}$$

3.10

Saturated State: $I_D = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{tn})^2$

$$I_D = \frac{250\times10^{-6}}{2} \times 3 \times (2-0.5)^2 = 0.844 \text{ mA}$$

$$V_D = V_G - V_{tn} = 2 - 0.5 = 1.5 \text{ V}$$

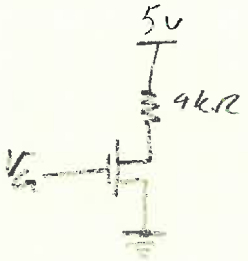


$$R_L = \frac{5 - V_D}{I_D} = \frac{5 - 1.5}{0.844\times10^{-3}}$$

$$\boxed{R_L = 4.147 \text{ k}\Omega}$$

3.11.

$$V_{DS} = V_G - V_{tn} = V_G - 0.5$$



$$I_D = \frac{5 - V_D}{4\text{k}} = \frac{5.5 - V_G}{4\text{k}}$$

$$\frac{5.5 - V_G}{4\text{k}} = \frac{250\times10^{-6}}{2} \times 3 \times (V_G - 0.5)^2$$

$$\boxed{V_G = 2.023 \text{ V}}$$

$$I_D = \frac{5.5 - 2.023}{4\text{k}} = 0.869 \text{ mA}$$

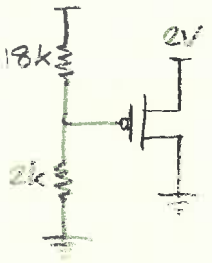
$$V_{DS} = V_{GS} - V_{tn} = 2.023 - 0.5 = 1.523 \text{ V}$$

3.15

$V_{GS} = 2 - 2 = 0\ V$, $V_{DS} = 2\ V$

$V_{GS} > V_{tp}$ → transistor is off

$\boxed{I_D = 0}$



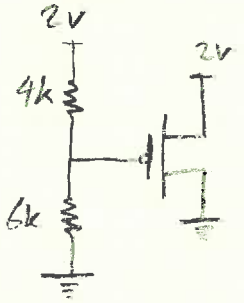
$V_G = \left(\frac{2}{2+18}\right) \times 2 = 0.2\ V$

$V_{GS} = 0.2 - 2 = -1.8\ V$, $V_{DS} = 0 - 2 = -2V$

$V_{GS} > V_{DS} + V_{tp}$

$-1.8 > -2 - 0.4$ Saturation State

$I_D = \frac{K_p'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{tn})^2 = \frac{100}{2} \times 4 \times (-1.8 + 0.4)^2 = \boxed{392\ \mu A}$



$V_G = 2 \times \left(\frac{6}{10}\right) = 1.2\ V$

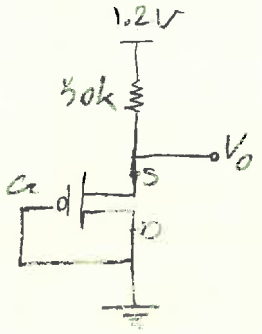
$V_{DS} = 0 - 2 = -2V$

$V_{GS} > V_{DS} + V_{tp}$ $V_{GS} = 1.2 - 2 = -0.8V$

$-0.8 > -2 - 0.4$ → Saturation State

$I_D = \frac{K_p'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{tn})^2 = \frac{100}{2} \times 4 \times (-0.8 + 0.4)^2 = \boxed{32\ \mu A}$

3.21.



$|V_{GS}| = V_o$, $|V_{DS}| = V_o$

$|V_{DS}| > |V_{GS}| - |V_{tp}|$ ⇒ Saturation

$$I_D = \frac{k_p'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{tp})^2$$

$$I_D = \frac{40\times10^{-6}}{2} \times 6 \times (V_o - 0.3)^2 = \frac{1.2 - V_o}{50\,k\Omega}$$

$$V_o = 0.6128\ V$$

$$I_D = 11.756\ \mu A$$

3.24.

a) $V_{GS} = V_G - V_S = 0 - 1.8V = -1.8V$ at $t = 0^+$

$$|I_D| = \frac{k_p'}{2}\left(\frac{W}{L}\right)(|V_{GS}| - |V_t|)^2 = \frac{40\times10^{-6}}{2} \times 5 \times (1.8 - 0.4)^2$$

$$I_D = 196\ \mu A$$

b) No current goes through the capacitor

Non Saturation

c) $W = \frac{1}{2}CV^2 = \frac{1}{2}(15\times10^{-9})(1.8)^2 = 24.3\ nJ$