3.2

$V_{DS} = 0.8V$

$V_{GS} = 3V$

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

(a)

$0.8 < 3 - 0.5$

$0.8 < 2.5$ [Linear region]

$K_n = 200\mu A/V^2$; $W/L = 4$; $V_{th} = 0.5V$; $V_D = 0.8V$

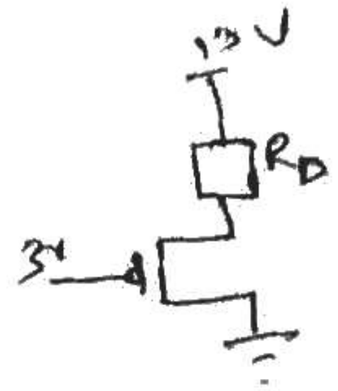
$$I_D = K_n(W/L)\left[2(V_{GS} - V_{th})V_{DS} - V_{DS}^2\right]$$

$$= 200(4)\left[\frac{2(3-0.5)(0.8) - (0.8)^2}{2}\right] = \frac{2.688\mu A}{2}$$

$= 1.344\mu A$

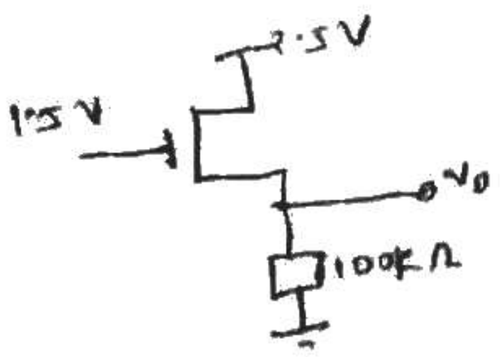
(b) Value of R_D

$$R_D = \frac{1.5 - V_D}{I_D} = \frac{1.5 - 0.8}{1.344}$$



$= 520.83\Omega$.

3.5



$W/L = 3$

$V_{th} = 0.6V$

$K_n = 75\mu A/V^2$

find V_D & I_D

$V_{GS} = V_G - V_D$

$$I_D = \frac{V_D}{100K}$$

$$I_D = \frac{K_n'}{2}(W/L)(V_{GS} - V_T)^2$$

$$\frac{V_D}{100} = \frac{75}{2}(3)\left[(1.5 - V_D) - 0.6\right]^2$$

$\boxed{V_D = 0.658V}$

$$I_D = \frac{V_D}{100K}$$

$$= \frac{0.658}{100K}$$

$= 0.658mA \; V \times 10^{-5}$

$= 6.58 \times 10^{-6}$

$\boxed{I_D = 6.58\mu A}$

3.2

$V_{DS} = 0.8V$

$V_{GS} = 3V$

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

(a) $0.8 < 3 - 0.5$

$0.8 < 2.5$ [Linear region]

$K_n = 200\mu A/V^2$; $W/L = 4$; $V_{th} = 0.5V$; $V_D = 0.8V$

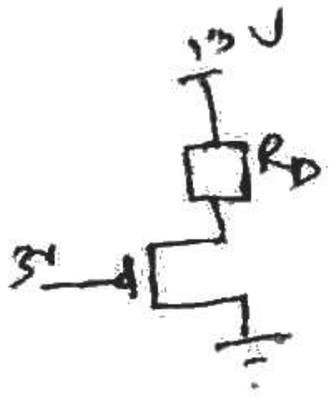
$$I_D = K_n(W/L)\left[2(V_{GS} - V_{th})V_{DS} - V_{DS}^2\right]$$

$$= 200(4)\left[\frac{2(3-0.5)(0.8) - (0.8)^2}{2}\right] = \frac{2.688mA}{2}$$

$= 1.344mA$

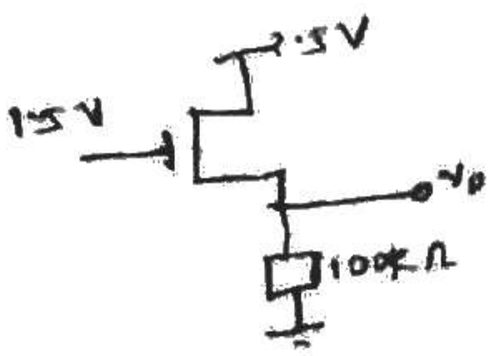
(b) Value of R_D

$$R_D = \frac{1.5 - V_D}{I_D} = \frac{1.5 - 0.8}{1.344}$$



$= 520.83\Omega$.

3.5



$W/L = 3$

$V_{th} = 0.6V$

$K_n = 75\mu A/V^2$

find V_o & I_D

$V_{GS} = V_G - V_o$

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

$I_D = \frac{K_n'}{2}(W/L)(V_{GS} - V_T)^2$

$\frac{V_o}{100} = \frac{75}{2}(3)\left[(1.5 - V_o) - 0.6\right]^2$

$V_o = 0.658V$

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

$= \frac{0.658}{100K}$

$= 0.658\mu A/V \times 10^6$

$= 6.58 \times 10^{-6}$

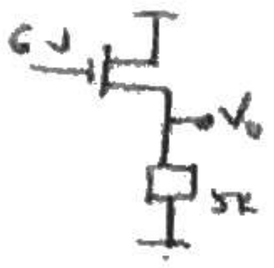
$I_D = 6.58\mu A$

3 c $V_{th} = 0.8\,V$

$K_n = 200\mu A/V^2$

$W/L = 4$

$V_o = ?$



$I_D = \frac{V_o}{5K}$

$V_{GS} = V_G - V_S = 6 - V_o$

$V_{DS} = V_D - V_S = 5 - V_o$

$V_{GS} - V_t \geq V_{DS}$

$6 - V_o - 0.8 \geq 5 - V_o$

$5.2 > 5$ [Linear region]

$I_D = K_n'(W/L)\left[2(V_{GS} - V_{th})V_{DS} - (V_{DS})^2\right]$

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

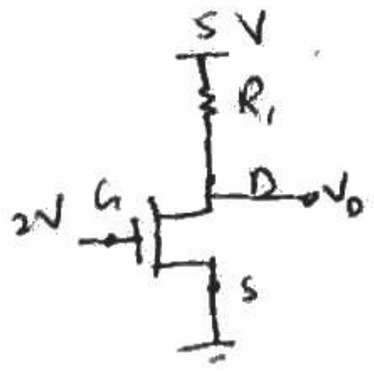
$\boxed{V_o = 3.806V}$

3.10

$K_n' = 250\mu A/V^2$

$V_{tn} = 0.5V$

$W/L = 3$



$I_{DS} = \frac{K_n'}{2}(W/L)_n(V_{GS} - V_{tn})^2$

$= \frac{250\times10^{-6}}{2}(3)(2 - 0.5)^2$

$\boxed{I_D = 0.84375mA}$

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

$V_D - V_S = V_G - V_S - V_{tn}$

$V_D = V_G - V_{tn}$

$V_D = 2 - 0.5 = 1.5V$

$R_D = \frac{V_{DD} - V_D}{I_{DS}} = \frac{5 - 1.5}{0.84375\times10^{-3}}$

$\boxed{R_D = 4.148k\Omega}$

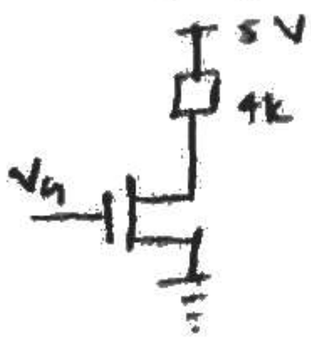
3.11

$K_n = 250\mu A/V^2$

$V_{th} = 0.5V$

$W/L = 3$

$V_G = ?$



$V_D = V_G - V_{th}$

$V_D = V_G - 0.5$

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

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

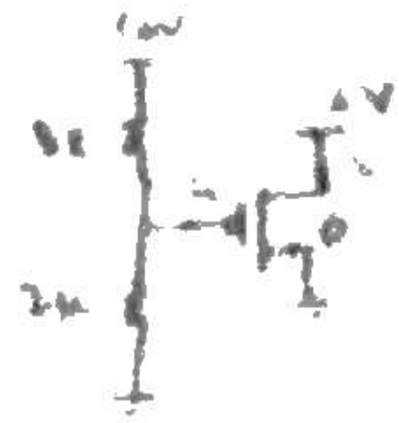
$5.5 - V_G = 3V_G^2 - 3V_G + 0.75$

$V_G = 3V_G^2 - 3V_G - 4.75$

$3V_G^2 - 4V_G - 4.75 = 0$

$\boxed{V_G = 2.09V}$

3.15



$V_{tp} = 0.4V$

$\mu_p C_{ox} = 100\mu A/V^2$

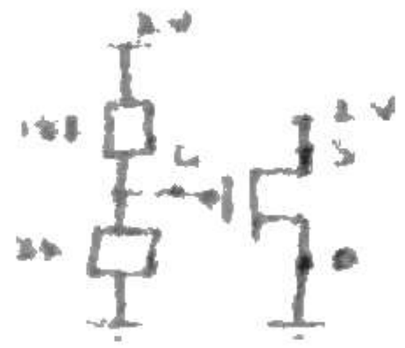
$V_{sg} = 10\left(\frac{2K}{2+8}\right) = 2V$

$V_{GS} = V_G - V_S$

$2 - 2 = 0$

$V_{GS} > V_{tp}$

So $\boxed{I_{DS} = 0}$



$V_S = 2\left(\frac{2}{2+8}\right) = 0.2V$

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

$2 < -1.8 + 0.4$

$-2 < -1.4$

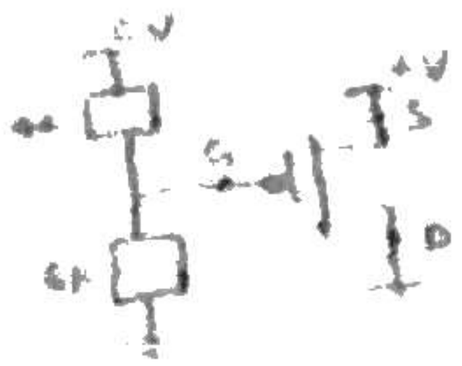
Saturation mode

$I_D = \frac{K_p'}{2}(W/L)(V_{gs} - V_{tn})^2$

$= \frac{100}{2}(4)(-1.4)^2$

$= 200\,(1.96)$

$\boxed{I_D = 392\mu A}$



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

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

$-2 < (1.2 - 2) + 0.4$

$-2 < (-0.8 + 0.4)$

$\boxed{-2 < -0.4}$

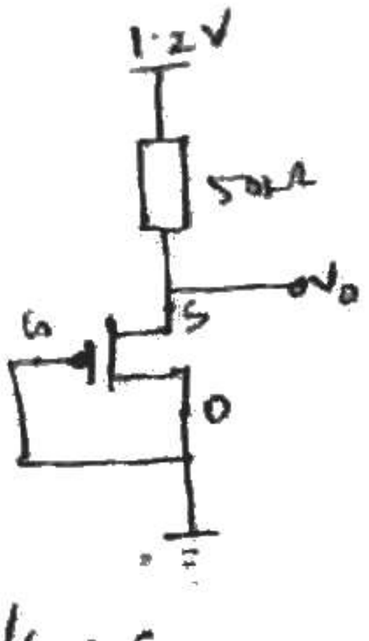
Saturation mode

$I_D = \frac{K_p'}{2}(W/L)(V_{gs} - V_{tn})^2$

$= \frac{100}{2}(4)(0.16)$

$\boxed{I_D = 32\mu A}$

3.21



$W/L = 6$

$V_{tp} = -0.3V$

$K_p = 40\mu A/V^2$

$V_o, I_D \Rightarrow ?$

$|V_{gs}| - |V_t| < |V_{ds}|$

$V_o - V_t < V_o \rightarrow$ saturation

$I_D = \frac{K_p'}{2}(W/L)\left[V_{gs} - V_t\right]^2$

$\frac{V_o - 1.2}{50K} = \frac{40}{2}(6)(V_o + 0.3)^2$

$\frac{V_o - 1.2}{50K} = 120\left(V_o^2 + 0.09 + 0.6V_o\right)\times 10^{-6}$

$V_o - 1.2 = 50 \times 120 \times 10^{-3}\left(V_o^2 + 0.09 + 0.6V_o\right)$

$V_o - 1.2 = 6000 \times 10^{-3}\left(V_o^2 + 0.09 + 0.6V_o\right)$

$V_o - 1.2 = 6V_o^2 + 0.36V_o + 0.54$

$6V_o^2 + 2.64V_o + 1.74 = 0$

$V_o^2 + 0.1066V_o + 0.29 = 0$

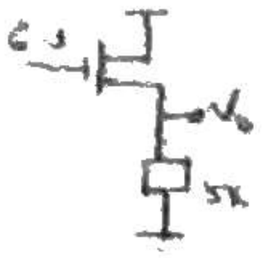
$V_o = 0.27V \;;\; -0.7916V$

3.6 $V_{tn} = 0.8V$

$K_n = 200\mu A/V^2$

$W/L = 4$

$V_G = 0$



$$I_D = \frac{V_D}{5K}$$

$$V_{GS} = V_G - V_S = 6 - V_D$$

$$V_{DS} = V_D - V_S = 5 - V_D$$

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

$$6 - V_D - 0.8 > 5 - V_D$$

$$5.2 > 5 \text{ [Linear region]}$$

$$I_D = K_n'(W/L)\left[2(V_{GS} - V_{tn})V_{DS} - (V_{DS})^2\right] \cdot \frac{1}{2}$$

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

$$\boxed{V_D = 3.806V}$$

3.10 $K_n' = 250\mu A/V^2$

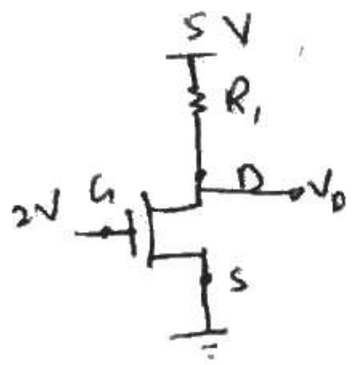
$V_{tn} = 0.5V$

$W/L = 3$

$$I_{DS} = \frac{K_n'}{2}(W/L)_n(V_{GS} - V_{tn})^2$$

$$= \frac{250\times10^{-6}}{2}(3)(2 - 0.5)^2$$

$$\boxed{I_D = 0.84375mA}$$



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

$$V_D - V_S = V_G - V_S - V_{tn}$$

$$V_D = V_G - V_{tn}$$

$$V_D = 2 - 0.5 = 1.5V$$

$$R_D = \frac{V_{DD} - V_D}{I_{DS}} = \frac{5 - 1.5}{0.84375\times10^{-3}}$$

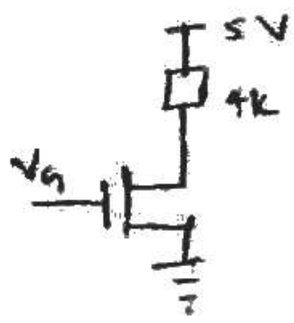
$$\boxed{R_D = 4.148K\Omega}$$

3.11 $K_n = 250\mu A/V^2$

$V_{th} = 0.5V$

$W/L = 3$

$V_G = 0$



$$V_D = V_G - V_{th}$$

$$V_D = V_G - 0.5$$

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

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

$$5.5 - V_G = 3V_G^2 - 3V_G + 0.75$$

$$V_G = 3V_G^2 - 3V_G - 4.75$$

$$3V_G^2 - 4V_G - 4.75 = 0$$

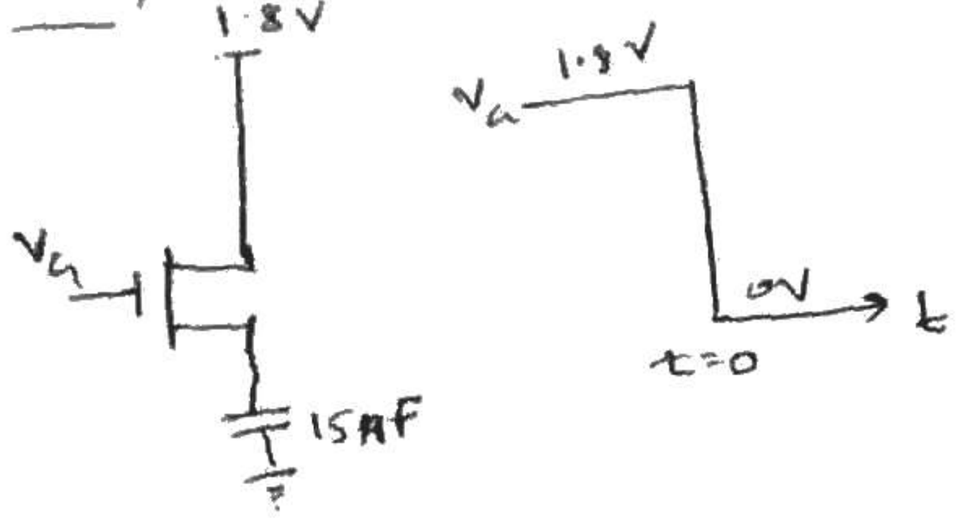
$$\boxed{V_G = 2.09V}$$

$$I_D = \frac{(1.2 - 0.27)V}{50k}$$

$$I_D = 0.0186mA$$

$$\boxed{I_D = 18.6\mu A}$$

3.24



(a) $K_p = 40\mu A/V^2$

$V_{tp} = -0.4V$

$W/L = 5$

$V_{GS} = V_G - V_S = 0 - 1.8$

$= -1.8V$ @ $t = 0^+$

$$|I_{DS}| = \frac{K_p'}{2}(W/L)_p (|V_{GS}| - |V_{TP}|)^2$$

$$= \frac{40 \times 10^{-6}}{2}(5)(1.8 - 0.4)^2$$

$$\boxed{I_{DS} = 196\mu A}$$

(b) No current flows through the capacitor

∴ non-saturation or linear region

(c) $W = \frac{1}{2}CV^2 = \frac{1}{2}(15 \times 10^{-9})(1.8)^2$

$$\boxed{W = 24.3nJ}$$