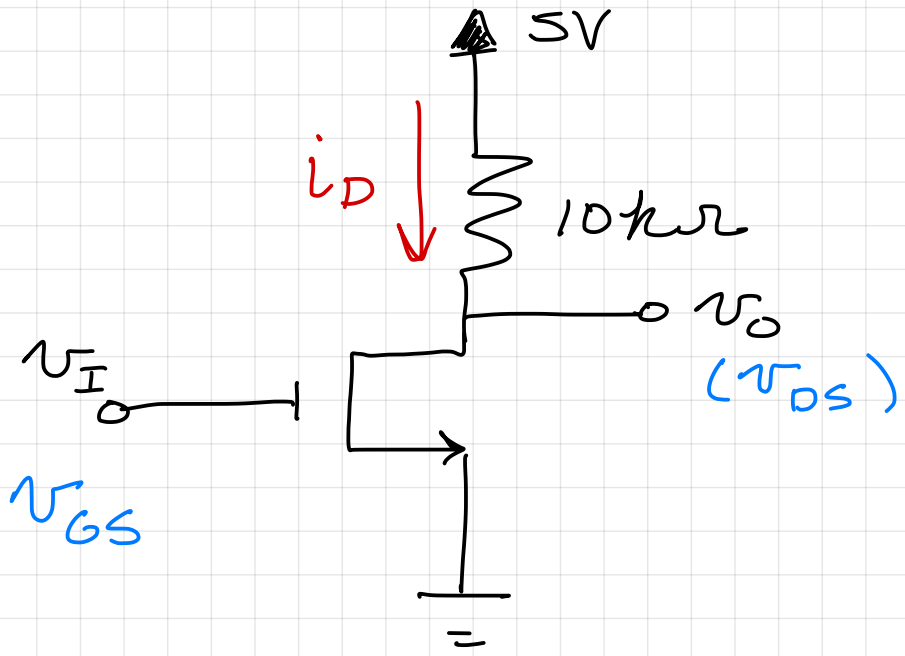
Module 6 Practice Problems
Solutions

① 


$V_t = 1.5V$

$k'_n \frac{W}{L} = 0.2 \frac{mA}{V^2}$

point A: $v_I = V_t$ (cutoff)

$v_O = V_{DD}$

point B: edge of saturation

$v_O = v_I - V_t$

$v_O \uparrow v_{DS}$ $\quad v_I \uparrow v_{GS}$

$$v_I = v_{GS} = V_t + \frac{\sqrt{1 + 2(R_D k'_n \frac{W}{L} V_{DD})} - 1}{R_D k'_n \frac{W}{L}}$$

$v_I = 3.29V$ or $-1.29V$

$$v_O = v_{DS} = v_I - V_t$$

$$= 3.29 - 1.5$$

$$v_O = 1.79\,V$$

point C: $v_{GS} = v_I = V_{DD} = 5V$

$$v_{DS} = v_O = \frac{v_{GS}}{1 + R_D k'_n \frac{W}{L}(v_{GS} - V_t)}$$

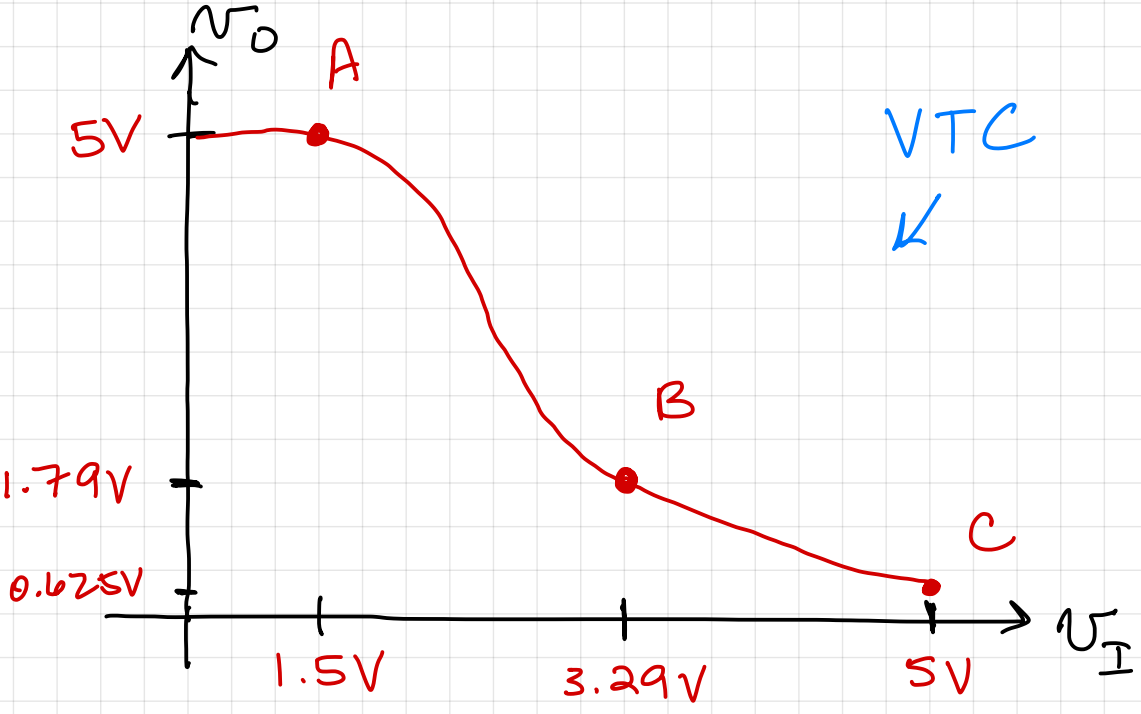
$$v_O = v_{DS} = 0.625\,V$$

$v_O$, $v_I$

point A : (5V, 1.5V)

point B : (1.79V, 3.29V)

point C : (0.625V, 5V)



b) $I_{DQ} = 0.15\,mA$

$$V_{OQ} = V_{DSQ} = V_{DD} - I_{DQ} R_D$$

$$= 5 - (0.15)(10)$$

$$\boxed{V_{OQ} = 3.5V}$$

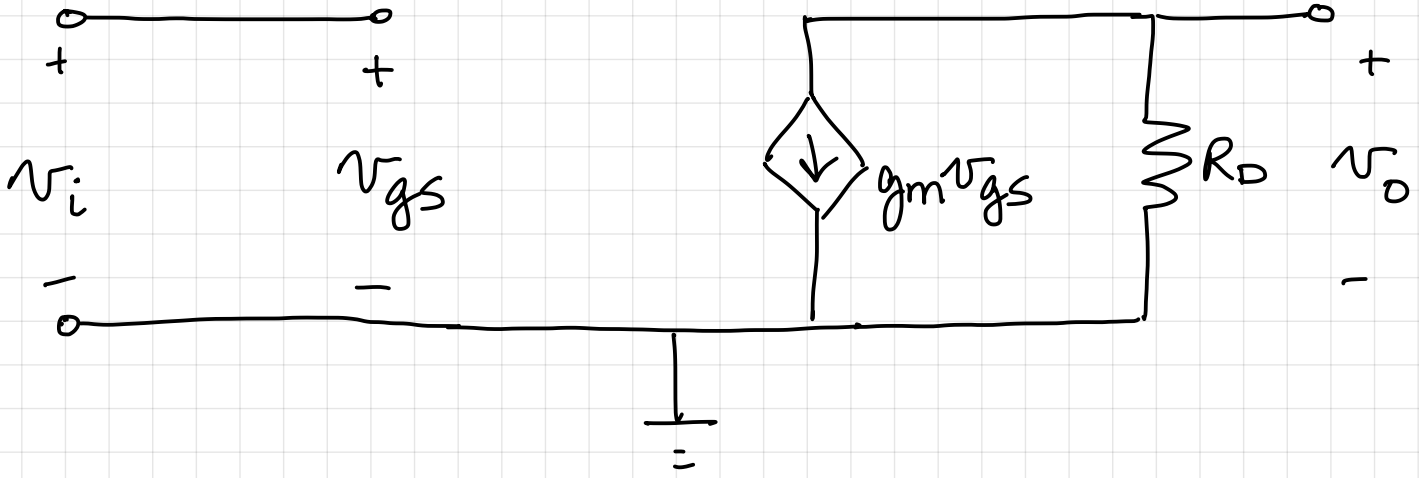
$V_{IQ} = V_{GSQ}$

$$I_{DQ} = \frac{1}{2} k'_n \frac{W}{L} (V_{IQ} - V_t)^2$$

$$0.15 = \frac{1}{2}(.2)(V_{IQ} - 1.5)^2$$

$$\boxed{V_{IQ} = 2.72\,V}$$

c)




$v_i = v_{gs}$

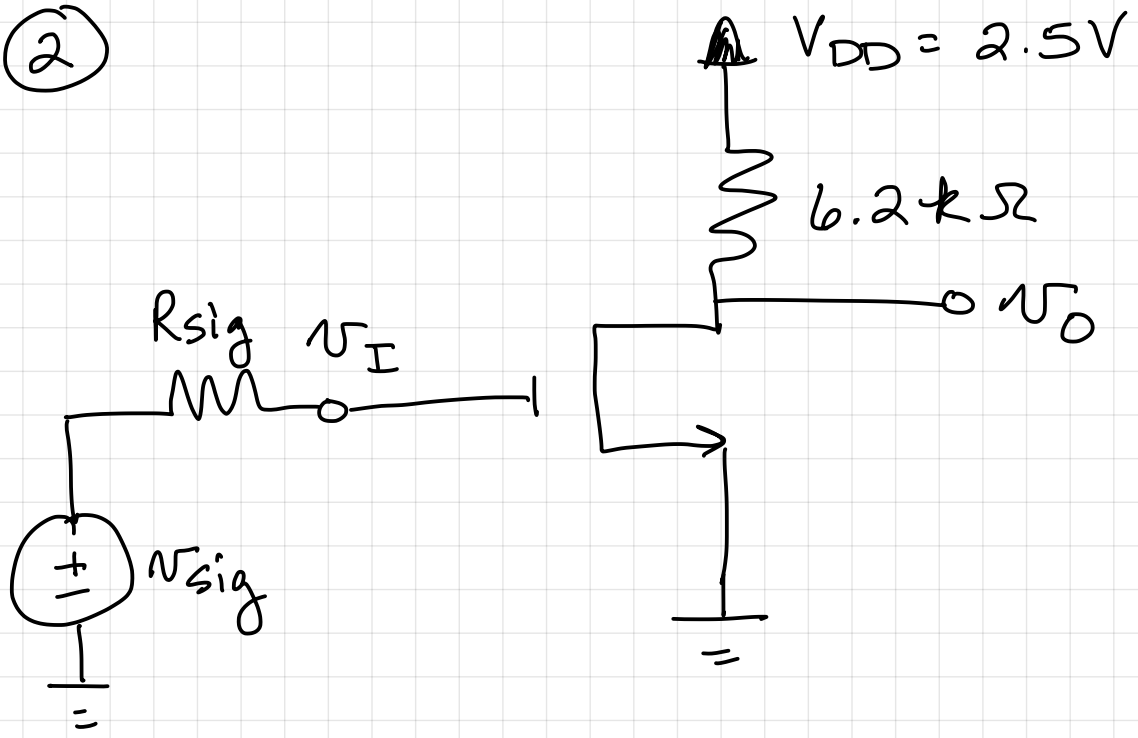
$$A_{v_o} = \frac{v_o}{v_i} = -g_m R_D$$

$$= -\left(k'_n \frac{W}{L}(V_{IQ} - V_t)\right) R_D$$

$$A_{vo} = -(.2)(2.72 - 1.5)(10)$$

$$\boxed{A_{vo} = -2.45 \text{ V/V}}$$

(2)




$$k'_n = 0.4 \frac{mA}{V^2} \quad \frac{W}{L} = 10 \quad V_t = 0.4V$$

$$V_A = 10V$$

a) $$I_{DQ} = 0.2mA = \frac{1}{2} k'_n \frac{W}{L} (V_{GSQ} - V_t)^2$$

$$V_{GSQ} = 0.716V$$

$$V_{DSQ} = 2.5 - I_{DQ} R_D = 1.26V$$

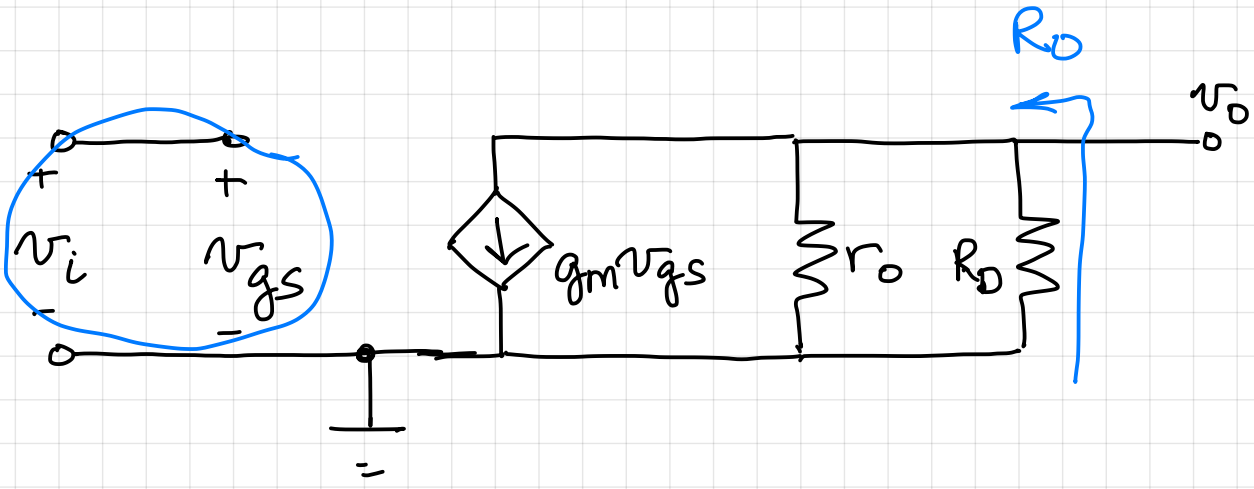
b) $R_{in} = \infty$

$$g_m = k'_n \frac{W}{L}(V_{GSQ} - V_t)$$

$$= 0.4(10)(0.716 - 0.4)$$

$$g_m = 1.264\ mA/V$$

$$r_o = \frac{V_A}{I_{DQ}} = \frac{10}{.2 \times 10^{-3}} = 50\ k\Omega$$

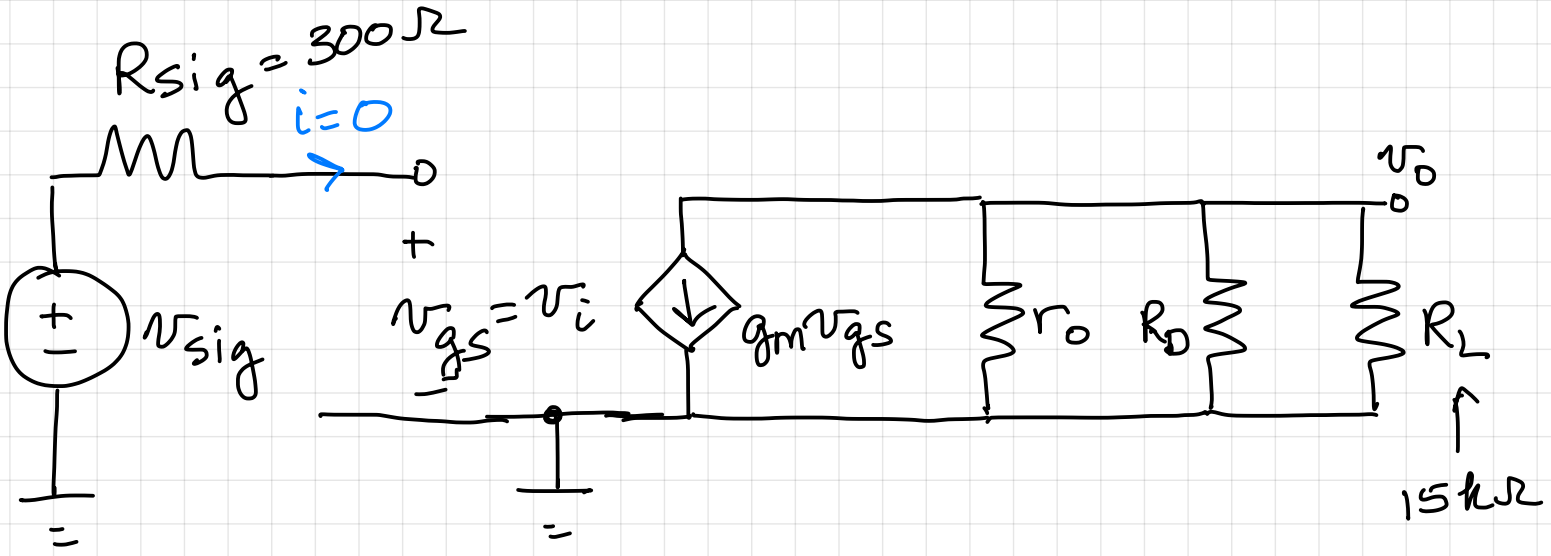



$$R_o = r_o \| R_D = 50 \| 6.2 = 5.52\ k\Omega$$

$$A_{vo} = \frac{v_o}{v_i} = -g_m(r_o \| R_D)$$

$$= -1.264(5.52)$$

$$= -6.98\ V/V$$




c) $$A_v = \frac{v_o}{v_i} = -g_m(r_o \| R_D \| R_L)$$

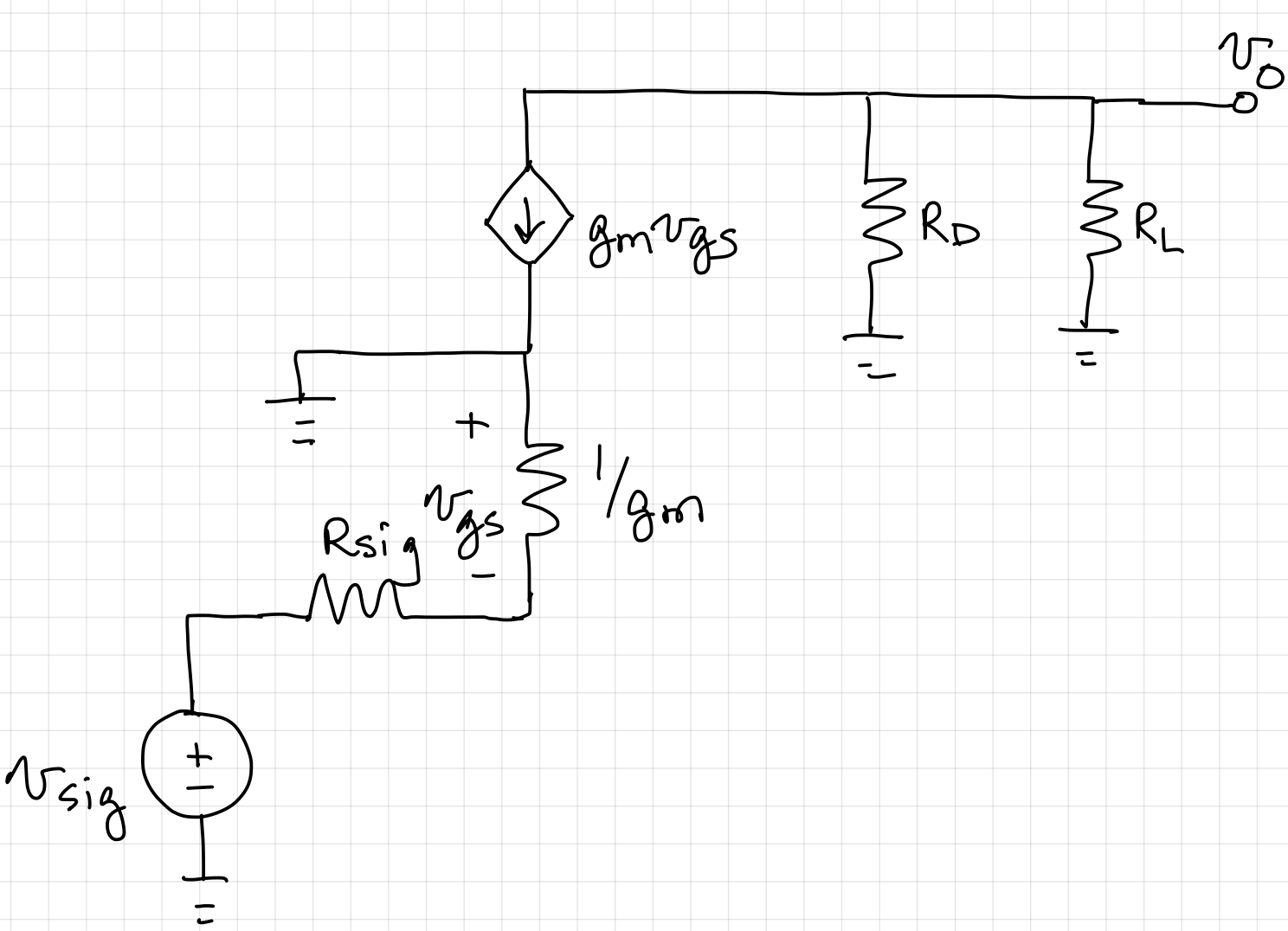
$$= -1.264(50 \| 6.2 \| 15)$$

$$A_v = -5.1 \text{ V/V}$$

d) $$G_v = \frac{v_o}{v_{sig}} = -5.1 \text{ V/V}$$

(3) $g_m = 4\text{mA/V}$ $R_D = 5\text{k}\Omega$ $R_L = 7.5\text{k}\Omega$ $R_{sig} = 500\Omega$

a) $$R_{in} = \frac{1}{g_m} = \frac{1}{4\times10^{-3}} = 250\Omega$$




$$G_v = \frac{(R_D \,||\, R_L)}{R_{sig} + 1/g_m} = \frac{(5 \,||\, 7.5)}{500 + 250}$$

$$= \frac{3000}{750}$$

$$\boxed{G_v = 4 \text{ V/V}}$$

b) $R_{in} = R_{sig}$ at the Q pt what would the $I_{DQ}$ need to change to.

$R_{sig} = 500$

$R_{in} = 250 = \frac{1}{g_m}$ $\quad g_{m_1} = \frac{4mA}{V}$

$$\frac{1}{g_m} = 500 \qquad g_m = 2\,\frac{mA}{V}$$

$$I_{DQ} = \frac{1}{2} k'_n \frac{W}{L} (V_{GSQ} - V_t)^2$$

$$g_m = k'_n \frac{W}{L} (V_{GSQ} - V_t)$$

$$g_m = \frac{2 I_{DQ}}{(V_{GSQ} - V_t)}$$

$$(V_{GSQ} - V_t)^2 = \frac{2 I_{DQ}}{k'_n W/L}$$

$$(V_{GSQ} - V_t) = \sqrt{\frac{2 I_{DQ}}{k'_n W/L}}$$

$$g_m = \sqrt{\underbrace{2 k'_n \frac{W}{L}}_{\text{constant}} I_{DQ}}$$

$g_m$ reduces by a factor of $\frac{1}{2}$

$I_{DQ}$ reduce by a factor $\frac{1}{4}$

CD

(4) $k'_n = 0.1 \frac{mA}{V^2}$ $\quad V_t = 0.6V$

$V_{GSQ} = 0.85V$

a) $R_o = 300\Omega$ - what is $\frac{W}{L}$

$$R_o = \frac{1}{g_m} = 300$$

$$g_m = 3.33 \frac{mA}{V} = k'_n \frac{W}{L} (V_{GSQ} - V_t)$$

$$3.33 = .1 \left(\frac{W}{L}\right)(0.85 - 0.6)$$

$$\frac{W}{L} = 133.2$$

b) $I_{DQ} = \frac{1}{2} k'_n \frac{W}{L} (V_{GSQ} - V_t)^2$

$$I_{DQ} = \frac{1}{2} (.1)(133.2)(.85 - .6)^2$$

$I_{DQ} = 0.416\,mA$

c) $R_L =$ 10kΩ pot $\quad 0 \rightarrow 10k\Omega$

$$G_V = \frac{R_L}{R_L + 1/g_m} = \frac{R_L}{R_L + 300}$$

for $R_L = 0 \qquad G_V = 0$

$R_L = 10k\Omega \qquad G_V = 0.97\ V/V$