Ex: 5.1

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{34.5\ \text{pF/m}}{4\ \text{nm}} = 8.625\ \text{fF}/(\mu\text{m})^2$$

$$\mu_n = 450\ \text{cm}^2/\text{VS}$$

$$k_n' = \mu_n C_{ox} = 388\ \mu\text{A}/\text{V}^2$$

$$V_{OV} = (v_{GS} - V_t) = 0.5\ \text{V}.$$

$$g_{DS} = \frac{1}{1\ \text{k}\Omega} = k_n' \frac{W}{L} V_{OV} \Rightarrow \frac{W}{L} = 5.15$$

$L = 0.18\ \mu$m, so $W = 0.93\ \mu$m

Ex: 5.3 $I_D = \frac{1}{2} k_n' \frac{W}{L} V_{OV}^2$ in saturation

Change in I_D is:

(a) double L, 0.5

(b) double W, 2

(c) double V_{OV}, $2^2 = 4$

(d) double V_{DS}, no change (ignoring length modulation)

(e) changes (a) - (d), 4

case (c) would cause leaving saturation if $V_{DS} < 2V_{OV}$

Ex: 5.5 $V_{OV} = 0.5\ \text{V}$

$$g_{DS} = k_n' \frac{W}{L} V_{OV} = \frac{1}{1\ \text{k}\Omega}$$

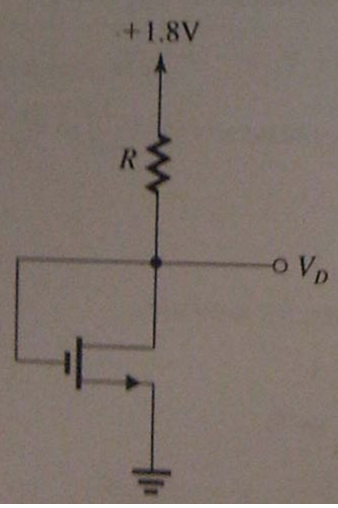
$$\therefore k_n = k_n' \frac{W}{L} = 2\ \text{mA}/\text{V}^2$$

For $v_{DS} = 0.5\ \text{V} \cdot = V_{OV}$

$$I_D = \frac{1}{2} k_n' \frac{W}{L} V_{OV}^2 = 0.25\ \text{mA}$$

for all $v_{DS} \geq V_{OV} = 0.5\ \text{V}.$

Ex: 5.9



$$\frac{W}{L} = \frac{0.72\ \mu\text{m}}{0.18\ \mu\text{m}} = 4.0$$

$\lambda = 0$

saturation mode ($v_{GD} = 0 < V_{tn}$)

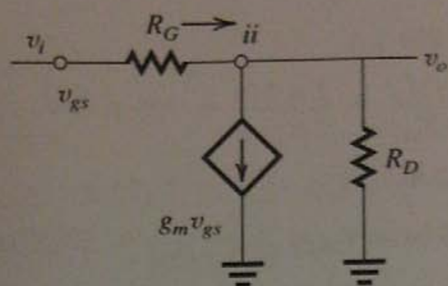
$V_D = 0.8\ \text{V}. = 1.8 - I_D R_D$

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_D - V_{tn})^2 = 72\ \mu\text{A}$$

$$\therefore R = \frac{1.8 - 0.8}{72\ \mu\text{A}} = 13.9\ \text{k}\Omega$$

$V_t = 0.7$ V.

$k_n = 1$ mA / V^2



Design for $A_v = \dfrac{v_O}{v_i} = -25$, $R_{in} = 500$ kΩ

$$\therefore g_m R_D = 25 = k_n V_{OV} R_D$$

$$R_{in} = \frac{v_i}{ii} = \frac{v_i}{v_i - v_o} R_G$$

$$\Rightarrow R_G = 26 R_{in} = 13 \text{ M}\Omega$$

$$I_D R_D = \left(\frac{1}{2} k_n V_{OV}^{\,2}\right) R_D$$

$$= \frac{1}{2} g_m R_D V_{OV} = 12.5\ V_{OV}$$

and

$$V_{OV} = V_{DD} - V_t - I_D R_D = 4.3 - 12.5\ V_{OV}$$

$$\therefore V_{OV} = 0.319 \text{ V}.$$

$$g_m = 319\ \mu\text{A / V}$$

$$R_D = 78.5 \text{ k}\Omega$$

$$V_{DS} = V_{OV} + V_t$$

$$\hat{v}_{GD} = 0 + 26\hat{v}_i \le V_t$$

$$\therefore \left|\hat{v}_i\right| < \frac{V_t}{26} = 27 \text{ mV}.$$

5.18

Ex: 5.24

$$I_D = \frac{1}{2}k_n'\frac{W}{L}(V_{SG} - |V_t|)^2$$

$$= \frac{1}{2} \times 60 \times \frac{16}{0.8} \times (1.6 - 1)^2$$

$$I_D = 216\ \mu\text{A}$$

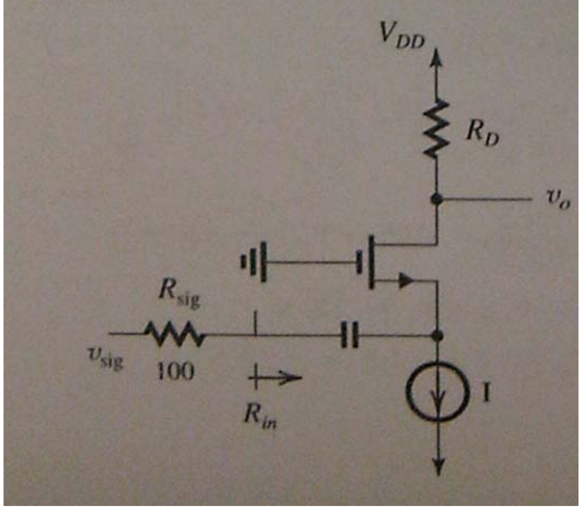
$$g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 216}{1.6 - 1} = 720\ \mu\text{A/V}$$

$$= 0.72\ \text{mA/V}$$

$$\lambda = 0.04 \Rightarrow V_A' = \frac{1}{\lambda} = \frac{1}{0.04} = 25\ \text{V}/\mu\text{m}$$

$$r_o = \frac{V_A' \times L}{I_D} = \frac{25 \times 0.8}{0.216} = 92.6\ \text{k}\Omega$$

Ex: 5.29



$$R_{in} = \frac{1}{g_m} = R_{sig} = 100\ \Omega$$

$$\Rightarrow g_m = 10\ \text{mA / V}$$

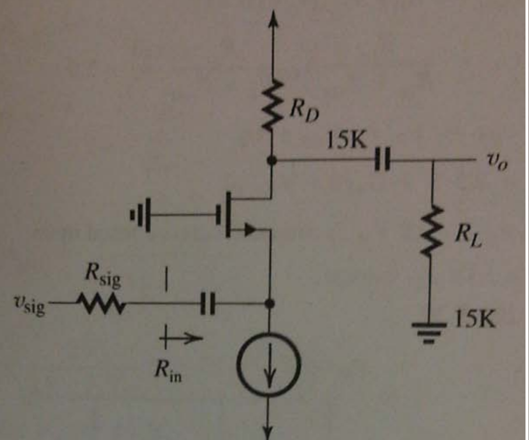
$$g_m = \frac{2I_D}{V_{OV}} = \frac{2I_D}{0.2\text{V}.} \Rightarrow I_D = 1\ \text{mA}$$

$$G_V = \frac{v_O}{v_{sig}} = \frac{R_{in}}{R_{sig} + R_{in}} g_m R_D$$

$$= \left(\frac{1}{2}\right)(10\ \text{mA / V})(2\ \text{k}\Omega)$$

$$= +10$$

Ex: 5.40



$g_m = 1\ \text{mA/V}$

For $R_{sig} = 50\ \Omega$

$k_{in} = \frac{1}{g_m} = 1\ \text{k}\Omega$

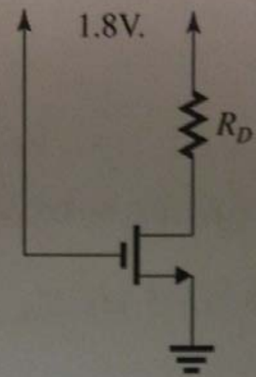
$k_{out} = R_D = 15\ \text{k}\Omega$

$A_{vO} = +g_m R_D = +15$

$A_V = g_m(R_D \| R_L) = +7.5$

$G_V = \frac{R_{in}}{R_{sig} + R_{in}} A_V = 7.1$

5.47



$k_n' = 0.4\text{mA/V}^2$

$V_t = 0.5\ \text{V},$

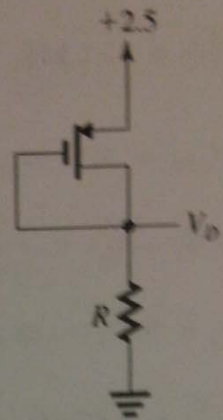
$\lambda = 0$

sat. boundary $V_{GD} = 0.5\text{V}, = I_D R_D$

$0.5\text{V}, = \frac{1}{2} k_n' \frac{W}{L} (1.8 - 0.5)^2 R_D$

$\therefore \frac{W}{L} R_D = 1.48\ \text{k}\Omega$

5.49



$V_t = -0.6\text{V}$.

$k_n' = 100\ \mu\text{A}/\text{V}^2$

$L = 0.25\ \mu\text{m}$

$\lambda = 0$

make $i_D = 0.8\ \text{mA}$, $V_D = 1.5\ \text{V}$,

$R = \dfrac{1.5\ \text{V}}{0.8\ \text{mA}} = 1.875\ \text{k}\Omega$ $V_{SG} = +1\text{V}$.

$0.8\text{mA} = \frac{1}{2}k_n'\frac{W}{L}(1-0.6)^2$

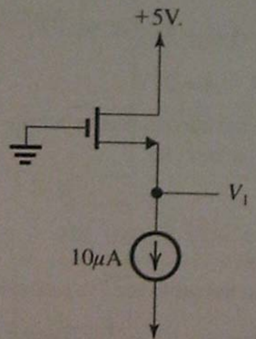
$\frac{W}{L} = 100$

$W = 25\ \mu\text{m}$

5.56 All parts $k_n' = 0.5 \frac{\text{mA}}{\text{V}^2}$, $V_t = 0.8\text{V}$,

$\lambda = 0$

(a)



$$V_1 = -V_{GS} = -\sqrt{\frac{(2)(10\ \mu A)}{0.5\ \text{mA/V}^2}} - 0.8\text{V}.$$

$$= -1\text{V}.$$

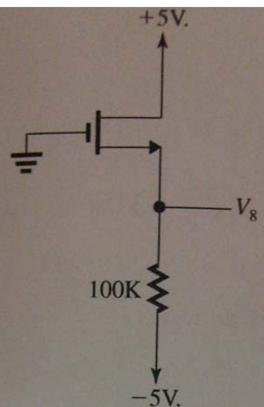
(b) same as (a), except $i_D = 100\ \mu\text{A}$

$V_2 = -1.432$ V,

(c) same as (a), except $i_D = 1$ mA

$V_3 = -2.80$ V.

h



$V_8 = -V_{GS} = -5 + 100KI_D$

$V_{GS} = 5 - (100)\left(\frac{1}{2}\right)(0.5)\ \ [V_{GS} - 0.8]^2$

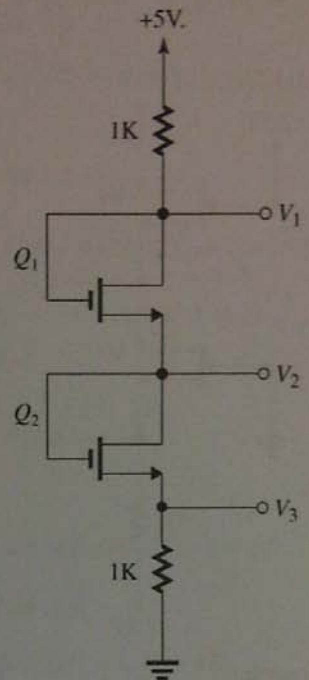
$0 = 5 - 25(V_{GS} - 0.8)^2 - V_{GS}$

see soln, in (f)

$V_{GS} = +1.19$ V. $I_D = 38.1\ \mu\text{A}$

$V_8 = -V_{GS} = -1.19$ V.

(b)



Both Q_1 and Q_2 in sat.

$(V_{GD1} = V_{GD2} = 0)$

$\therefore$ both Q_1 and Q_2 have same V_{GS}

$$+5 - 1KI_D - V_{GS} - V_{GS} - 1KI_D = 0$$

$$5 - (2)\left(\frac{1}{2}\right)(5)[V_{GS} - 1]^2 - 2V_{GS} = 0$$

$$0 = -5V_{GS}^2 + 8V_{GS}$$

$V_{GS} = +1.60\text{V}$, (bad root $< V_t$)

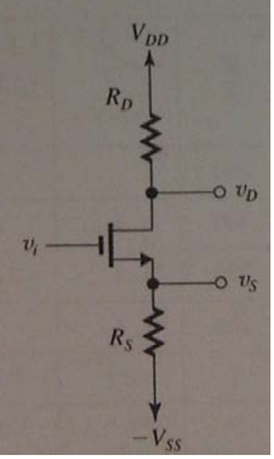
$$I_D = 0.90\text{mA} = \frac{1}{2}\left(5\frac{\text{mA}}{\text{V}^2}\right)[1.6 - 1]^2$$

$V_1 = +5 - (1k)I_D = +4.1\text{V}.$

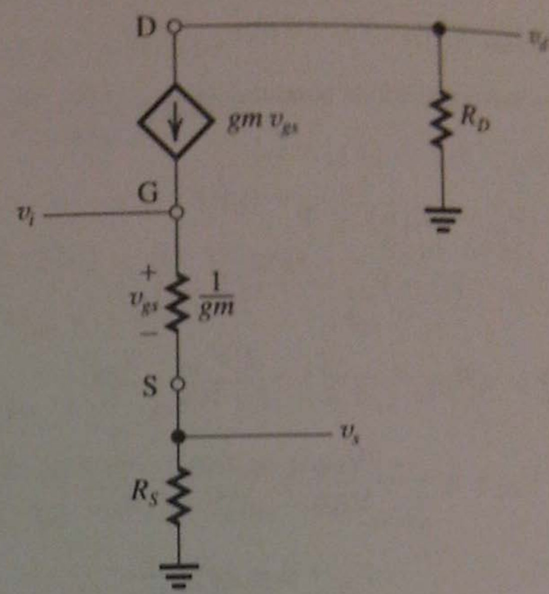
$V_2 = V_1 - V_{GS} = +2.5\text{V}.$

$V_3 = V_2 - V_{GS} = (1k)I_D = 0.9\text{ V}$

5.76



5.76 continues here



$$v_i = (g_m v_{gs})\left(\frac{1}{g_m} + R_S\right)$$

$$v_d = -g_m v_{gs} R_D$$

$$v_S = +g_m v_{gs} R_S$$

$$\therefore \frac{v_S}{v_i} = \frac{R_S}{\frac{1}{g_m} + R_S} = \frac{+g_m R_S}{1 + g_m R_S}$$

$$\frac{v_d}{v_i} = \frac{-R_D}{\frac{1}{g} + R_S} = \frac{-g_m R_D}{1 + g_m R_S}$$

5.79 $V_t = 1V$, $k_n' = \frac{W}{L} = 2\ mA/V^2$

(a) dc analysis $V_G = \frac{5}{15}\ 15\ V, = 5V$, assume

$I_D = 1$ mA

$V_S = 3$ V, $V_{GS} = 2$ V, $V_{OV} = 1$V.

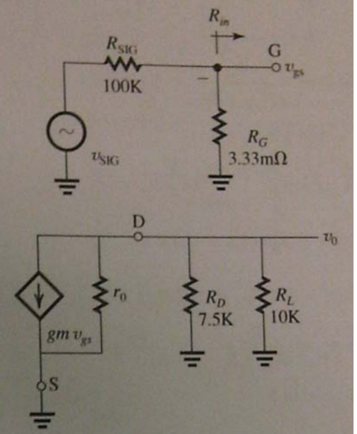
$I_D = \frac{1}{2} k' V_{OV}^2 = 1$ mA (check)

$V_D = V_{DD} - I_D R_D = 7.5\text{V}.$

(b) $r_o = \frac{V_A}{I_D} = \frac{100\text{ V.}}{1\text{ mA}} = 100\text{ k}\Omega$

$g_m = \sqrt{2k_n I_D} = 2\text{ mS}$

(c)



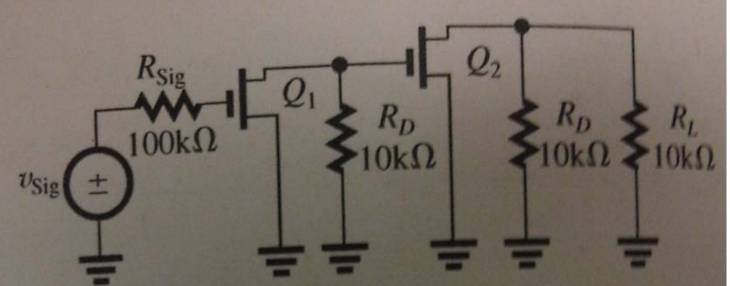
(d) $R_{in} = R_G = 3.33\text{ M}\Omega$

$\frac{v_{gs}}{v_{sig}} = \frac{R_{in}}{R_{sig} + R_{in}} = 0.97$

$\frac{v_o}{v_{gs}} = -g_m(r_o \| R_D \| R_L) = -8.2$

$\frac{v_o}{v_{sig}} = -8.0$

5.88



For Q_1 and Q_2: $I_D = 0.25\text{ mA}$

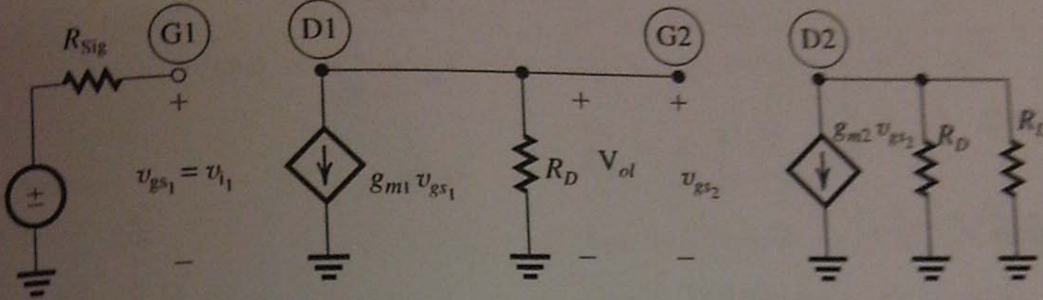
$Vov = 0.25\text{V} \Rightarrow g_{m1,2} = \frac{2 \cdot 0.25\text{ mA}}{0.25\text{ V}}$

$= \frac{2\text{ mA}}{\text{V}}$

V_A very large $\Rightarrow r_{o\,1,2} = \infty$

This figure belongs to 5.88

a)



b) Overall $G_V = G_{V1} \cdot G_{V2}$

$$Gv_1 = -g_{m1} \cdot (\infty \| R_D)$$

$$= \frac{-2 \text{ mA}}{\text{V}} \cdot 10 \text{ k}\Omega = -20\text{V/V}$$

$$Gv_2 = -g_{m2} \cdot (\infty \| R_D \| R_L)$$

$$= -\frac{2 \text{ mA}}{\text{V}} \cdot (10 \text{ K} \| 10 \text{ K})\Omega = -10\text{V/V}$$

$$\Rightarrow Gv = (-20) \cdot (-10) = 200\text{V/V}$$

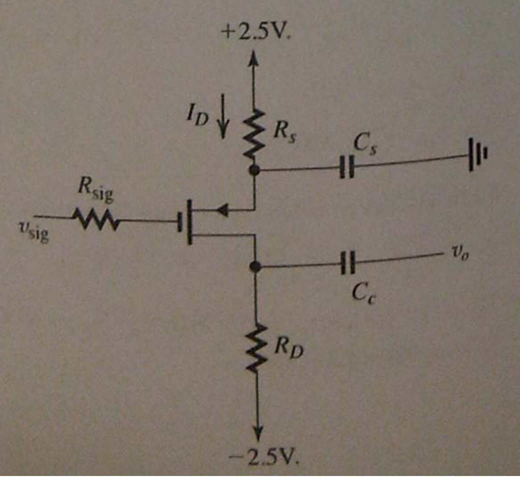
5.90 $g_m = 5 \text{ mS}$

$$i_d = g_m v_{gs} = \frac{g_m}{1 + g_m R_s} v_g$$

$$\frac{g_m}{1 + g_m R_s} = 1 \text{ mS}$$

$$\therefore R_s = \frac{4}{g_m} = 800\Omega$$

***D5.113**



$V_{tp} = -0.7\text{V}, \quad V_A \to \infty$

a) for $I_D = 0.3$ mA, $|V_{OV}| = 0.3$ V.

$V_{SG} = 1.0$ V., $V_G = 0$

$V_S = 2.5 - I_D R_S = 1.0$ V.

$\therefore R_S = 5.0\ \text{k}\Omega$

b) $g_m = \dfrac{2I_D}{V_{OV}} = 2$ mS

$$G_V = \frac{v_O}{v_{sig}} = -g_m R_D = -10$$

$\therefore R_D = 5.0\ \text{k}\Omega$

c) $v_{gd} + V_{GD} \geq V_{tp} = -0.7$

$$-\left|\hat{v}_o + \frac{\hat{v}_o}{10}\right| + 1\text{V.} \geq -0.7$$

$$\hat{v}_O \leq 1.55\text{V}_{\text{pk}}$$

$$\hat{v}_{sig} \leq \frac{\hat{v}_o,\ \text{max}}{10} = 0.155\text{V}_{\text{pk}}$$

d) for $\hat{v}_{sig} = 50$ mV, changed R_D

$$-\left|\hat{v}_O + \frac{\hat{v}_O}{g_m R_D}\right| + (2.5 - I_D R_D) \geq -0.7$$

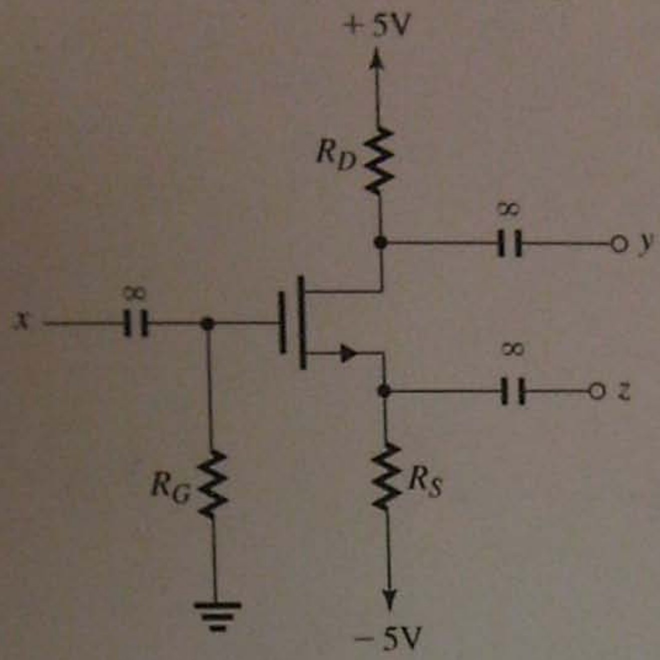
for $g_m = 2$ mS, $I_D = 0.3$ mA

$$-\left|\frac{1 + g_m R_D}{g_m R_D}\right| g_m R_D \hat{v}_{sig} + 2.5 - I_D R_D \geq -0.7$$

$R_D \leq 7.88\ \text{k}\Omega \qquad (\hat{v}_{sig} = 50\ \text{mV})$

$G_V = -g_m R_D = -15.8$

5.115



$V_t = 1V.$ $k_n = 0.8mA/V^2$

$V_A = 40V.$ $I_D = 0.1mA$

a) $R_G = 10\ M\Omega$

$$V_{OV} = \sqrt{\frac{2I_D}{k_n}} = 0.5V.$$

$V_{GS} = 1.5V.$ $R_S = 35k\Omega$

for $V_D = V_S + V_O + 1V. = 0V.$

$R_D = 50k\Omega$

b) $$g_m = \frac{2I_D}{V_{OV}} = 0.4mS$$

$$r_0 = \frac{V_A}{I_D} = 400\ k\Omega$$

c) $$G_V = \frac{v_\varphi}{v_{sig}} = -\frac{10M}{1M + 10M} g_m \cdot$$

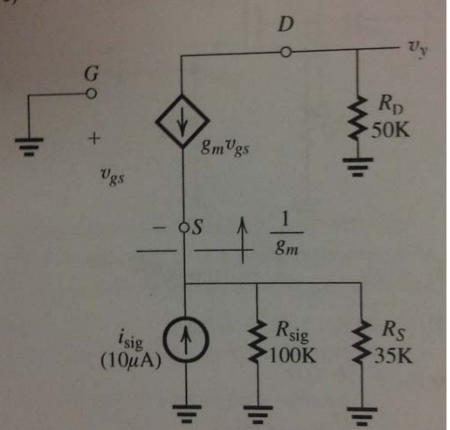
$(r_0 \| R_D \| 40K) = -7.7$

$$\frac{v_Z}{v_X} = \frac{+g_m(R_S \| r_O)}{1 + g_m(R_S \| r_O)} = 0.93$$

$$R_{out} = \frac{1}{g_m} \| R_s \| r_O$$

$$= 2.32 \text{ k}\Omega$$

e)



$$v_y = i_{sig}\left[\frac{1}{g_m} \| R_{sig} \| R_s\right] g_m R_D$$

$$= (45.6 \text{ k}\Omega) i_{sig}$$

$$= 0.456\text{V}.$$