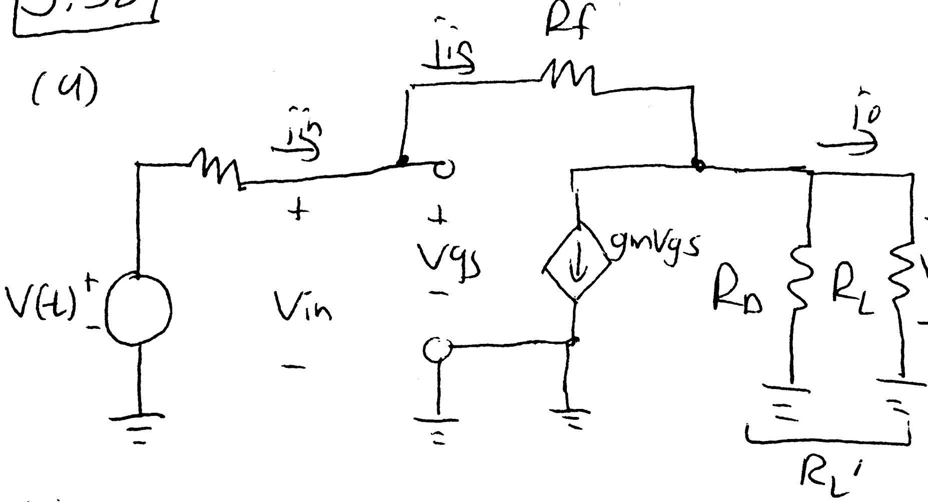
EECS 245 HMWK #7 Soln

5.38

(a)



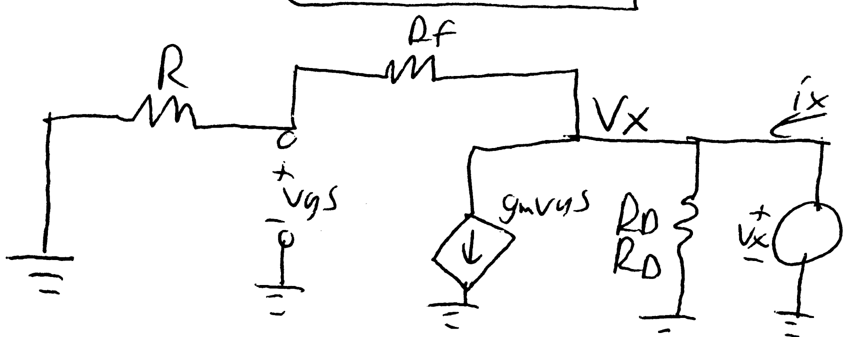
Remember, for small-signal model, C's + DC voltage sources are shorted, but the small signal, $V(t)$ is <u>not</u> shorted!

(b) From above, $V_o = R_L' i_o$ $i_o = i_{in} - g_m V_{gs}$ ∴ $\underline{V_o = R_L'(i_{in} - g_m V_{gs})}$

$\underline{i_{in} = \frac{V_{in} - V_o}{R_f}}$. Combing these two yields $\boxed{\frac{V_o}{V_{in}} = \frac{R_L' - g_m R_L' R_f}{R_L' + R_f} = A_v}$

$R_{in} = \frac{V_{in}}{i_{in}}$. $i_{in} = \frac{(V_{in} - V_o)}{R_f} \Rightarrow \frac{i_{in}}{V_{in}} = \left(\frac{1 - \frac{V_o}{V_{in}}}{R_f}\right) \Rightarrow \frac{V_{in}}{i_{in}} = \frac{R_f}{1 - \frac{V_o}{V_{in}}}$

$\frac{V_o}{V_{in}} = A_v$ ∴ $\boxed{R_{in} = \frac{R_f}{1 - A_v}}$



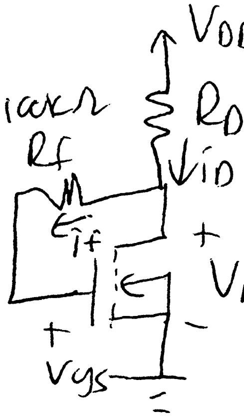
To measure output impedance, use the following circuit. $V(t)$ is shorted, but the dependen dant source cannot be ignored.

Note that $R_D // (R + R_f) = R_D'$ (R_D is in parallel with $(R + R_f)$)

$V_{gs} = V_x \left(\frac{R}{R + R_f}\right)$ (V_{gs} will divide along $R + R_f$) $i_x = \frac{V_x}{R_D'} + g_m V_{gs}$

Combining, $\frac{V_x}{i_x} = \boxed{R_o = \frac{1}{\frac{1}{R_D'} + \frac{g_m R}{R_f + R}}} = \frac{R_D'(R_f + R)}{R_f + R(1 + g_m R_D')}$

(c) The dc circuit is:



$i_f = 0$ since input impedance of MOSFET for DC $= \infty$ ∴

$V_{GSQ} = V_{DSQ}$ Assuming saturation →

$I_{DSQ} = K(V_{GSQ} - V_{TO})^2 = \underline{K(V_{DSQ} - V_{TO})^2}$

$I_{DQ} = \dfrac{(V_{DD} - V_{DSQ})}{R_D}$ Combining ⇒

$3V_{DSQ}^2 - 24V_{DSQ} + 55 = 0$

Solving, $V_{DSQ} = 7.08, 2.59$

Since $V_{DS} = V_{gs}$, & $V_{TO} = 5V$, V_{DS} must $= 7.08$ for transistor to be on.

Check: $7.08 > 7.08 - 5$ ✓ Saturation assumption correct

$\boxed{V_{DSQ} = 7.08}$ $I_{DQ} = \dfrac{(20 - 7.08)}{3K} = \boxed{4.31 mA}$

$g_m = \left.\dfrac{\partial i_D}{\partial v_{gs}}\right|_{Q\text{-point}}$ $I_{DQ} = K(V_{gsQ} - V_{TO})^2 \Rightarrow \dfrac{\partial I_{DQ}}{\partial V_{gsQ}} = 2K(V_{gsQ} - V_{TO})$

$\boxed{g_m = 4.16 \times 10^{-3} S}$

(d) $R_L' = R_D \| R_L = \boxed{2.31 K\Omega}$ plugging into expressions in (d) yields:

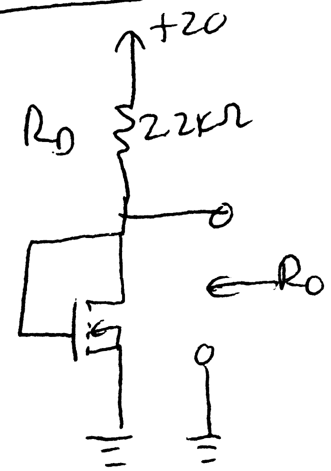
$\boxed{A_v = -9.37}$ $\boxed{R_{in} = 9.64 K\Omega}$ $\boxed{R_o = 414 \Omega}$

(e) $V_o(t) = V(t)\left(\dfrac{R_{in}}{R + R_{in}}\right) A_v$ $V_o(t) = (-.164)\sin(2000\pi t)$

(f) This is an inverting amplifier (A_v is negative). The input impedance is very low in comparison with most FET amplifiers

This is generally not a good thing, as seen in part (e); the output is smaller than the input because $R_{in} << R$.

5.34

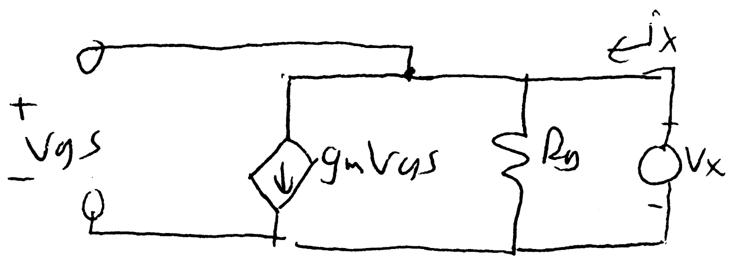


$V_{gsQ} = V_{DSQ} \therefore \underline{I_{DQ} = K(V_{DSQ} - V_{TO})^2}$

$I_{DQ} = \dfrac{(V_{DD} - V_{DSQ})}{R_D}$ Combining, $1.1V_{DSQ}^2 - 5.6V_{DSQ} - 10.1 = 0$

$V_{DSQ} = \underline{6.5}, -1.41 \therefore$ $\boxed{V_{DSQ} = 6.5,\ I_{DQ} = 6.135mA}$

$g_m = \dfrac{\partial i_D}{\partial V_{gs}} = 2K(V_{gs} - V_{TO}) = \boxed{3.5mS}$

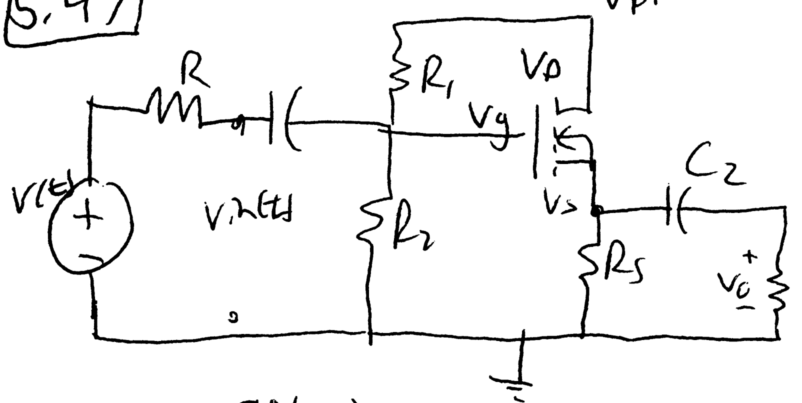


(V_x & i_x are used to calculate R_o and are <u>NOT</u> part of the normal Small-Signal model)

$i_x = \dfrac{V_x}{R_D} + g_mV_{gs}$ $V_{gs} = V_x \therefore R_o = \dfrac{V_x}{i_x} = \dfrac{V_x}{\frac{V_x}{R_D} + g_mV_x} =$

$\dfrac{1}{1/R_D + g_m}$ $\boxed{R_o = 253\Omega}$

5.47



First, $K = \left(\frac{W}{L}\right)\left(\frac{KP}{2}\right) = \left(\frac{160}{10}\right)\left(\frac{50\times10^{-6}}{2}\right)$

$\boxed{K = 400\frac{uA}{V^2}}$

$I_{DQ} = K(V_{gsQ} - V_{TO})^2 \Rightarrow$

$V_{GSQ} = V_{TO} + \sqrt{\frac{I_{DQ}}{K}}$ $\underline{V_{gsQ} = 3.236}$

$V_g = 15\left(\frac{2M}{1M+2M}\right) = \underline{10V}$ $V_g - V_s = V_{gs}$ $V_S = I_{DQ}R_S \therefore$

$V_{gs} = V_g - I_{DQ}R_S$ $R_S = \dfrac{V_{gs} - V_g}{-I_{DQ}}$ $\boxed{R_S = 3.382k\Omega}$

From eqn. 5.26, $g_m = 2K(V_{gsK} - V_{TO})$

$\underline{g_m = 1.79mS}$

Looking at pg 321 in the text, $R_L' = \dfrac{1}{\frac{1}{r_d} + \frac{1}{R_s} + \frac{1}{R_L}}$ $r_d = \infty$ ∴

$R_L' = 1{,}257\,k\Omega$

$R_{in} = R_1 \parallel R_2$ $\boxed{R_{in} = 666.7\,k\Omega}$

$A_V = \dfrac{g_m R_L'}{1 + g_m R_L'}$ $\boxed{A_V = .6923}$ $R_o = \dfrac{1}{g_m + \frac{1}{R_s} + \frac{1}{r_d}}$ $\boxed{R_o = 479.5\,\Omega}$