ENEE 233 Ch 5 Homework Solutions

5.30

$I_{DS} = 1mA$, $V_D = 0V$

$$I_{DS} = \frac{V_{DD} - V_D}{R_D}$$

$$\therefore R_D = \frac{V_{DD} - V_D}{I_{DS}} = \frac{2.5 - 0}{1mA} = 2.5\,K\Omega$$

$$I_{DS} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} \left(V_{GS} - V_T \right)^2$$

$$1mA = \frac{1}{2}(60)\left(\frac{100}{3}\right)\left(V_{GS} - 1\right)^2$$

$$\therefore V_{GS} = 2V$$

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

$$\therefore V_S = -2V$$

$$I_{DS} = \frac{V_S - V_{SS}}{R_S} = \frac{-2 + 2.5}{1mA} = 0.5K\Omega$$

5.33

$$I_{DS1} = \frac{1}{2}\mu_n C_{ox}\frac{W_1}{L_1}\left(V_{GS1} - V_T\right)^2$$

$$V_{GS1} = V_{DS1} = 1.5\,V$$

$$120\,\mu A = \left(\frac{1}{2}\right)\left(250\,\frac{\mu A}{V^2}\right)\frac{W_1}{0.25\,\mu m}\left(1.5-0.6\right)^2$$

$$\therefore W_1 = 0.296\,\mu m$$

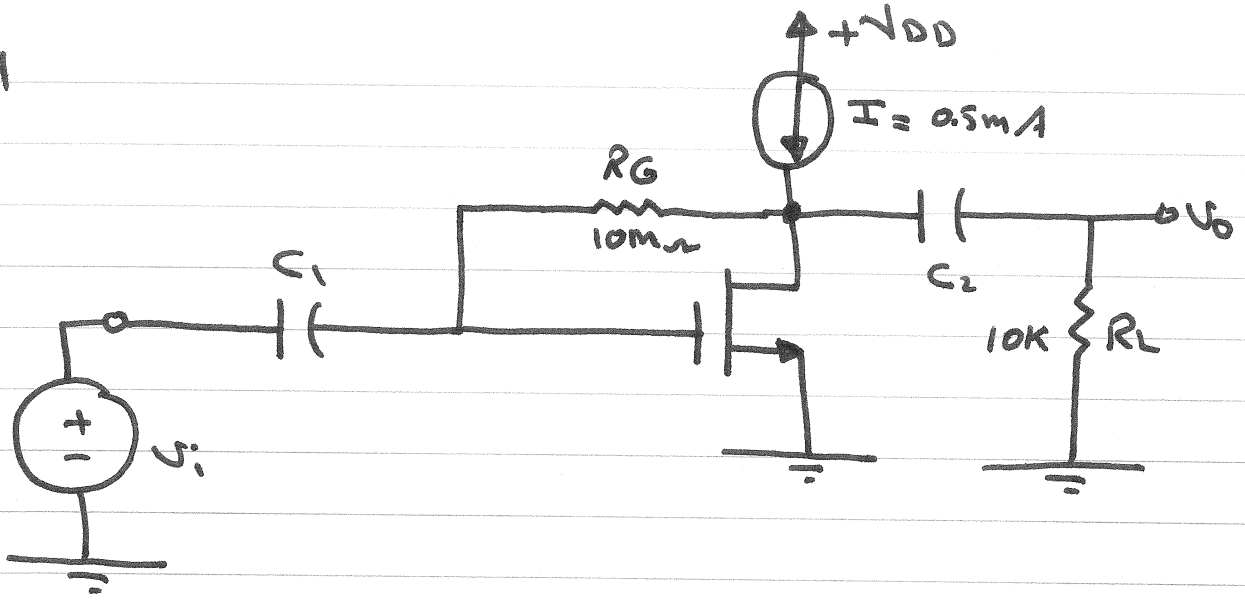
$$V_{GS2} = V_{G2} - V_{S2} = 3.5 - 1.5 = 2V$$

$$I_{DS2} = \frac{1}{2}\mu_n C_{ox}\frac{W_2}{L_2}\left(V_{GS2} - V_T\right)^2$$

$$\therefore W_2 = 0.122\,\mu m$$

$$R = \frac{5-3.5}{120\,\mu A} = 12.5\,K$$

5.54



$V_T = 0.9V$, $V_A = 50V$, $V_D = 2V$

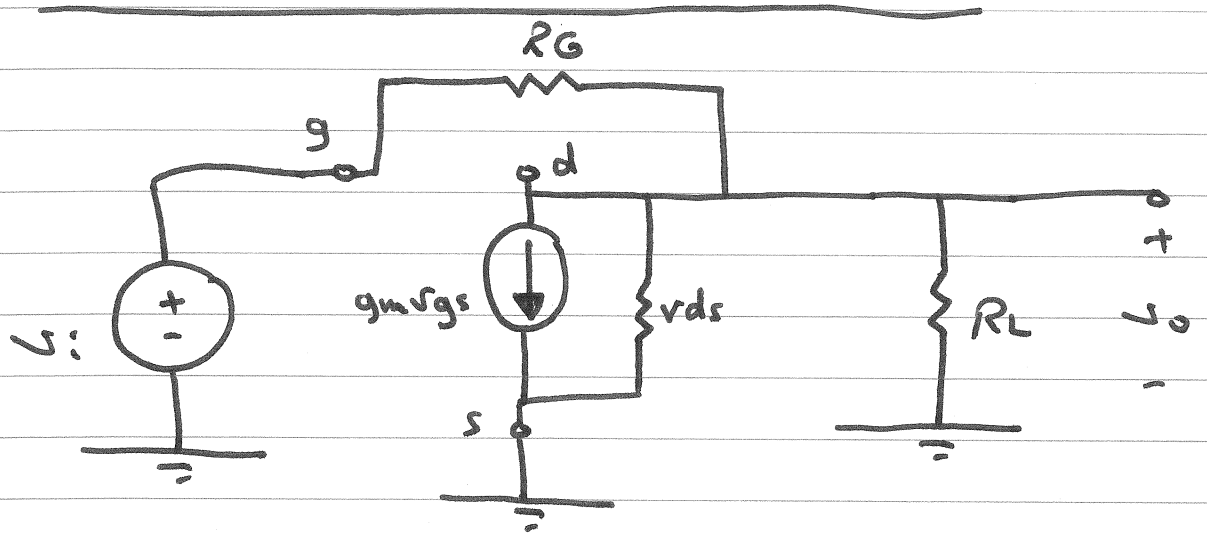
$$r_{ds} = \frac{V_A}{I_{DS}} = \frac{50V}{0.5mA} = 100K\Omega$$

$$I_{DS} = K_n (V_{GS} - V_T)^2$$

$$g_m = 2K_n (V_{GS} - V_T)$$

$$\therefore g_m = \frac{2 I_{DS}}{V_{GS} - V_T} = 0.9 \, mA/V$$

ac Small Signal equivalent CKT



KCL : $0 = g_m v_{gs} + \frac{v_o}{r_{ds}} + \frac{v_o}{R_L} + \frac{v_o - v_i}{R_G}$

$v_{gs} = v_g - v_s$

$v_g = v_i$, $v_s = 0$

$\therefore A_v = \frac{v_o}{v_i} = -8.265$

For $I_{DS} = 0.5mA$

$I_{DS} = K_n (V_{GS} - V_T)^2$

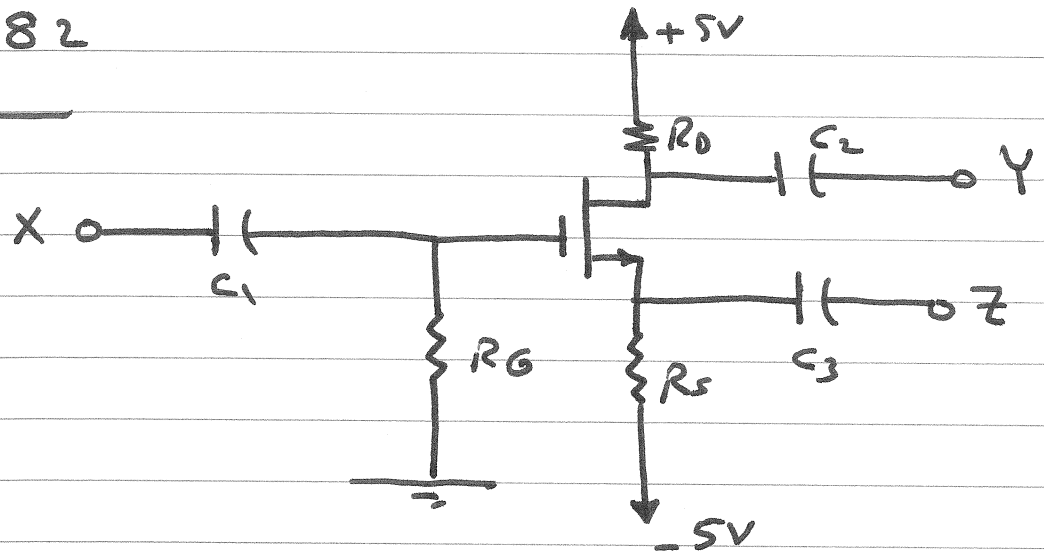
$\therefore K_n = \frac{I_{DS}}{(V_{GS} - V_T)^2} = \frac{0.5mA}{(2-0.9)} = 0.413 mA/V^2$

Now For $I_{DS} = 1mA$

$I_{DS} = K_n (V_{GS} - V_T)^2 = 1mA$

$\therefore V_{GS} = 2.456V$, $\therefore V_D = 2.456V$

5.82



For the n-channel EMOSFET to be in the pinch off region ; $V_{DS} > V_{GS} - V_T$

or $V_D > V_G - V_T$

$\therefore V_{D(min)} = V_G - V_T = 0 - 1 = -1V$

$\therefore$ let $V_D = 0$

$$5 = R_D I_{DS} + V_D$$

$$\therefore R_D = \frac{5 - V_D}{I_{DS}} = \frac{5}{0.1mA} = 50K\Omega$$

$$I_{DS} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)^2$$

$$0.1mA = \left(\frac{1}{2}\right)\left(0.8 \frac{mA}{V^2}\right)(V_{GS} - 1)^2$$

$\therefore V_{GS} = 1.5V$

KVL : $V_{GS} + R_S I_{DS} - 5 = 0$

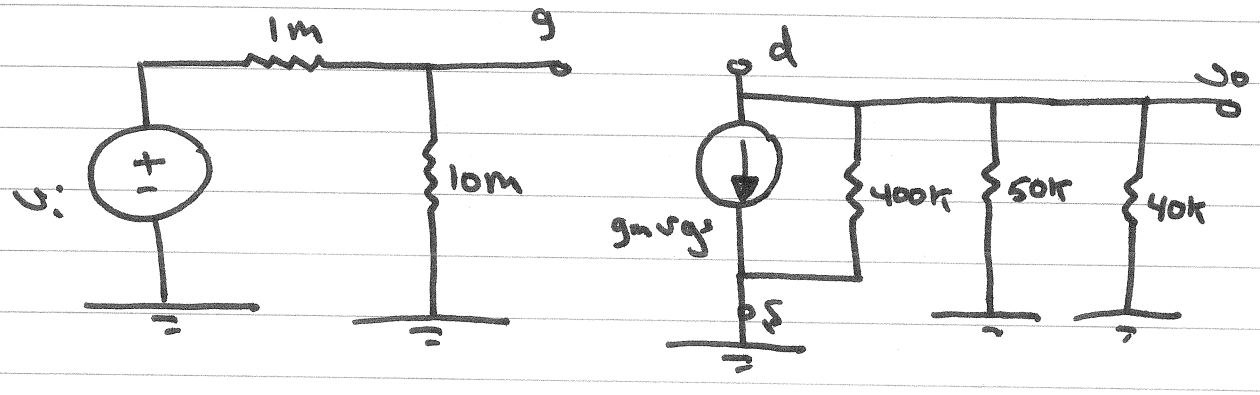
$\therefore R_S = 35K$

$$Z_i = R_G = 10M\Omega$$

$$g_m = \frac{2I_{DS}}{V_{GS} - V_T} = 0.4\ mA/V$$

$$r_{ds} = \frac{V_A}{I_{DS}} = 400k$$

c)



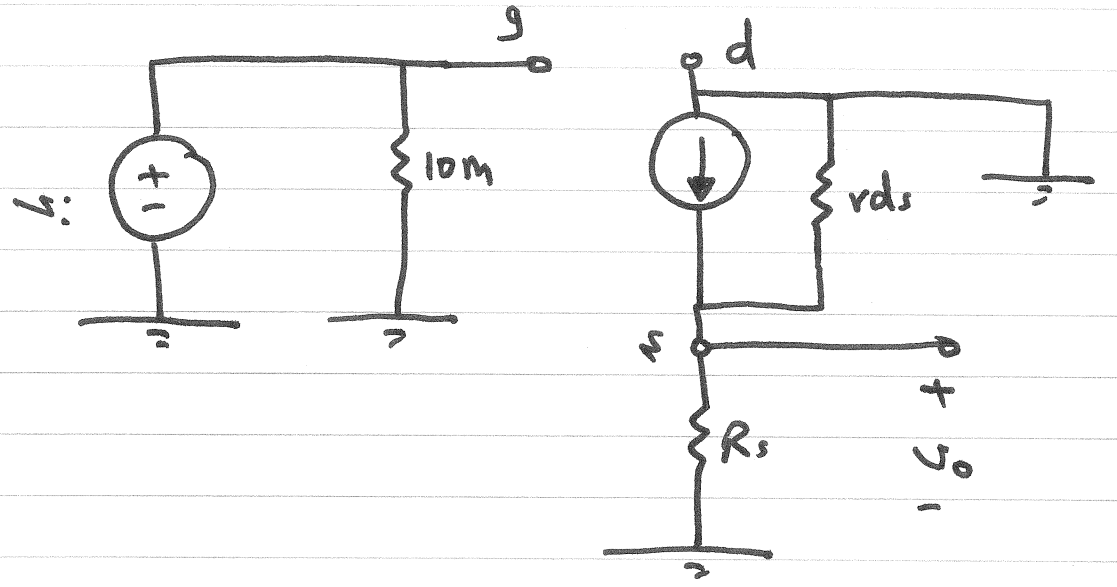
$$v_o = -g_m v_{gs} \left(400k \parallel 50k \parallel 40k \right)$$

$$v_{gs} = v_g - v_s = v_g$$

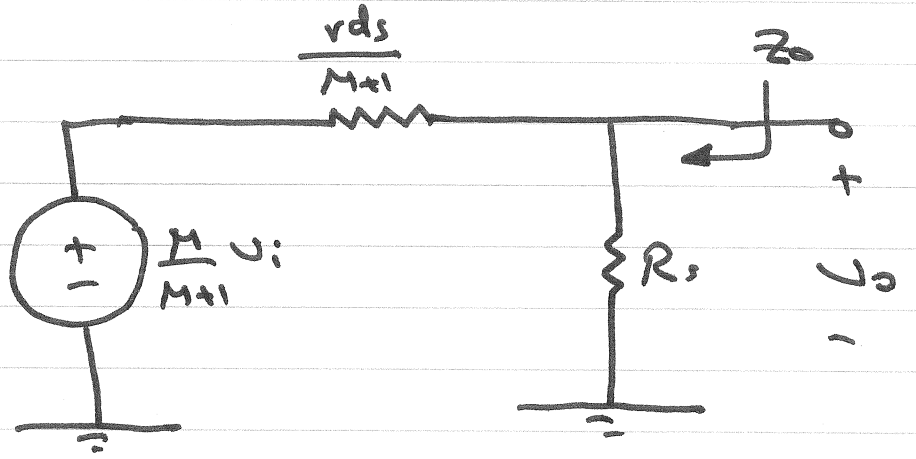
$$v_g = \frac{10M}{1M + 10M} v_i$$

$$\therefore A_v = \frac{v_o}{v_i} = -7.66$$

d)



To find V_o, we go to source equivalent ckt



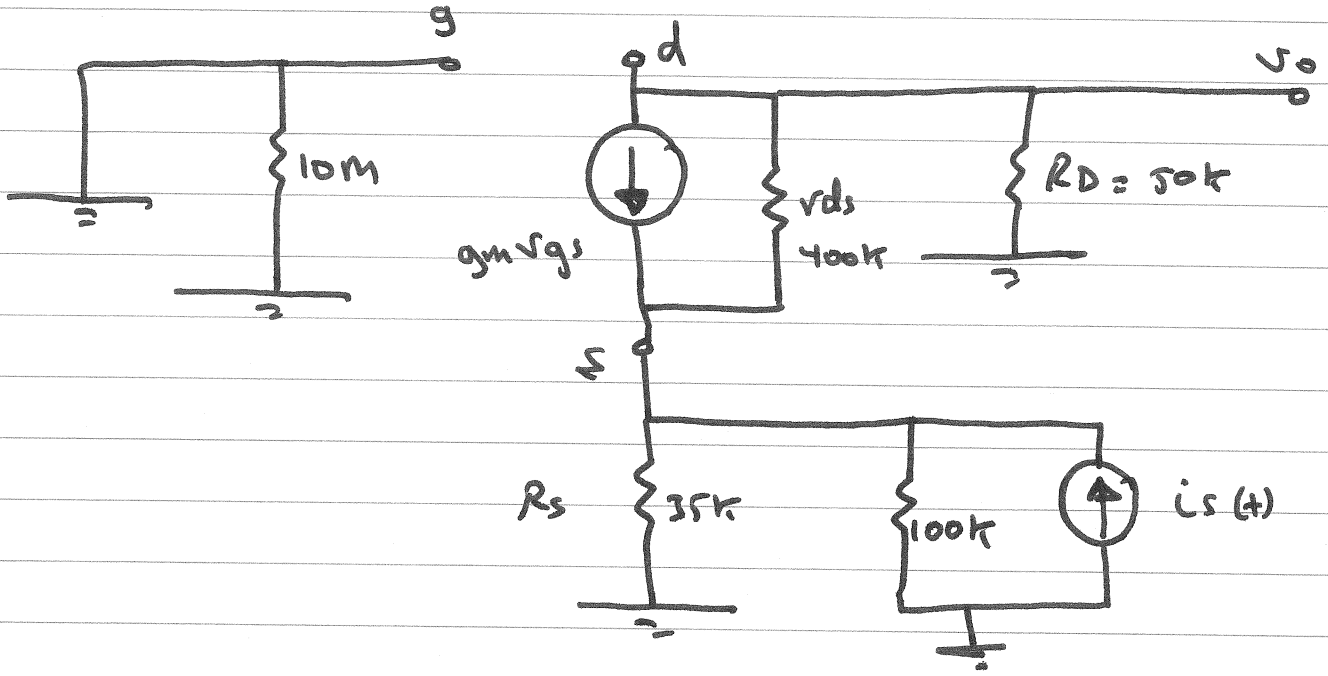
$$M = g_m r_{ds} = 160$$

$$V_o = \frac{R_s}{R_s + \frac{r_{ds}}{M+1}} \cdot \frac{M}{M+1} V_i$$

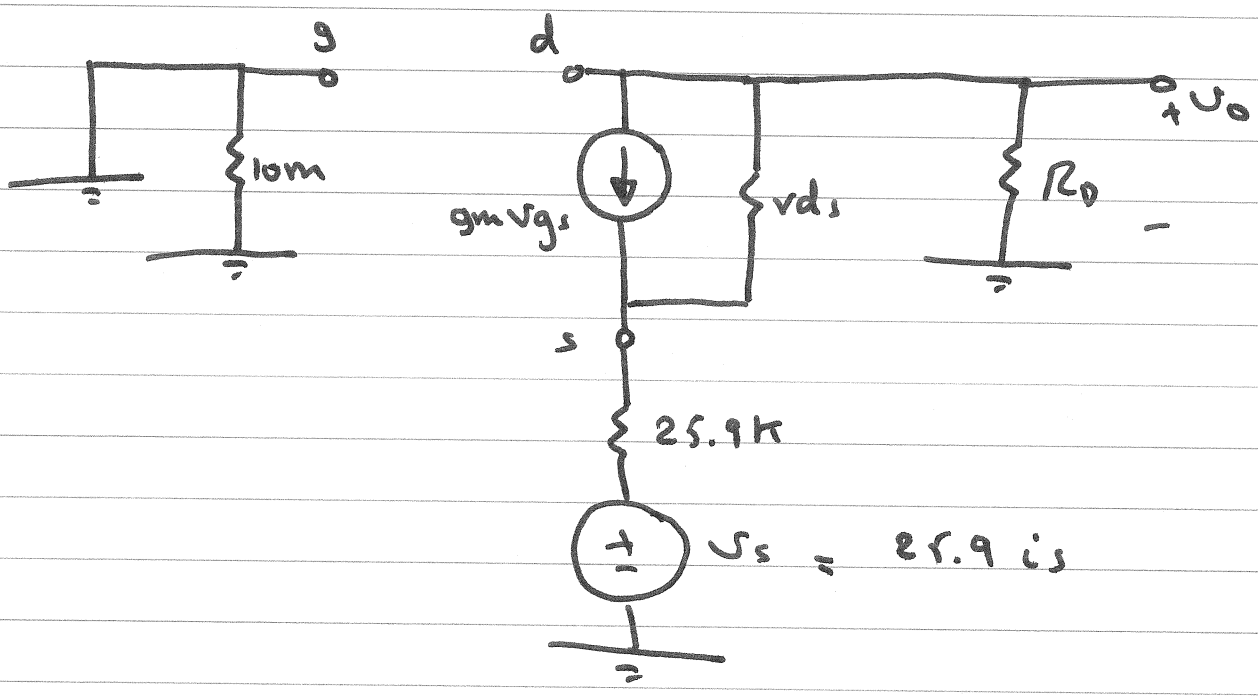
$$\therefore A_v = \frac{V_o}{V_i} = 0.993$$

$$Z_o = R_s \parallel \frac{r_{ds}}{M+1}$$

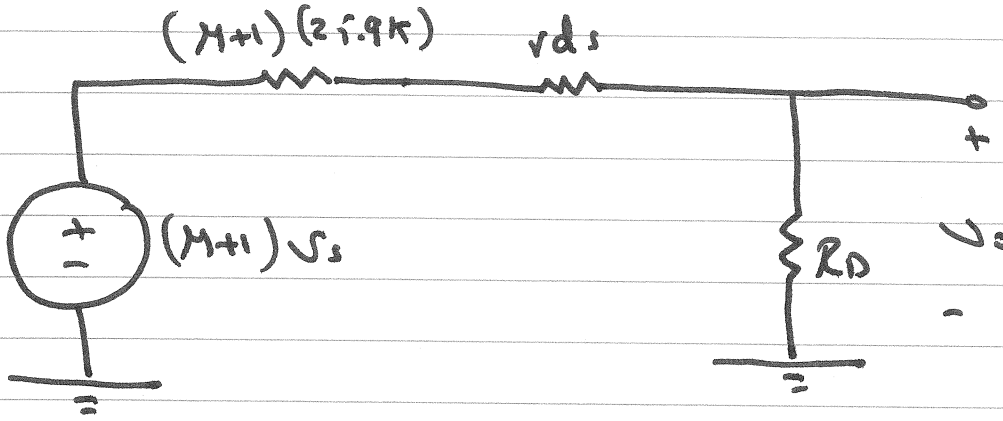
e)



The circuit can be simplified to the following



To find v_o, we go to drain equivalent ckt



$v_s = (25.9\,K)\,i_s$; $M = g_m r_{ds} = 160$

$$v_o = \frac{R_D\ (M+1)\,v_s}{R_D + (M+1)(25.9\,K)}$$

$$\therefore A_v = \frac{v_o}{v_s} = 1.74$$

$$\therefore v_o = 1.74\,v_s$$

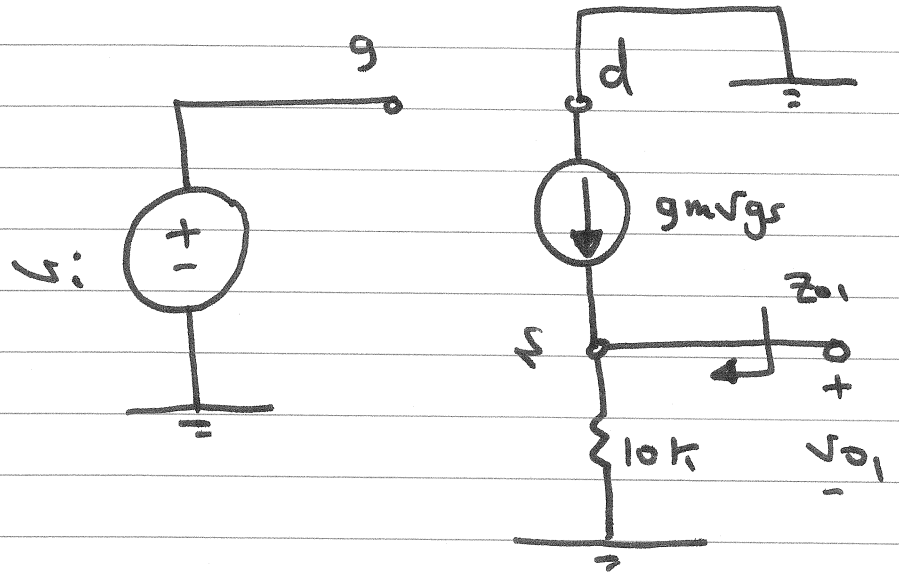
$$v_o = 1.74\ (25.9\,K)(10\,mA)$$

$$v_o = 0.45\ V$$

5.83

$g_m = 5\,mA/V$, $v_{ds} = \infty$

ac small signal equivalent ckt for 5.83 (a)



$v_{o1} = g_m v_{gs} (10k)$

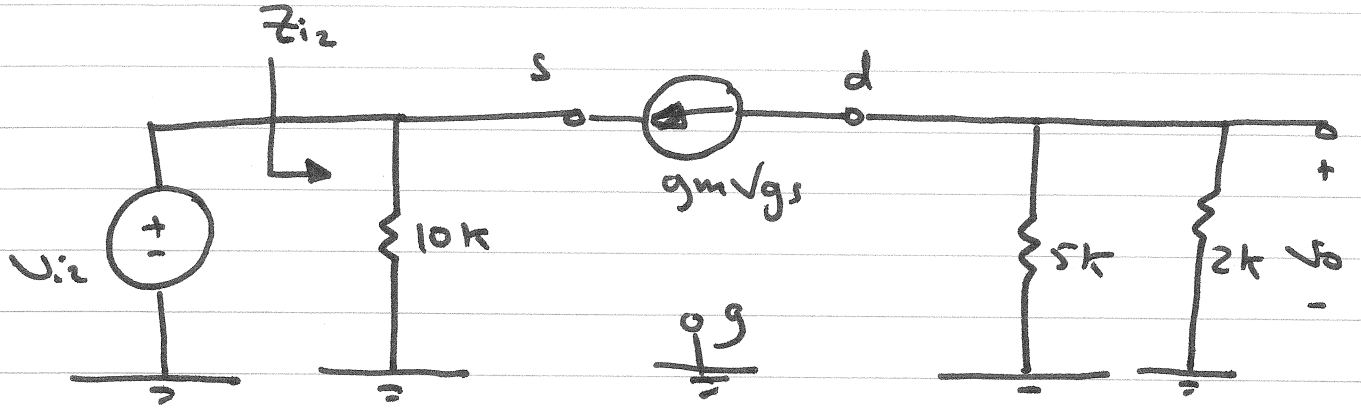
$v_{gs} = v_g - v_s$

$v_g = v_i$; $v_s = (10k)\, g_m v_{gs} = v_{o1}$

$$\therefore A_{v_1} = \frac{v_{o1}}{v_i} = \frac{50}{51} \approx 1$$

$$Z_{o_1} = 10k \,||\, \frac{1}{g_m} = 10k \,||\, 0.2k \cong 0.196k$$

ac small signal equivalent ckts for 5.83 (b)



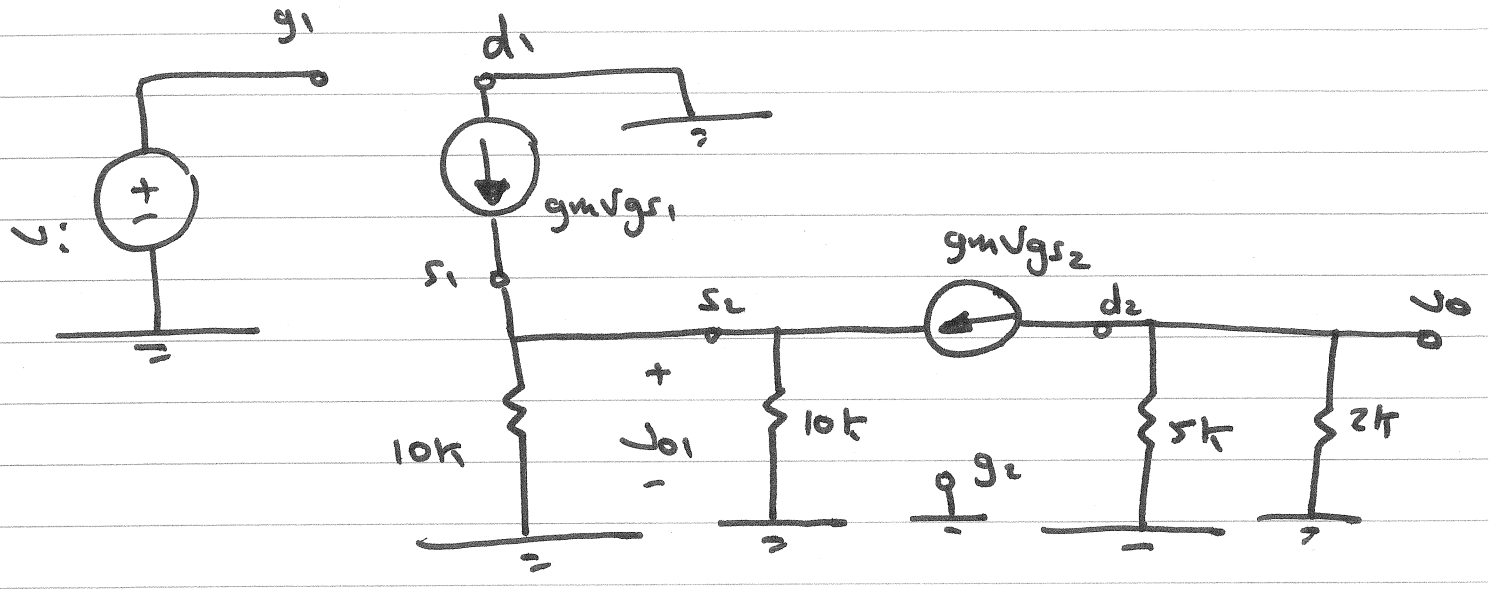
$$Z_{i2} = 10k \parallel \frac{1}{g_m} = 0.196k$$

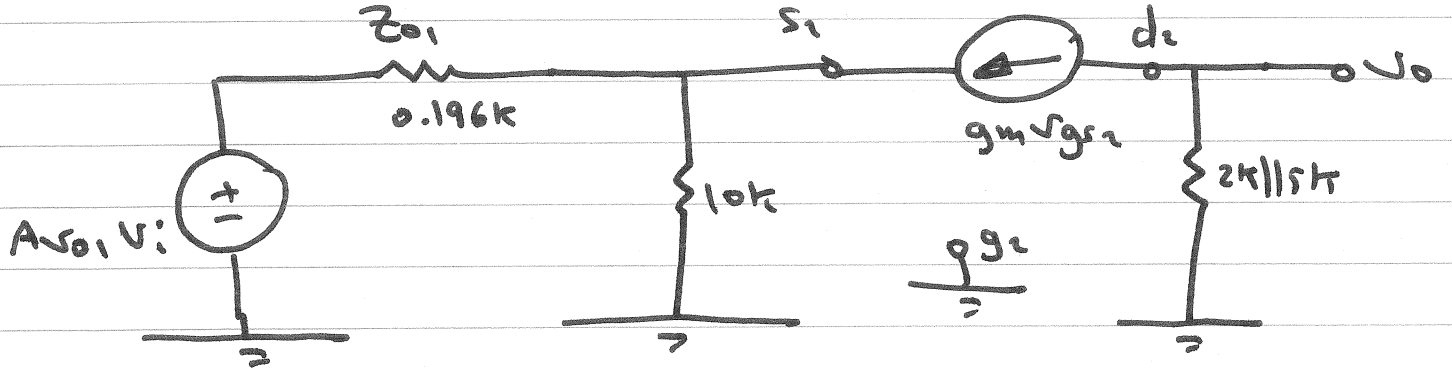
$$v_o = -g_m v_{gs} (5k \parallel 2k)$$

$$v_{gs} = v_g - v_s = 0 - v_s = v_{i2}$$

$$\therefore A_{v2} = \frac{v_o}{v_{i2}} = 7.143$$

ac small signal equivalent ckt for the Complete amplifier:





$$V_o = -g_m V_{gs2} (2k \| 5k)$$

$$V_{gs2} = V_{g2} - V_{s2} = -V_{s2}$$

$$V_{s2} = \frac{Z_{i2}}{Z_{i2} + Z_{o1}} A_{v01} V_i$$

$$A_v = \frac{V_o}{V_i} = (0.49)(7.14) = 3.5$$