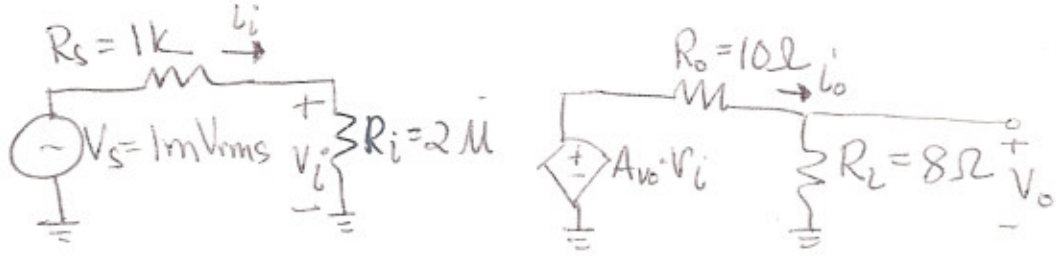
Homework #1 Soln

1.



a. Voltage gain, V_o/V_i:

Voltage divider $\Rightarrow V_o = A_{vo} \cdot V_i \frac{R_L}{R_L + R_o}$

$$\frac{V_o}{V_i} = 100 \frac{8}{8+10} = \boxed{44.4 \, V/V}$$

overall voltage gain, V_o/V_s:

voltage divider $\Rightarrow V_i = V_s \cdot \frac{R_i}{R_i + R_s}$

$$V_o = \underbrace{A_{vo} \frac{R_L}{R_L + R_o}}_{V_o/V_i} \cdot \frac{R_i}{R_i + R_s} \cdot V_s \Rightarrow \frac{V_o}{V_s} = \frac{100(8)}{18} \cdot \frac{2M}{2M+1K} = \boxed{44.4 \, V/V}$$

$$\frac{V_o}{V_s} = 20 \log(44.4) \cong \boxed{33 dB}$$

b. Current gain, i_o/i_i:

$$i_o = \frac{A_{vo} V_i}{R_o + R_L} \quad \text{and} \quad i_i = \frac{V_s}{R_s + R_i}$$

$$\therefore \frac{i_o}{i_i} = \frac{A_{vo}}{R_o + R_L} \cdot \frac{V_i}{V_s} \cdot \frac{R_s + R_i}{1} = \frac{100}{18} \cdot \frac{V_s \cdot R_i}{V_s (R_i + R_s)} \cdot (R_i + R_s)$$

$$\frac{i_o}{i_i} = \frac{100}{18} \cdot 2M = 11.1 \, M \, A/A$$

OR

$$i_o = \frac{V_o}{R_L} \quad \text{and} \quad i_i = \frac{V_i}{R_i}$$

$$\therefore \frac{i_o}{i_i} = \frac{V_o}{V_i} \frac{R_i}{R_L} = 44.4 \left(\frac{2M}{8} \right) = \boxed{11.1 \, M \, A/A} = \boxed{141 dB}$$

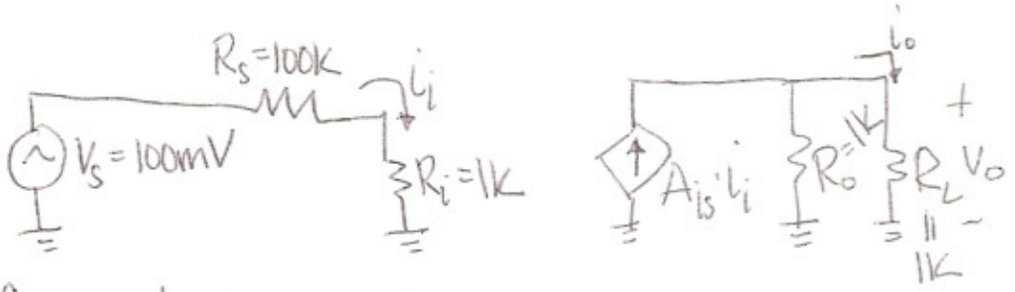
1. c. (cont.)

power gain $= A_{vs} \cdot A_i = (44.4 \cdot 11.1\,M) \cong \boxed{493\,M\,\frac{W}{W} \cong 87\,dB}$

d. If $R_i = 1K\Omega$:

$$A_{vs} = \frac{A_{vo} \cdot R_L}{R_L + R_o} \cdot \frac{R_i}{R_i + R_s} = \frac{100(8)}{18} \cdot \frac{1K}{2K} = \boxed{22.2\,V/V \cong 27\,dB}$$

2.



a. Current gain: $\frac{i_o}{i_i}$

$i_o \Rightarrow$ current divider $\Rightarrow i_o = \frac{A_{is} \cdot i_i \cdot R_o}{R_o + R_L}$

$$\frac{i_o}{i_i} = \frac{100\,(1K)}{2K} = \boxed{50\,A/A \cong 34\,dB}$$

b. Voltage gain: $V_o = A_{is} \cdot i_i (R_o \| R_L)$

$$i_i = \frac{V_s}{R_s + R_i} \Rightarrow \frac{V_o}{V_s} = 100\left(\frac{1}{101K}\right)(500) \cong \boxed{0.5\,V/V = -6.1\,dB}$$

c. power gain $= \frac{V_o}{V_s} \cdot \frac{i_o}{i_i} = 0.5\,V/V \cdot 50\,A/A = \boxed{25\,W/W \cong 14\,dB}$

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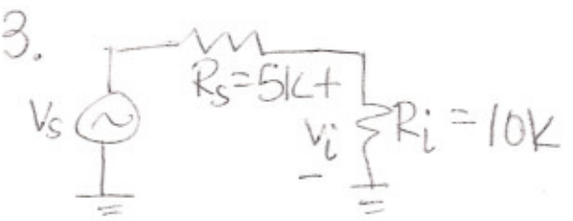
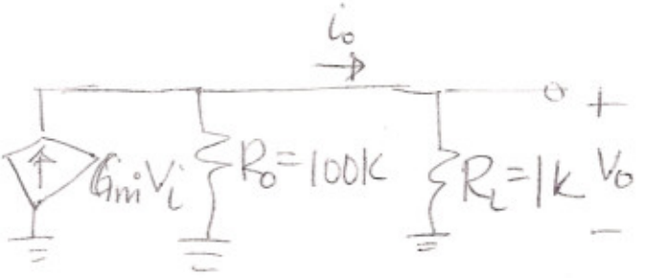
3.





$$V_o = G_m \cdot V_i \cdot (R_o \| R_L) = 80m \cdot V_i (100k \| 1k)$$

$$V_i = \frac{V_s \cdot R_i}{R_i + R_s} = \frac{V_s \cdot 10k}{15k} = 0.67 V_s$$

$$\frac{V_o}{V_s} = 80m\,(0.67)(990) = \boxed{53\ V/V}$$

4. $i_D = \frac{1}{2} k_n' \left(\frac{W}{L}\right)(V_{GS} - V_t)^2$

$$1m = \tfrac{1}{2}(0.5m)(V_{GS}-1)^2$$

$$\sqrt{4} = (V_{GS}-1)^2$$

$$2 = V_{GS} - 1$$

$$\therefore V_{GS} = \boxed{3V}$$

$$V_{DSmin} = V_{GS} - V_t = 3 - 1 = \boxed{2V}$$

$$i_D = 0.3m \Rightarrow 0.3m = \tfrac{1}{2}(0.5m)(V_{GS}-1)^2$$

$$V_{GS} \cong \boxed{2.1V}$$

$$V_{DSmin} = V_{GS} - V_t = 2.1 - 1 = \boxed{0.1V}$$

5.

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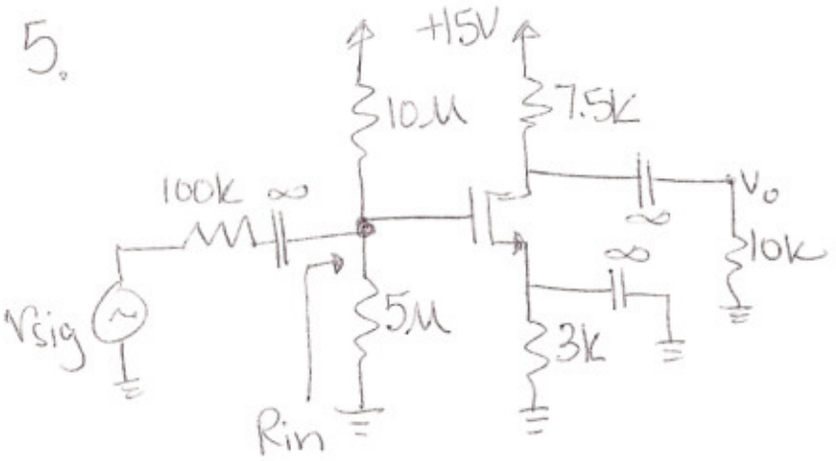
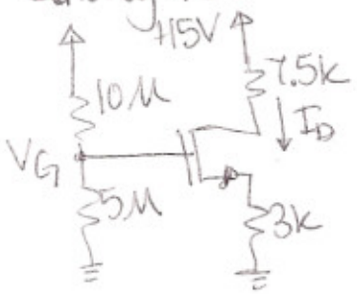


• DC analysis:



$$V_G = \frac{15(5M)}{5M+10M} = 5V$$

$$I_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)(V_{GS}-V_t)^2$$

$$I_D = \frac{1}{2}(1m)(5-I_D(3k)-1)^2$$

$$2kI_D = 16 - 24kI_D + I_D^2(3k)^2$$

$$0 = 16 - 26kI_D + I_D^2(3k)^2 \Rightarrow I_D = \frac{+26k \pm \sqrt{(26k)^2 - 4(3k)^2(16)}}{2(3k)^2}$$

$$I_D = 0.002,\ 890\mu$$

$I_D = 0.002(3k) = 6V \Rightarrow V_{GS} = -1$ (cutoff)

$\therefore I_D \cong 890\mu$, $V_{GS} = 5 - 890\mu(3k) = 2.33V$

$V_D = 15 - 890\mu(7.5k) = 8.325V$

$\therefore$ SAT $\Rightarrow (V_{DS} \geq V_{GS} - V_t)$ → correct choice

• parameters: $g_m = \frac{2I_D}{V_{OV}} = \frac{2(890\mu)}{2.33-1} = 1.34m$

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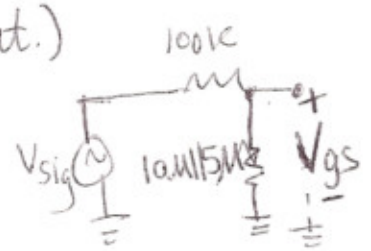
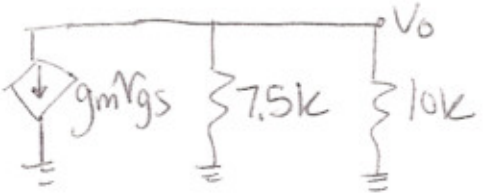
5. (cont.)





$R_{in} = 10M \,||\, 5M = \boxed{3.33M}$

voltage divider:

$\frac{V_{gs}}{V_{sig}} \Rightarrow V_{gs} = \frac{V_{sig}(3.33M)}{3.33M + 100K} \Rightarrow \frac{V_{gs}}{V_{sig}} = 0.97 \frac{V}{V}$

$V_o = -g_m V_{gs} (7.5K) || (10K) = (+1.34m)(4.3K) V_{gs}$

$\frac{V_o}{V_{gs}} = 5.74$

$\frac{V_o}{V_{sig}} = \frac{V_o}{V_{gs}} \cdot \frac{V_{gs}}{V_{sig}} = 5.74(0.97) = \boxed{5.6 \frac{V}{V}}$

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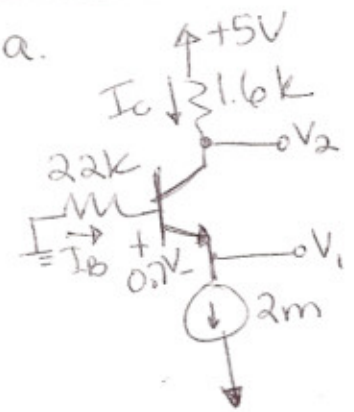
6. a.



$\beta = 50$

$I_E = 2m$

$I_B = I_E / \beta + 1 = 39.2\mu$

$V_B = -I_B (22K) = -0.86$

$V_1 = -0.7 - 0.86 = \boxed{-1.56V}$

$I_C = \alpha I_E = \frac{50}{51}(2m) = 1.96m$

$V_2 = 5 - 1.96m(1.6k) = \boxed{1.86V}$

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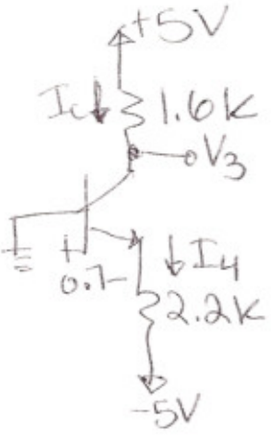
6. b.



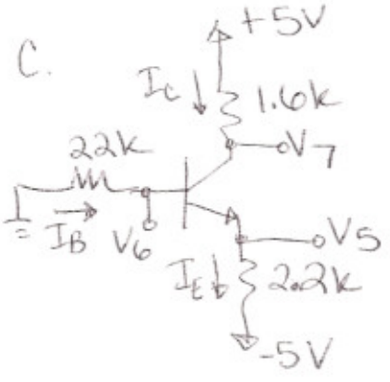
$+0.7 + I_4(2.2k) - 5 = 0$

$I_4 = \boxed{1.96m}$

$I_c = \alpha I_4 = 1.92mA$

$V_3 = 5 - 1.6k(1.92m) = \boxed{1.93V}$

c.



$0 - I_B(22k) + 0.7 - I_E(2.2k) + 5 = 0$

$I_B = I_E/\beta+1$

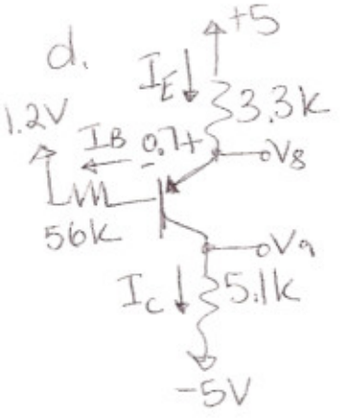
$\therefore I_E = 1.78mA$

$V_5 = I_E(2.2k) - 5 = \boxed{-1.1V}$

$I_E = \alpha I_E = 1.75mA$

$V_7 = 5 - 1.6k(1.75m) = \boxed{2.2V}$

d.



$+5 - 3.3k I_E - 0.7 - I_B(56k) - 1.2V = 0$

$(I_B = I_E/\beta+1)$

$\therefore I_E = 0.70mA$

$V_8 = 5 - 0.70m(3.3k) = \boxed{2.7V}$

$I_c = \alpha I_E = \frac{50}{51}(.70m) = .69mA$

~~$V_8 = 5 - 0.8m(3.3k) = 2.3V$~~

$V_9 = 5.1k(.69m) - 5 = \boxed{-1.48V}$

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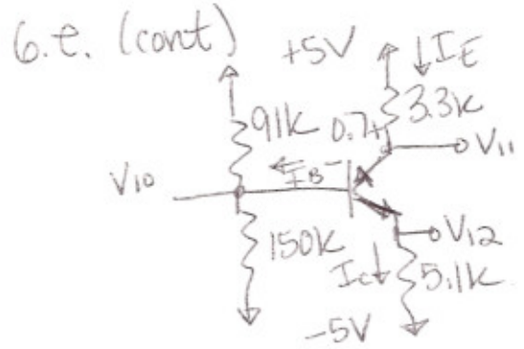
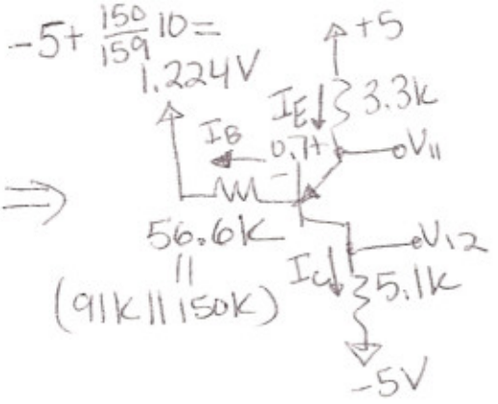
6.e. (cont)



$\Rightarrow$



$$5 - I_E(3.3k) - 0.7 - I_B(56.6k) - 1.224 = 0$$

$(I_B = I_E/\beta+1)$

$I_E = 0.7m$

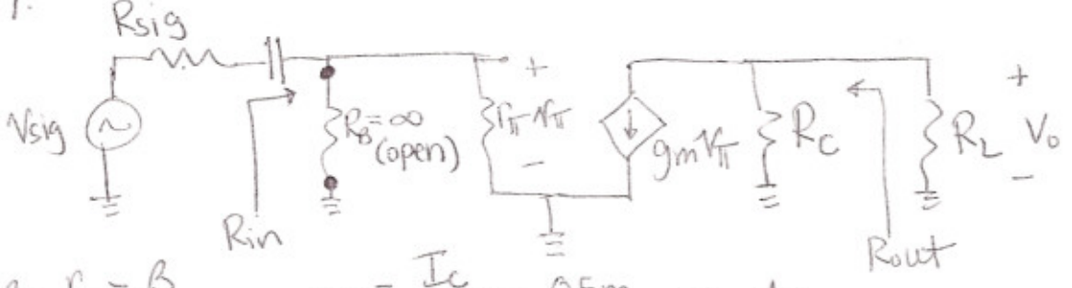
$V_{11} = 5 - 0.7m(3.3k) = \boxed{2.7V}$

$I_C = \alpha I_E = \frac{50}{51}(.7m) = 0.69m$

$V_{12} = 5.1k(.69m) - 5 = \boxed{-1.48V}$

$V_{10} = -0.7 + V_{11} = 2.7 - 0.7 = \boxed{2V}$

7.



$5k\Omega = r_\pi = \frac{\beta}{g_m}$, $g_m = \frac{I_C}{V_T} = \frac{0.5m}{25m} = 20mA/V$

$R_{in} = r_\pi = \boxed{5k\Omega}$

$A_{vo} \Rightarrow -g_m v_\pi (R_C \| R_L) = -g_m \left(\frac{v_{sig} \cdot r_\pi}{r_\pi + R_{sig}}\right)(R_C \| R_L) = v_o$

$\frac{v_o}{v_{sig}} = -20m\left(\frac{5k}{5k+1k}\right)(20k \| 1k) = \boxed{-15.9 V/V}$

$R_{out} = R_C = \boxed{20k\Omega}$