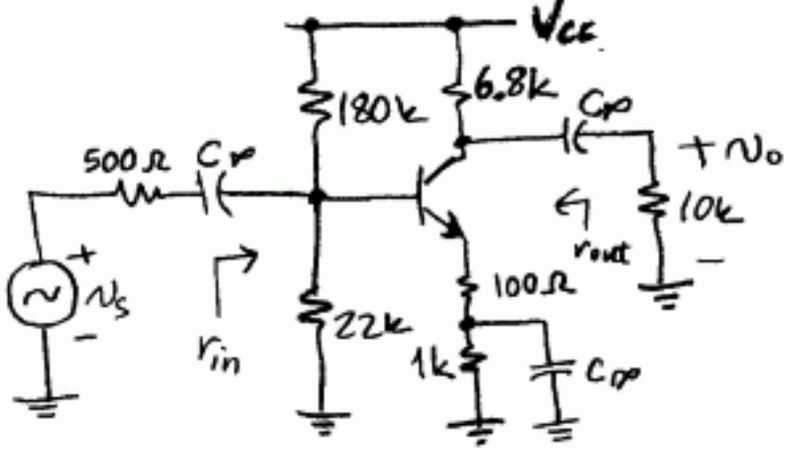
Electronics I * Midterm II * December 05, 2006 * 60 minutes

I have never given nor received any unauthorized help with this exam, nor do I have reason to believe that anybody else has.

ID number: SOLUTIONS *Name:* ERKAYA *Signature:* _____

1) Obtain a small-signal equivalent circuit for the amplifier given below. Then find the input resistance, output resistance and voltage gain of the amplifier.



$I_c = 1.5\,mA$

$\beta = 240$

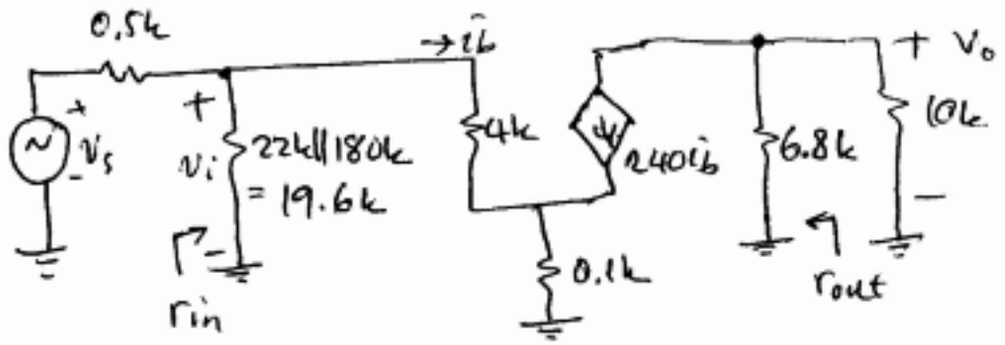
$g_m = \frac{I_c}{V_T} = \frac{1.5}{0.025} = 60\ mA/V$

$r_\pi = \frac{\beta}{g_m} = \frac{240}{60} = 4k\Omega$

$r_{in} =$ 11.54kΩ

$r_{out} =$ 6.8kΩ

$v_o/v_s =$ −33.13



$r_{in} = 19.6k\,||\,[4k + 0.1(240+1)] = 19.6k\,||\,28.1k = 11.54k$

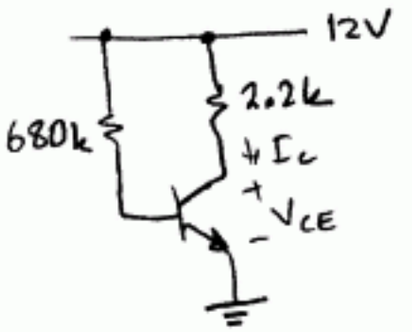
$r_{out} = 6.8k$

$$\left.\begin{aligned} v_o &= -240\,i_b\,(6.8\,||\,10) \\ v_i &= [4k + 0.1(240+1)]\,i_b \end{aligned}\right\} \frac{v_o}{v_i} = \frac{-240\,(6.8\,||\,10)}{28.1} = -34.57$$

$$\frac{v_o}{v_s} = -34.57\,\frac{11.54}{0.5 + 11.54} = -33.13$$

2) Find the operating points of the bipolar junction transistors in the circuits given below:

$\beta = 250$, $V_{BE} = 0.7\,V$



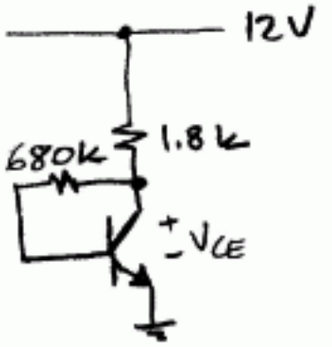
$I_c = \underline{4.154\,mA}$

$V_{CE} = \underline{2.86}$

$I_B = \frac{12 - 0.7}{680k} = 0.0166\,mA$

$I_c = \beta I_B = 4.154\,mA$

$V_{CE} = 12 - 2.2 \times 4.154 = 2.86\,V$



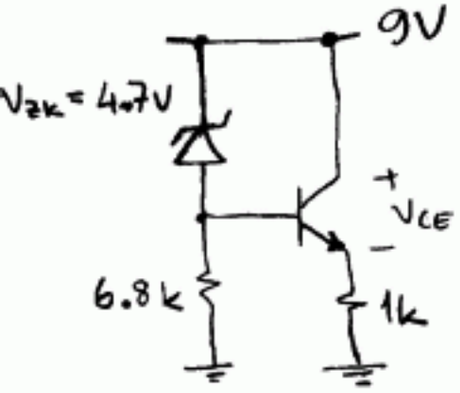
$I_c = \underline{2.5\,mA}$

$V_{CE} = \underline{7.5\,V}$

$I_B = \frac{12 - 0.7}{680 + 251 \times 1.8} = 0.01\,mA$

$I_c = 250 \times I_B = 2.5\,mA$

$V_{CE} = 12 - 1.8 \times 2.5 = 7.5\,V$



$I_c = \underline{3.6\,mA}$

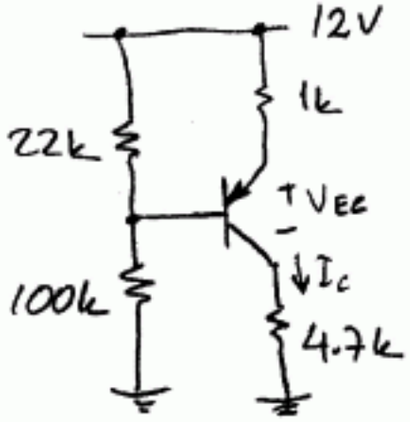
$V_{CE} = \underline{5.4\,V}$

$V_B = 9 - 4.7 = 4.3\,V$

$V_E = V_B - V_{BE} = 4.3 - 0.7 = 3.6V$

$I_E = \frac{3.6V}{1k} = 3.6\,mA.$ $I_c \simeq I_E$

$V_{CE} = 9 - 3.6 = 5.4V$



$I_c = \underline{1.47V}$

$V_{EC} = \underline{3.65V}$

$V_B = 12 \frac{100}{100+22} = 9.83V$

$V_E = V_B + 0.7 = 10.53V$

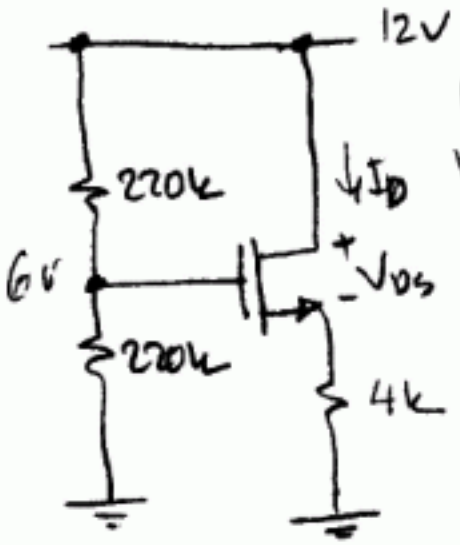
$I_E = \frac{12 - 10.53}{1k} = 1.47\,mA$

$I_c \simeq I_E$

$V_{EC} = 12 - 1 \times 1.47 - 4.7 \times 1.47$

$V_{EC} = 3.65\,V.$

3) Find the operating points of the field effect transistors in the circuits given below:



$K = 1mA/V^2$
$V_t = 1V$

$I_D = \underline{1mA}$

$V_{DS} = \underline{8V}$

$V_G = 12 \frac{220}{220+220} = 6V$

$4I_D + V_{GS} = 6$

$4 \times 1 (V_{GS} - V_t)^2 + V_{GS} - 6 = 0$

$4(V_{GS}^2 - 2V_{GS}V_t + V_t^2) + V_{GS} - 6 = 0$

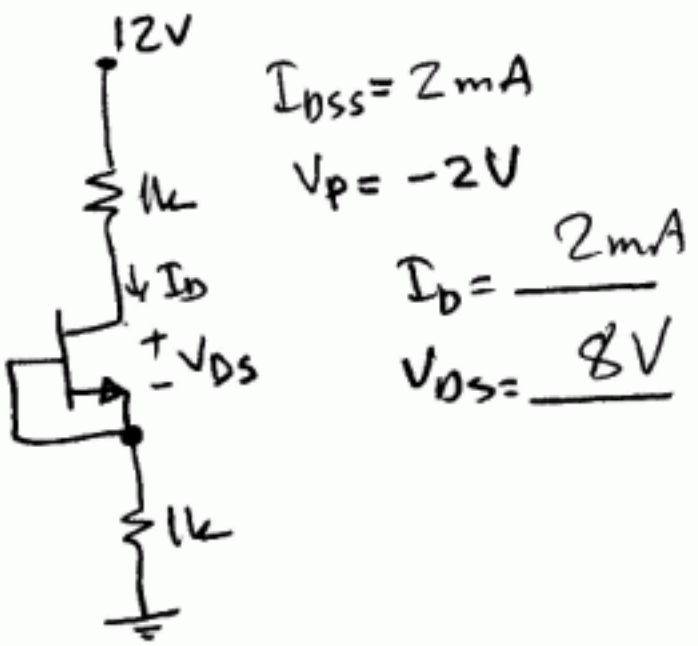
$4V_{GS}^2 - 7V_{GS} + 4 - 6 = 0$

$V_{GS1} = \frac{7 + \sqrt{49+32}}{8} = 2$ valid

$V_{GS2} = \frac{7 - \sqrt{49+32}}{8} = -\frac{2}{8} < V_t$ not valid

$I_D = 1(2-1)^2 = 1mA.$

$V_{DS} = 12 - 4 = 8V$



$I_{DSS} = 2mA$

$V_p = -2V$

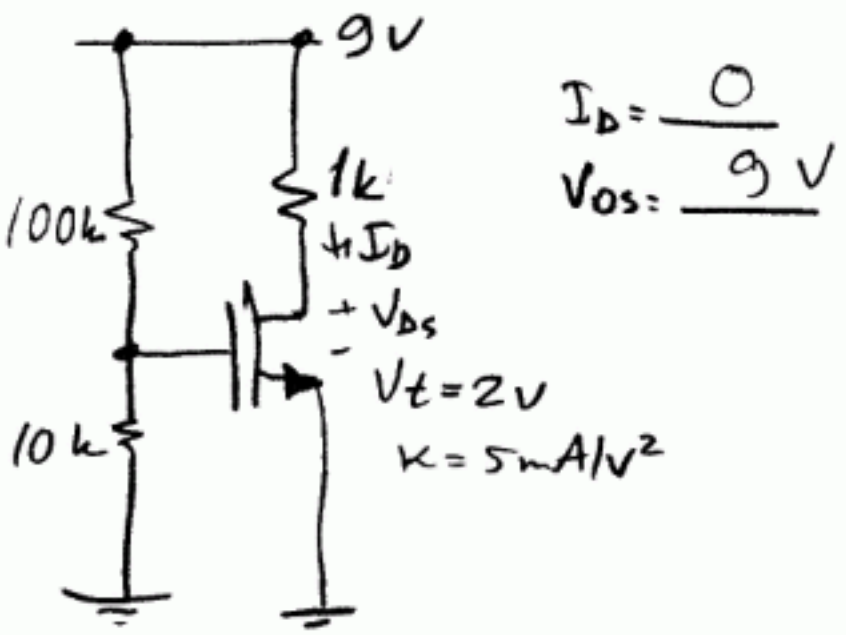
$I_D = \underline{2mA}$

$V_{DS} = \underline{8V}$

$V_{GS} = 0$

By definition of I_{DSS}, $I_{DD} = I_{DSS} = 2mA$

$V_{DS} = 12 - 2(1+1) = 8V$



$I_D = \underline{0}$

$V_{DS} = \underline{9V}$

$V_{GS} = 9 \frac{10}{10+100} = 0,82$ V $< V_t = 2V$

CUTOFF $\rightarrow$ $I_D = 0$

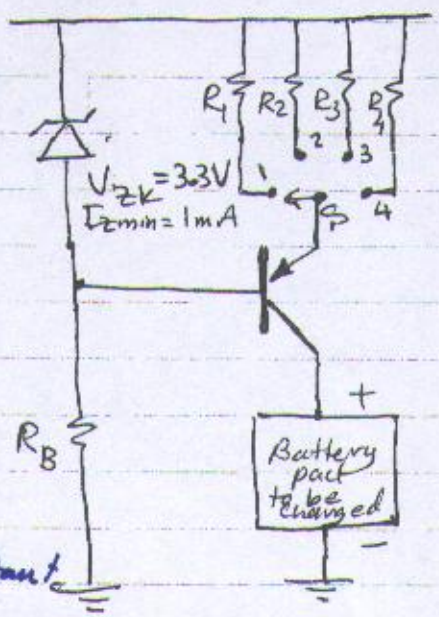
$V_{DS} = 9 - I_D \times 1 = 9V.$

Dec 13, 2005 Electronics I – Midterm 2 60 minutes

Name: ERICAYA ID number: SOLUTIONS Signature: _____

1) The circuit below is to be used as a constant current battery charger. The positions of the switch S corresponds to the following current values:

Position	Current
1	100 mA
2	200 mA
3	300 mA
4	400 mA



Silicon BJT
$\beta = 70$

$R_{B\max} = 1.29\,k\Omega$
$R_1 = 26\,\Omega$
$R_2 = 13\,\Omega$
$R_3 = 8.66\,\Omega$
$R_4 = 6.5\,\Omega$

a) What could be the max value for R_B?

The current in R_B is constant. It must be at least

$I_{Zmin} + I_{B\max} = 1 + \frac{400}{70} = 6.71\,mA, \quad R_{B\max} = \frac{12-3.3}{6.71} = 1.29\,k\Omega$

b) What should be the resistor values R_1, R_2, R_3, R_4?

The voltage across R_1, R_2, R_3, R_4 is $3.3 - 0.7 = 2.6\,V$

$R_1 = \frac{2.6}{0.1} = 26\,\Omega, \quad R_2 = \frac{2.6}{0.2} = 13\,\Omega \quad R_3 = \frac{2.6}{0.3} = 8.66\,\Omega \quad R_4 = \frac{2.6}{0.4} = 6.5\,\Omega$

c) What is the maximum voltage that the rechargeable battery pack may have?

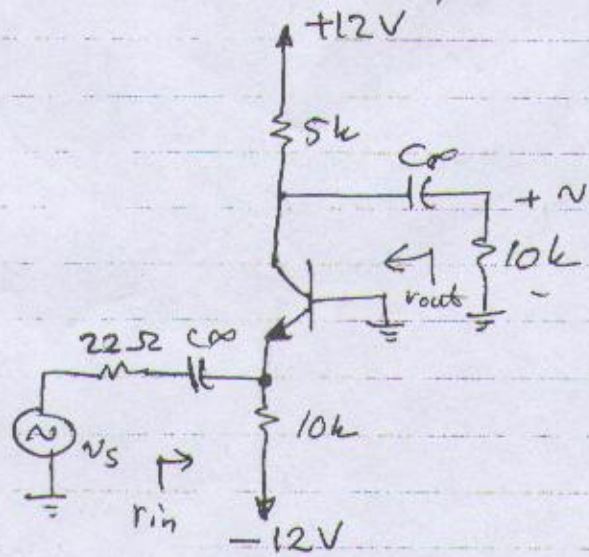
$V_{C\max} = V_E - V_{CESAT} = 12 - 2.6 - 0.2 = 9.2\,V. \quad V_{battery\,max} = 9.2\,V$

d) What must be the power rating of the BJT?

$P_{max} = |I_{C\max} V_{CE\max}| = 0.4 \times (12 - 2.6) = 3.76\,W$

2) Find the operating point of the transistor given in the circuit below. Also find a small signal equivalent circuit, input resistance, output resistance and voltage gain for the amplifier.

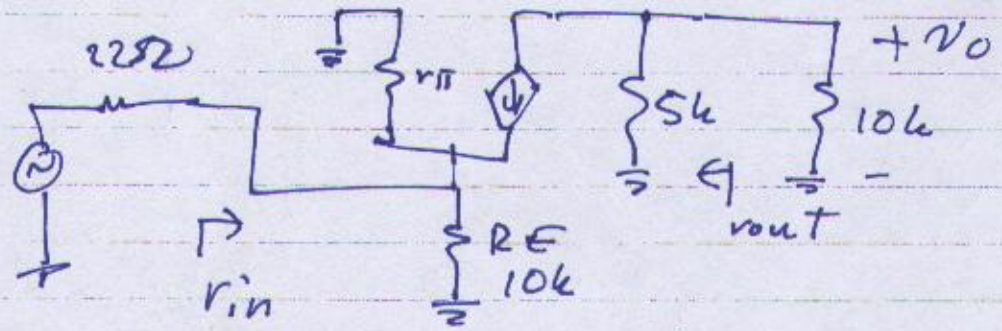
$V_{BE} = 0.7V$, $\beta = 250$, $V_T = 0.025\ V$



$$I_c \cong I_E = \frac{-0.7-(-12)}{10} = 1.13\ mA$$

$$g_m = \frac{I_c}{V_T} = \frac{1.13}{0.025} = 45.2\ mA/V$$

$$r_\pi = \frac{\beta}{g_m} = \frac{250}{45.2} = 5.53k\Omega$$



$$r_{in} = 10k \parallel \frac{r_\pi}{\beta+1} = 10k \parallel \frac{5.53k}{251} = 0.022k\Omega$$

$r_{out} = 5k$

$$\frac{V_o}{V_i} = g_m (R_c \parallel R_L) = 45.2 \times 5 \parallel 10 = 150$$

$$\frac{V_i}{V_s} = \frac{r_{in}}{R_s + r_{in}} = \frac{22}{22+22} = \frac{1}{2}$$

$$\frac{V_o}{V_s} = 150 \times \frac{1}{2} = 75$$

$I_c = 1.13\ mA$

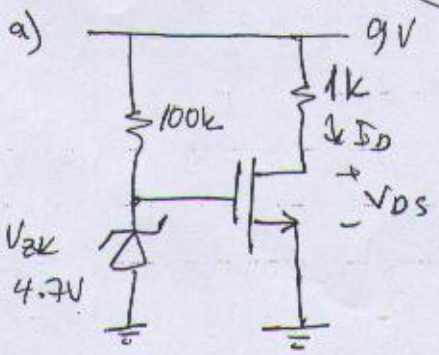
$r_{in} = 22\Omega$

$r_{out} = 5k$

$\frac{V_o}{V_s} = 75$

3) Find the operating points for the FETs given below:

a)



$V_t = 2.5\,V$

$K = 0.5\,mA/V^2$

$I_D =$ 2.42 mA

$V_{DS} =$ 6.58V

$V_{GS} = 4.7V$

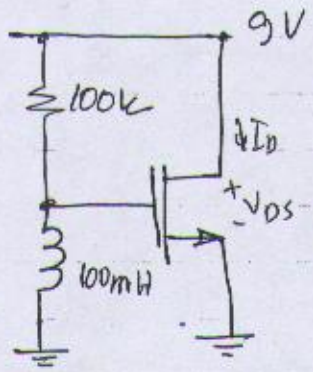
$I_D = 0.5\,(4.7-2.5)^2 = 2.42\,mA$

$V_{DS} = 9 - 1 \times 2.42 = 6.58V$

verification $V_{DS} \gtrless V_{GS} - V_t = 2.2V$

$6.58 > 2.2$ assumption is valid

b)



$V_t = 2.5V$

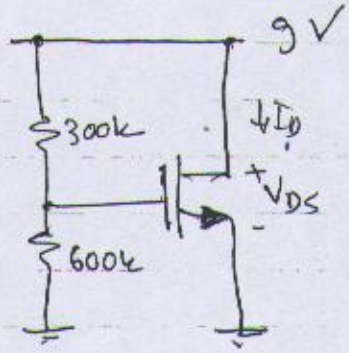
$K = 0.5\,mA/V^2$

$I_D =$ 0

$V_{DS} =$ 9V

$V_{GS} = 0$, $< V_t \rightarrow I_D = 0$

c)



$V_t = 2.5\,V$

$K = 0.5\,mA/V^2$

$I_D =$ 6.12mA

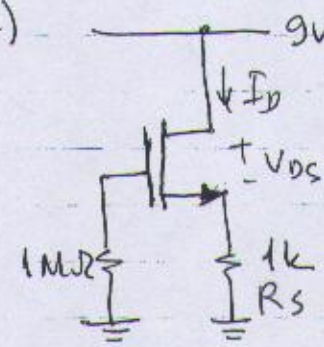
$V_{DS} =$ 9V

$V_{GS} = 9\,\frac{600}{300+600} = 6V$

$I_D = 0.5\,(6-2.5)^2 = 6.12\,mA$

$V_{DS} = 9V > 6-2.5 = 3.5$ ✓

d)



$V_t = -1\,V$

$K = 0.5\,mA/V^2$

$I_D =$ 0.27mA

$V_{DS} =$ 9-0.27 = 8.73V

$V_G = 0$, $V_S = I_D R_S$

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

$V_{GS} = -K\,(V_{GS} - V_t)^2 R_S$

$V_{GS} + K R_S\,(V_{GS}^2 - 2 V_{GS} V_t + V_t^2) = 0$

$2V_{GS} + V_{GS}^2 + 2V_{GS} + 1 = 0$

$V_{GS}^2 + 4V_{GS} + 1 = 0$

$V_{GS1,2} = \frac{-4 \pm \sqrt{16-4}}{2} = -2 \pm \sqrt{3}$

$I_D = \frac{+0.27}{1k} = 0.27\,mA$

$-2-\sqrt{3} < V_t = -1$ not valid

$-2+\sqrt{3} = 0.27\,V$