Write your name at the top right corner of every page (including this cover page).

Copy everything you want counted towards your grade onto the pages that I provided.

Write with a pen that cannot be erased!

No books are allowed!

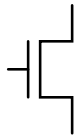
Only the calculators I provided are allowed!

Write down all the steps that lead to your result.

Identify new variables that you may introduce in the circuit diagrams that I provided.

Read all the problems before you start so that you can begin with those that seem easiest to you.

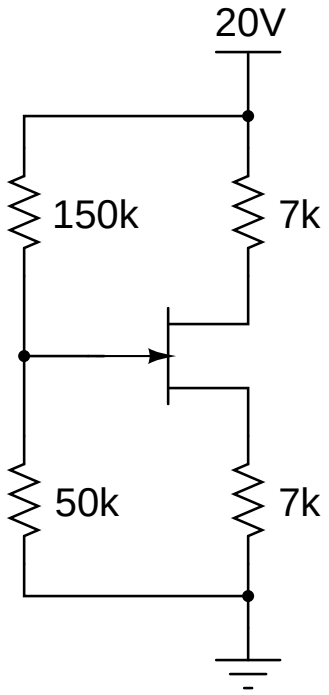
MOSFET circuit symbols:

enhancement mode MOSFET 

depletion mode MOSFET 

Problem 1 (6 pts):

The JFET in the figure has $I_{DSS} = 9$ mA and $V_p = -3$ V. Find V_{GS}, i_D, and V_{DS}.



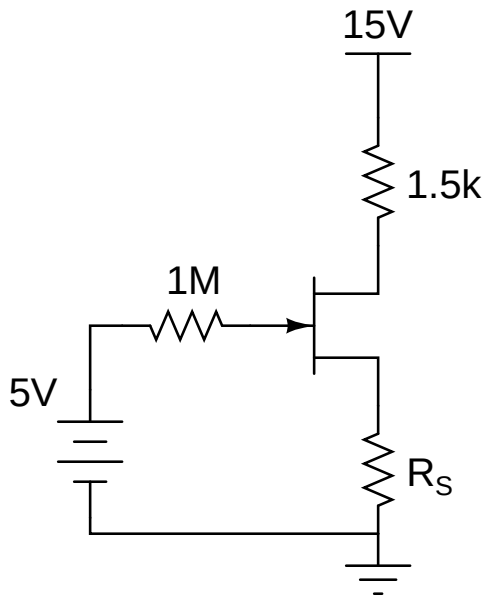
$V_G = \frac{50k}{50k+150k} 20V = 5V$
$i_D = I_{DSS}(1 - V_{GS}/V_p)^2 = 9m(1 + V_{GS}/3)^2 = 9m + 6mV_{GS} + 1mV_{GS}^2 = \frac{V_D}{7k} = \frac{V_G - V_{GS}}{7k} = (5 - V_{GS})/7k$
$\Rightarrow 7V_{GS}^2 + 43V_{GS} + 58 = 0 \Rightarrow V_{GS} = -2V (-4.14V < V_p)$

$i_D = \frac{5 - V_{GS}}{7k} = 1mA$

$V_{DS} = 20 - 2(7ki_D) = 6V$

Problem 2 (6 pts):

The JFET in the figure has $I_{DSS} = 16$ mA and $V_p = -2$ V. Find R_S, V_{GS}, and V_{DS} so that the transistor is biased in the active (saturation) region (verify!) and $i_D = 1$ mA.



$i_D = I_{DSS}(1 - V_{GS}/V_p)^2 \Rightarrow \sqrt{i_D/I_{DSS}} = 1 - V_{GS}/V_p \Rightarrow V_{GS} = V_p(1 - \sqrt{i_D/I_{DSS}}) \Rightarrow V_{GS} = -1.5V$

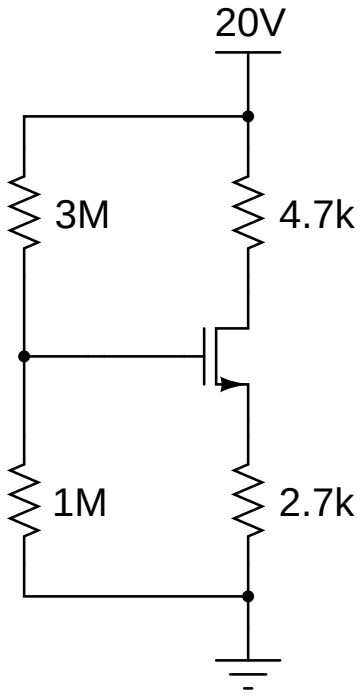
$i_G = 0 \Rightarrow V_G = 5V; R_S = (V_G - V_{GS})/i_D = 6.5k\Omega$

$V_{DS} = 15 - (1.5 + 6.5)ki_D = 7V$

$V_{DS} > V_{GS} - V_p = 0.5V$ active region okay.

Problem 3 (6 pts):

The NMOS in the figure has $K = 1$ mA/V^2 and $V_t = 2$ V. Find V_{GS}, i_D, and V_{DS}.



$V_G = \frac{1M}{3M+1M}20 = 5V$

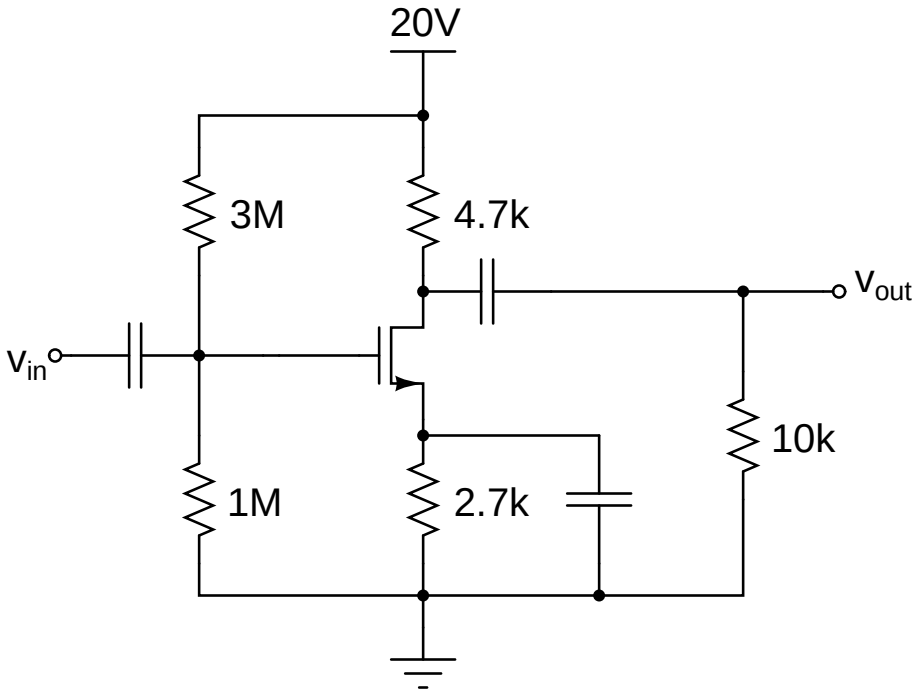
$V_G = V_{GS}+2.7ki_D = V_{GS}+2.7kK(V_{GS}-V_t)^2 \Rightarrow V_{GS}^2-3.63V_{GS}+2.148 = 0 \Rightarrow V_{GS} = 2.886V (0.744V < V_t)$

$i_D = K(V_{GS} - V_t)^2 = 0.784mA$

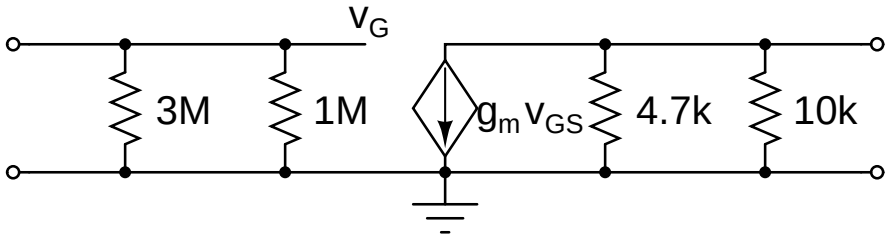
$V_{DS} = 20 - (2.7 + 4.7)ki_D = 14.2V \Rightarrow$ active region okay.

Problem 4 (7 pts):

In the circuit below, the 10 kΩ resistor from v_{out} to GND represents the load resistance R_L. Draw the small signal equivalent circuit for this whole circuit. (including R_L)
Given $g_m = 1.77$ mS, what is $A_v = v_{out}/v_{in}$? ($r_d = \infty$)
Is the amplifier inverting or not? (check sign!)



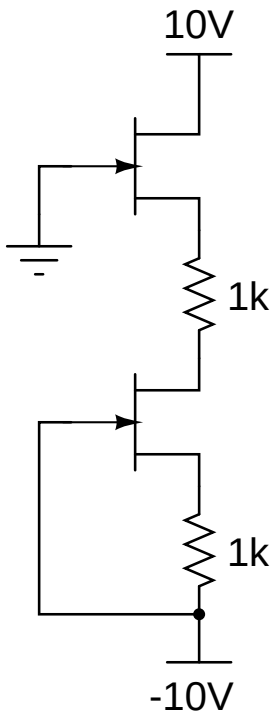
The small signal equivalent circuit looks like this:



Since $v_{in} = v_G = v_{gs}$ and $v_{out} = v_d = -g_m v_{gs} \frac{4.7k10k}{4.7k+10k}$. we get:
$A_v = v_{out}/v_{in} = -g_m \frac{4.7k10k}{4.7k+10k} = -5.66$

Problem 5 (7 pts):

Both JFETs have $I_{DSS} = 4$ mA and $V_p = -2$ V. Assume active (saturation) region operation to find i_D and confirm that both JFETs are in the active region.



Let us give the index 1 to the lower JFET and index 2 to the upper JFET in the circuit drawing.
$I_{DSS}(1 - V_{GS1}/V_p)^2 = i_D = 4m(1 + V_{GS1} + \frac{1}{4}V_{GS1}^2)$
Also: $i_D = V_S/1k = (-10 + V_{GS1})/1k \Rightarrow -V_{GS2}/1k = 4m(1 + V_{GS1} + \frac{1}{4}V_{GS1}^2)$
From $(V_{GS1} + 1)(V_{GS1} + 4) = 0$ we get: $V_{GS1} = -1V (-4V < -2V = V_p)$

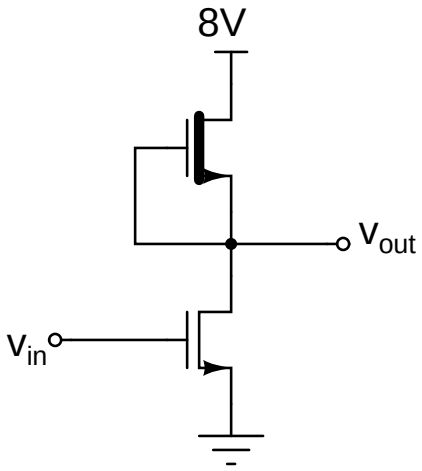
$i_D = -V_{GS1}/1k = 1mA$

$i_D/I_{DSS} = (1 - V_{GS2}/V_p)^2 \Rightarrow V_{GS2} = -1V \Rightarrow V_{S2} = 0 - V_{GS2} = 1V \Rightarrow (1V - (-10V)) = (1k + 1k)i_D + V_{DS1} \Rightarrow V_{DS1} = 9V > V_{GS1} - V_p = 1V$, q.e.d.

$V_{DS2} = 10V - V_{S2} = 9V > V_{GS2} - V_p = 1V$, q.e.d.

Problem 6 ONLY 6610 students !!! (7 pts):

The MOSFETs below have the following characteristics: $I_{DSS} = 4$ mA and $V_p = -4$ V and $K = 0.25$ mA/V^2 and $V_t = 1$ V respectively. What voltage will v_{in} have to be for both MOSFETs to be in the active region? What are i_D and v_{out} under these circumstances?



Let's give the index 1 to the lower MOSFET in the drawing and the index 2 to the upper one.

Active, $V_{GS1} = V_{in}$ and $V_{GS2} = 0 \Rightarrow I_{DSS}(1 - V_{GS2}/V_p)^2 = i_D = K(V_{GS1} - V_t)^2 \Rightarrow v_{in} = 5V$

$V_{GS2} = 0 \Rightarrow i_D = I_{DSS} = 4mA$

Check if active:

$V_{DS1} \geq V_{GS1} - V_t = 4V$ and $V_{DS2} \geq V_{GS2} - V_p = 4V$

Also: $V_{DS1} + V_{DS2} = 8V \Rightarrow V_{DS1} = V_{DS2} = 4V$