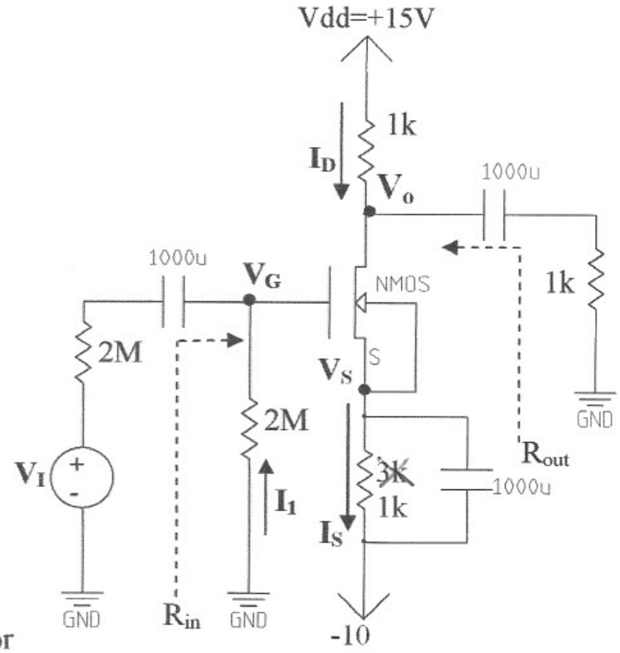
Problem 1 – (35 points)

Use: V_t=2V
$k_n'(W/L)=50\mu A/V^2$
$\lambda=0$
$V_I = 5+0.001\sin(10t)$



(a) Solve for the DC currents:
  a. $I_1 = 0$
  b. $I_D = 1.2m$
  c. $I_S = I_D$

(b) Solve for the DC voltages:
  a. $V_G = 0$
  b. $V_S = -8.8V$
  c. $V_o = 13.8V$

(c) Verify that the transistor is saturated

(d) State the operating point, bias point, or quiescent point for this amplifier

a. $\boxed{I_1 = 0}$ $\quad I_D = I_S$

$I_D = \frac{1}{2}(50\mu)(V_{GS} - V_t)^2$ (SAT. EQ.)

$V_{GS} = V_G - V_S$

$V_G = 0$

$V_S = I_D(1K) - 10$

$\therefore I_D = \frac{1}{2}(50\mu)(0 - I_D(1K) + 10 - 2)^2$

$I_D(40K) = (I_D^2(1K)^2 + 64 - 16(1K)I_D)$

$I_D = \frac{56K \pm \sqrt{(56K)^2 - 4(1K)^2(64)}}{2(1K)^2} = \boxed{1.2m}, 54.8m \rightarrow$ Gives $V_{GS} \cong -45$

$V_S = \boxed{-8.8V}$

d) $V_{GS} = \boxed{8.8V}$ which gives $\Rightarrow I_D = \boxed{1.2m}$

$V_D = V_o = 15 - I_D(1K) = \boxed{13.8V}$

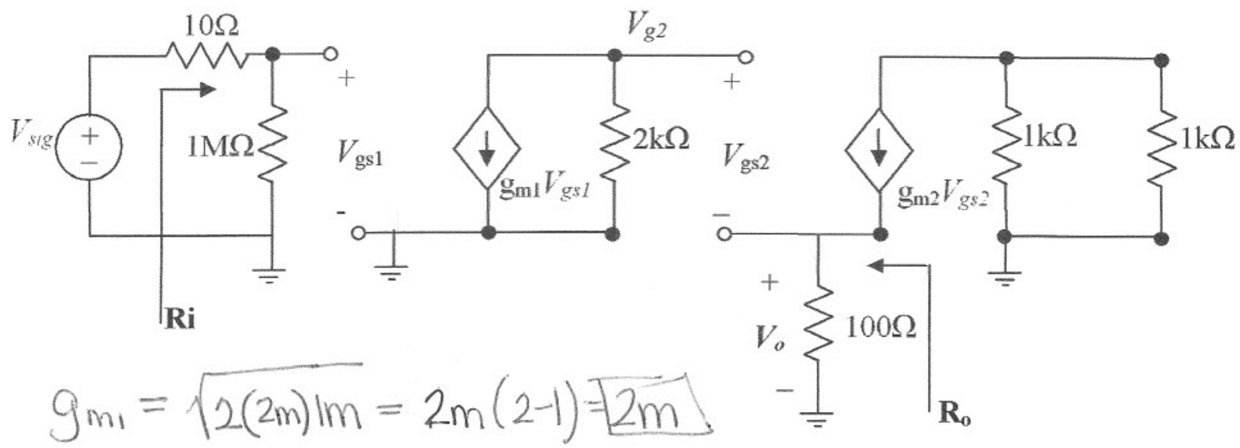
$\therefore \boxed{V_{DS} = 22.6 > (V_{GS} - V_t) = 6.8V}$

Problem 2 – (35 points)

Use: V_t=1V
$k_n'(W/L)$=2mA/V^2
V_{sig} is an AC source
Transistor 1 has DC values: VGS1=2V, ID1=1mA
Transistor 2 has DC values: VGS2=3V, ID2=4mA
λ=0 (for all transistors)

For the following hybrid-π equivalent circuit, find the following values:

(a) R_i (input resistance –ignore the 10Ω and Vsig)
(b) Ro (output resistance-ignore the 1k load)
(c) gain, $\frac{Vo}{Vsig}$



$g_{m1} = \sqrt{2(2m)1m} = 2m(2-1) = \boxed{2m}$

$g_{m2} = \sqrt{2(2m)4m} = 2m(3-1) = \boxed{4m}$

a) $\boxed{R_i = 1M}$

b) $R_o = 100\Omega \| 1/g_{m2} = 100 \| 250 \cong \boxed{71\Omega}$

c) $V_o = +g_{m2}V_{gs2}(100)$

$V_{gs2} = V_{g2} - V_o = -g_{m1}V_{gs1}(2K) - g_{m2}V_{gs2}(100)$

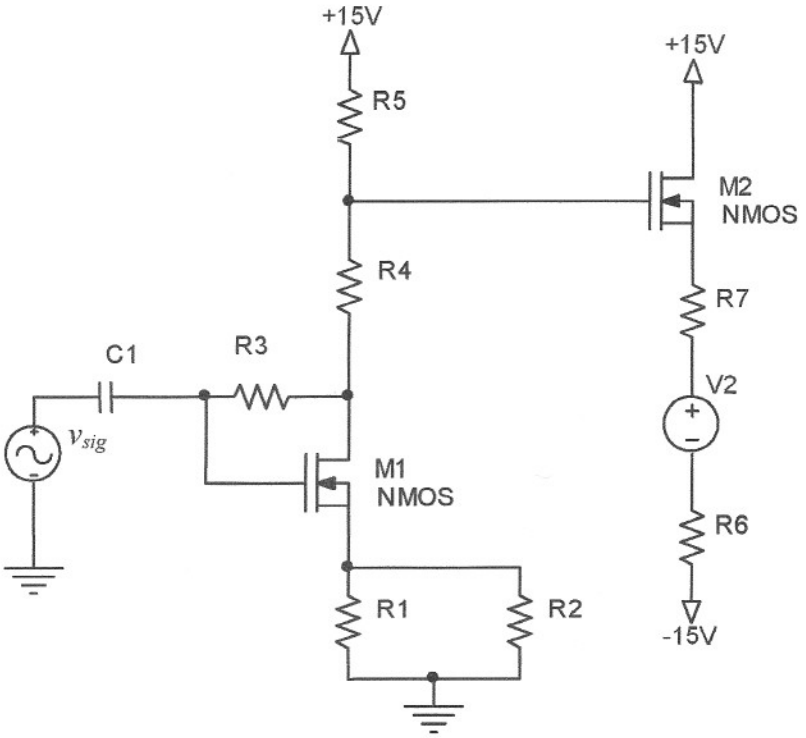
$V_{gs1} = \frac{V_{sig}(1M)}{1M+10} \approx V_{sig}$

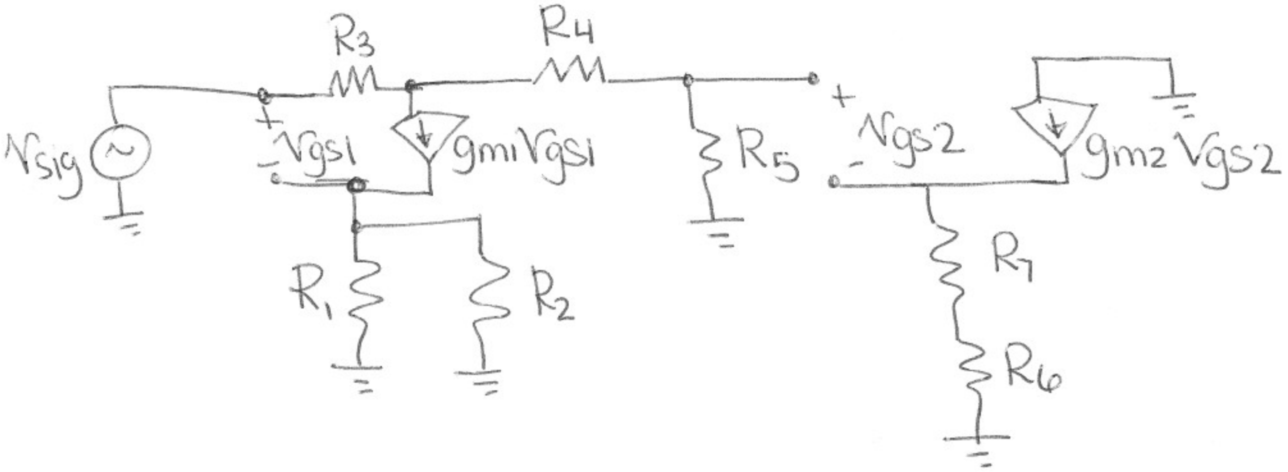
$V_{gs2} = \frac{-g_{m1}(2K)\,V_{sig}}{1+g_{m2}(100)}$

$\frac{V_o}{V_{sig}} = \frac{g_{m2}(100)(-g_{m1})(2K)}{1+g_{m2}(100)} = \boxed{-1.14\,V/V}$

Problem 3 – (17 points)

For the circuit shown below, **draw** the AC small-signal equivalent circuit(use hybrid-π or model T). Make sure that everything is labeled in terms of the transistor number. (e.g. g_{m1}, v_{gs2}, etc.). λ=0 for all transistors. v_{sig}=0.001sin(10t) AC and V2=10V DC.



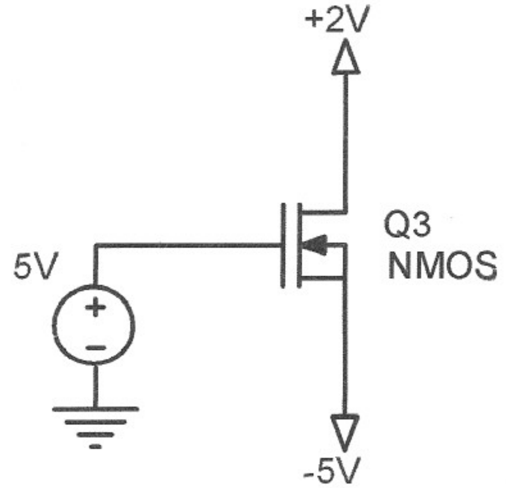


Problem 4 – (8 points)

Use: V_t=2V
$k_n'(W/L)$=1mA/V^2

(a) What region of operation is the transistor below operating?

(b) Draw a cross section of the transistor below making sure to label all voltages and show how the current is flowing.



$V_{GS} = +10V \quad \therefore$ ON

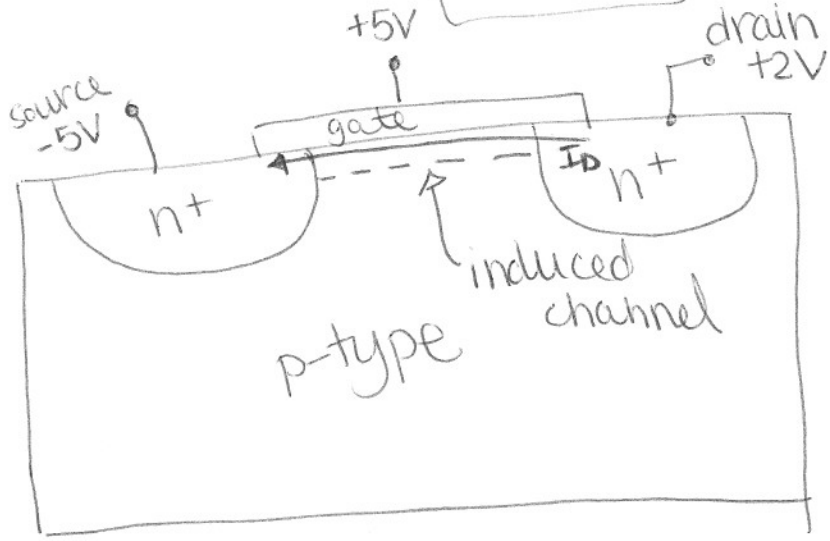
$V_{GS} > V_t$

$V_{DS} = 7$

$(V_{GS} - V_t) = 10 - 2 = 8V$

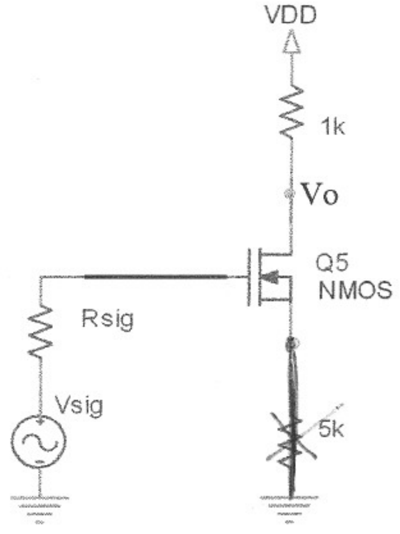
$\therefore \ V_{DS} < V_{GS} - V_t$

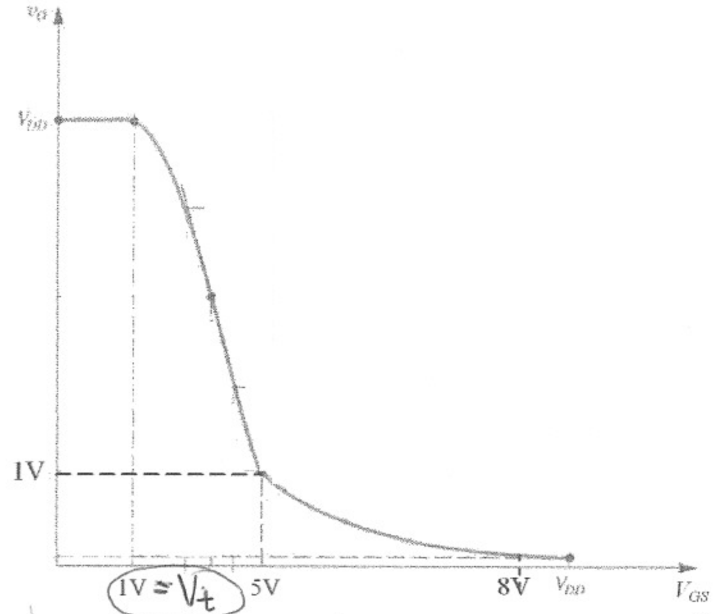
TRIODE Operation



Problem 5 – (5 points)

v_{sig} ={8+0.01sin(ωt)}Volts. Does this circuit operate as a **linear** AC amplifier? If so, what is the gain, $\frac{Vo}{Vsig}$, of the following circuit in terms of VDD, Vsig, Rsig, k'(W/L)? If not, explain why. The graph below shows measurements taken for this circuit.





This mosfet is biased at a gate voltage of $V_G = 8V$ and $V_S = 0$.

∴ $V_{GS} = 8V$.

It looks like the transistor will be in triode ⇒

$V_{DS} \triangleq 0 < (V_{GS} - V_t) = 8 - 1 = 7V$

∴ TRIODE Region → will not amplify linearly