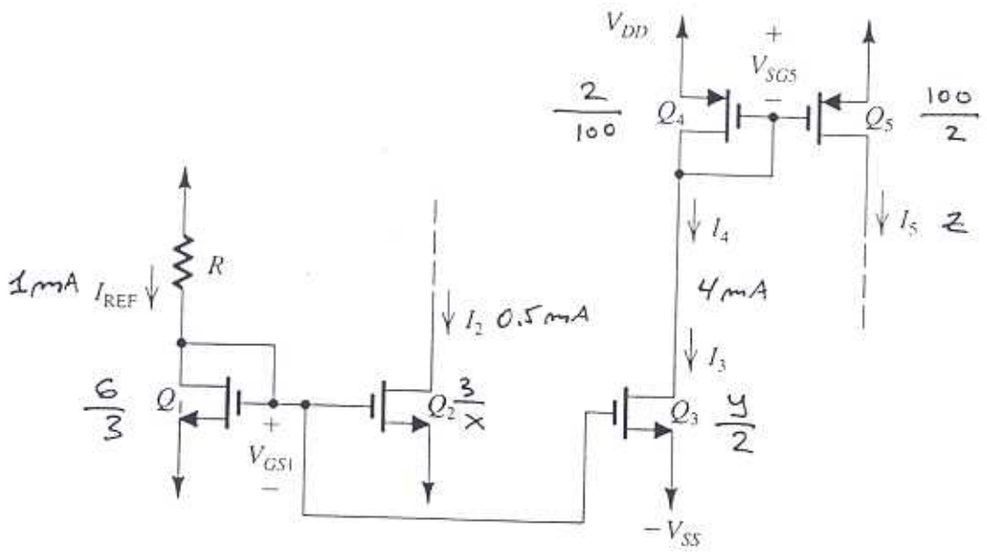
In the below schematic, $I_{REF}$=1 mA, $I_2$=0.5 mA, $I_3$=$I_4$=4 mA, W/L of $Q_1$=6/3, W/L of $Q_2$=3/X, W/L of $Q_3$=Y/2, W/L of $Q_4$=2/100, and W/L of $Q_5$=100/2. Showing your work, find X, Y, and $I_5$.




$$\frac{\frac{3}{X}}{\frac{6}{3}} = \frac{0.5\,mA}{1\,mA}, \quad X = 3$$

---

$$\frac{\frac{Y}{2}}{\frac{6}{3}} = \frac{4\,mA}{1\,mA}, \quad Y = 16$$

---

$$\frac{\frac{100}{2}}{\frac{2}{100}} = \frac{Z}{4\,mA}, \quad Z = 10\,A\ !!!$$

(5pts) X= 3, (5pts) Y= 16, (5pts) $I_5$= 10 A

NOTE: UNITS WERE NOT SPECIFIED. O.K. IF ~~PUT~~ PUT "μm"

MUST INDICATE UNITS

EG 2225

.40

ECE 113B Midterm Exam
(February 12, 2004, Professor Kleinfelder)

CLOSED BOOK AND NOTES, NO ELECTRONIC AIDS
To receive credit, please **show all work** and **place your answers where requested.**

NAME:_____ ID:_____

Signature:_____ Seat/Row:_____

(5 pts) An n-channel transistor has $V_A$=50V, $V_t$=1, $V_{GS}$=2, (W/L)=5, and $k_n'$=100μA/V². Find $r_o$:

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_t)$$

$$= \frac{1}{2}(100\,\mu A/V^2)(5)(2-1) = 250\,\mu A$$

$$r_o = V_A/I_D = 50V/250\mu A = 200K\Omega$$

(2 pts) What is the name of the phenomena that causes $r_o$?

CHANNEL LENGTH MODULATION

(3 pts) What would $r_o$ be if $V_A$ were infinite?

INFINITE

(3 pts) What is the slope of the above transistors I-V curve when in saturation (include units)?

$$\frac{1}{r_o} = 5\,\mu A/V \left(5\times10^{-6}\frac{A}{V}\right)(200K)$$

(5 pts) If the transistor's χ=0.1, $v_{gs}$=1V, $v_{sb}$=2V, and its transconductance is 1mA/V, find $g_{mb}$:

$$g_{mb} = \chi g_m = (0.1)(1\,mA/V)$$

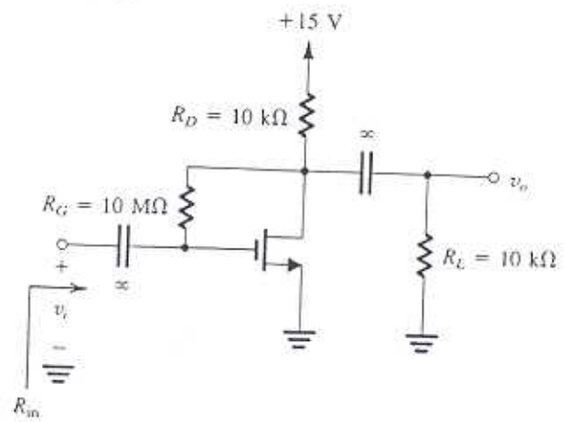
$$= 0.1\,mA/V$$

(NOTE, $V_{gs}$, $V_{sb}$ ARE IRRELEVANT HERE)

(2 pts) What phenomena is responsible in the above question?

BODY EFFECT

Refer to this figure for this page:




(2 pts) What kind of amplifier is this?

COMMON SOURCE AMPLIFIER

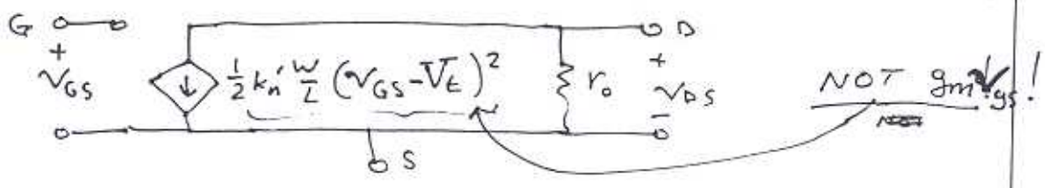
(3 pts) Explain the purpose of the resistor $R_G$:

PRIMARY: BIASES GATE VOLTAGE SUCH THAT Q IS IN SATURATION

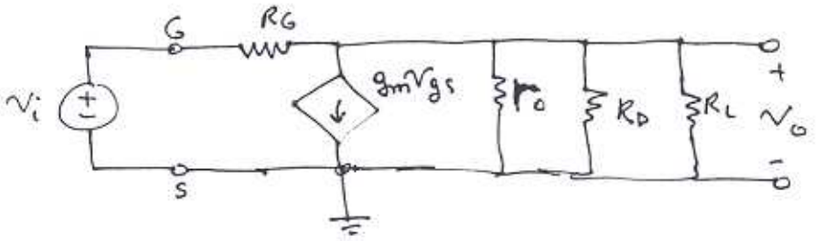
SECONDARY: FEEDBACK STABILIZES $I_D$

(10 pts) Draw and completely annotate the LARGE signal model of the circuit:

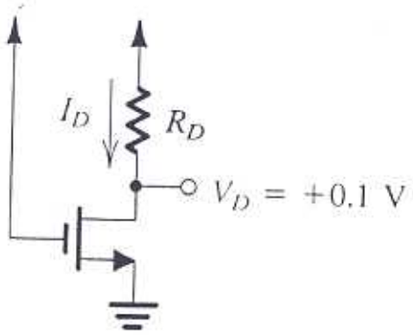
THE LARGE SIGNAL MODEL IS JUST THE ABOVE SCHEMATIC, SUBSTITUTING ↓ FOR THE TRANSISTOR.




MANY PEOPLE (MOST) DREW SOME VARIENT OF THE SMALL SIGNAL MODEL:



Let the following NMOS transistor have a $V_t$ of 1V, $\mu_n C_{ox}$=200 $\mu$A/V$^2$, $\lambda$=0, L=1$\mu$m, and W=10$\mu$m. Set $V_{dd}$=10V.




(10 pts) Showing your work, find the $I_D$ that will yield an $V_D$ of 0.1V:

$V_{DS} < V_{GS} - V_t \quad (0.1) < (10-1)$ ✓ TRIODE

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

$$= (200\,\mu A/V^2)(10)\left[(10-1)(0.1) - \frac{1}{2}(0.1)^2\right]$$

$$= 1.79\ mA$$

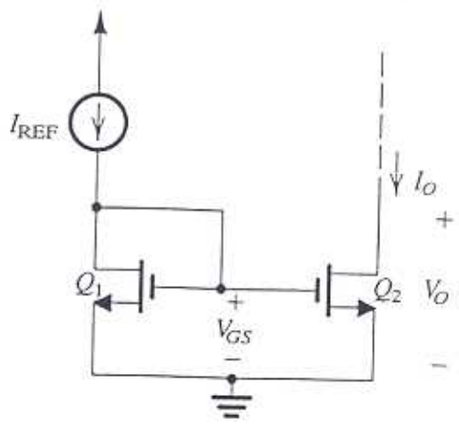
ANSWER 1.79 mA

(5 pt) Find $R_D$:

$$E = IR \qquad R = \frac{E}{I} = 5.53\ k\Omega$$

ANSWER 5,530 Ω (5.53 kΩ)

In the following figure, let $I_{REF}$=1 mA, $L_2$=$L_1$, $W_2$=2$W_1$, $V_{GS}$=2V, $V_O$=4V, $V_{A2}$=100V




CHANNEL-LENGTH MODULATION!

(10 pts) Find $I_O$:

(SATURATION $I_O = I_{D2} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_t)^2(1+\lambda V_{DS})$ )

NO $\lambda$: $\frac{I_O}{I_{REF}} = \frac{(W/L)_2}{(W/L)_1}$, $I_O = \frac{(2)}{(1)}(1mA) = 2\ mA$

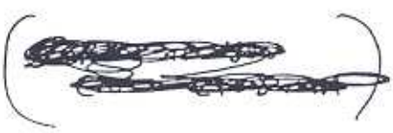
$(1+\lambda V_{DS_2}) = (1 + V_O/V_{A_2})$

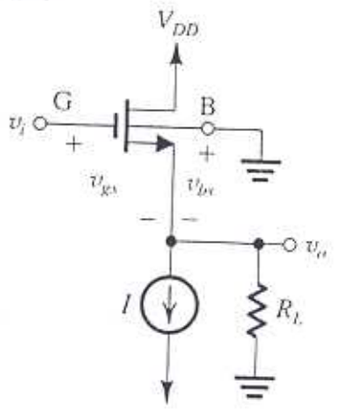
$V_{A1}$ DOES NOT MATTER BECAUSE WE ARE GIVEN $V_{GS}$!

CH. LEN. MOD. WILL CHANGE $I_O$ TO THE DEGREE THAT $V_O$ DIFFERS FROM $V_{GS}$ ($V_{DS}$ OF $Q_1$), SO

ANSWER $I_O' = I_O\left(1 + \frac{V_O - V_{GS}}{V_{A2}}\right) = 2mA\left(1+\frac{4-2}{100}\right) = 2.04\ mA$

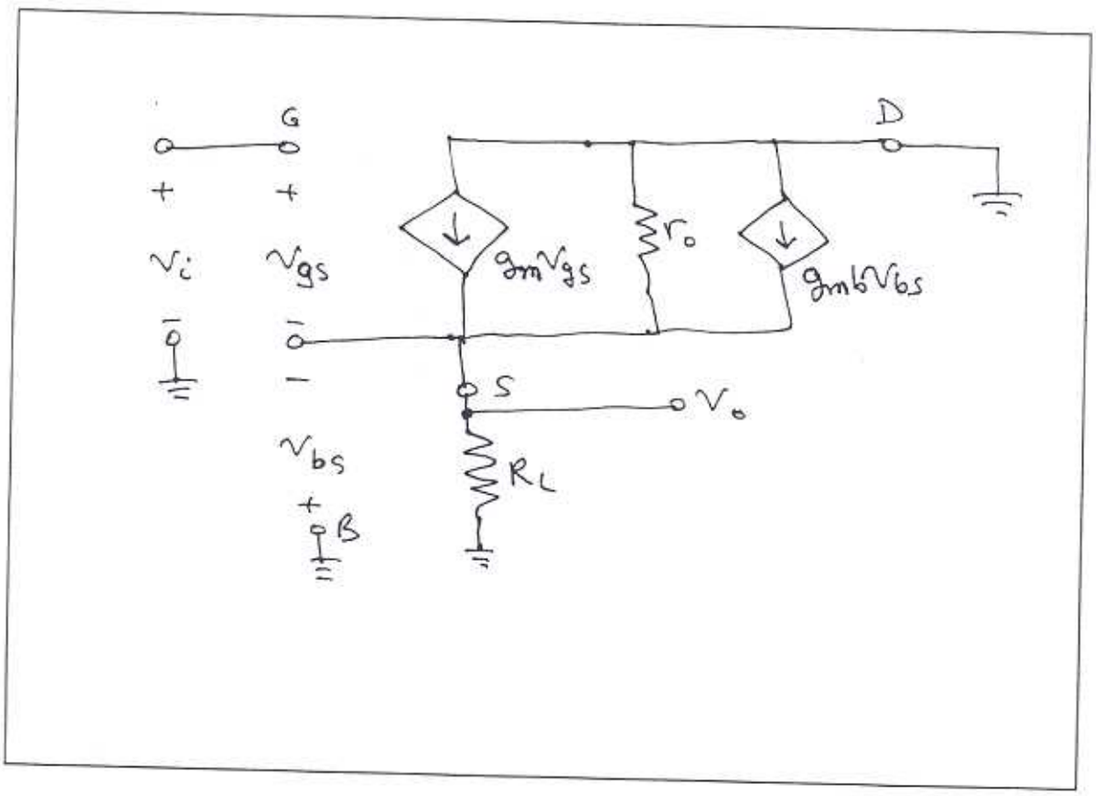
Refer to this figure for the next page



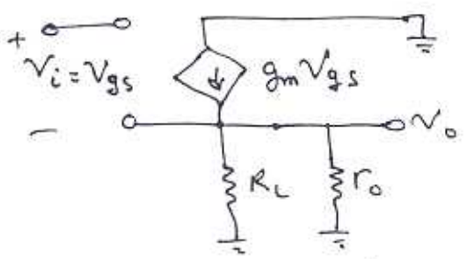



(a)

(10 pts) Draw and annotate the complete SMALL signal model of this circuit:




(10 pts) *Leave out any body effect*, and derive the formula for the voltage gain of the entire circuit (including $R_L$) in terms of $g_m$, etc. Again, do not include the body effect:




$$v_o = g_m v_{gs} (R_L \| r_o)$$

NOTE : NON INVERTING !

$$A_V \equiv \frac{v_o}{v_i} = \frac{g_m v_{gs} (R_L \| r_o)}{v_i}$$

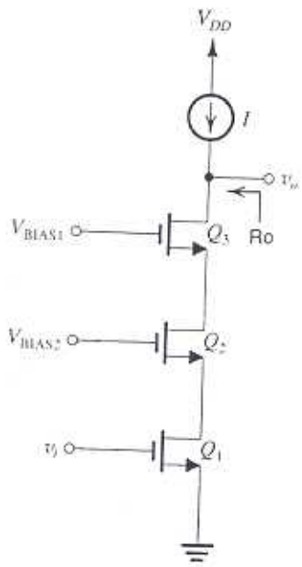
$$v_{gs} = v_i - v_o$$

$$v_i = v_{gs} + g_m v_{gs} (R_L \| r_o)$$

$$A_V = \frac{g_m v_{gs} (R_L \| r_o)}{1 v_{gs} + g_m v_{gs} (R_L \| r_o)}$$

$$= \frac{g_m (R_L \| r_o)}{1 + g_m (R_L \| r_o)}$$

ANSWER $A_V = \dfrac{g_m (R_L \| r_o)}{1 + g_m (R_L \| r_o)}$




(5 pts) If all transistors in the above circuit have identical $r_o$ and $g_m$, what is the output resistance Ro at the output of this circuit?

$$R_o = (g_{m3} r_{o3})(g_{m2} r_{o2})(r_{o1})$$
$$= g_m^2 r_o^3 \qquad (= A^2 r_o)$$

} EITHER IS FINE

ANSWER_____

Please report any problems you found in this exam below.

Thank you.