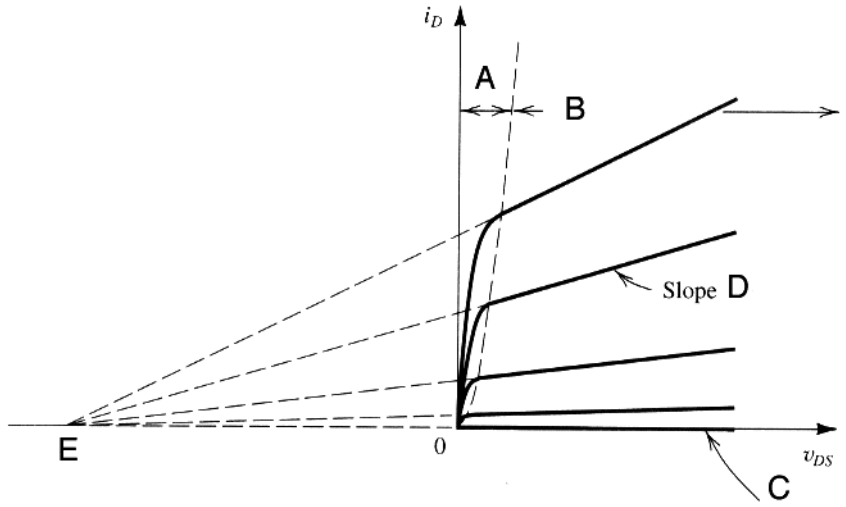
ECE 113B Midterm #2
(March 3, 2003, Professor Kleinfelder)

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:_____



The above is from a MOSFET

(2 pts) What is region A called?_____

(2 pts) Give the formula for the i_D in region A:_____

(2 pts) What is region B called?_____

(2 pts) Give the formula for the i_D in region B:_____

(2 pts) What is V_{gs} at the transition to line C?_____

(2 pts) What is point E called?_____

(2 pts) Give a formula for point E:_____

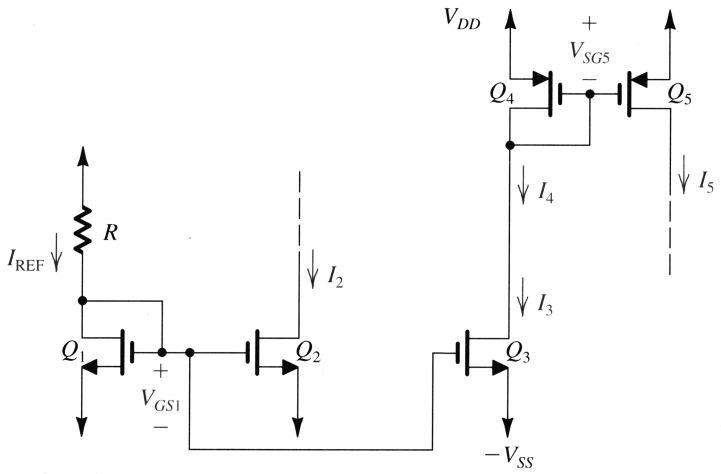
(2 pts) Give a formula for slope D:_____

(2 pts) What is the phenomena that causes slope D called?

_____

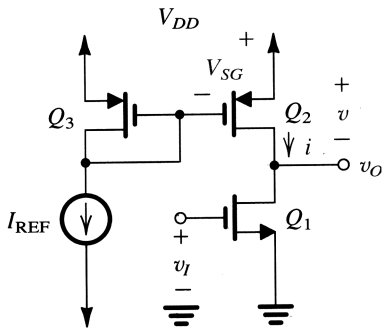
(2 pts) What is happening to the channel along the dotted line between region A and B?

_____



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

(5pts) X=_____, (5pts) Y=_____, (5pts) I_5=_____



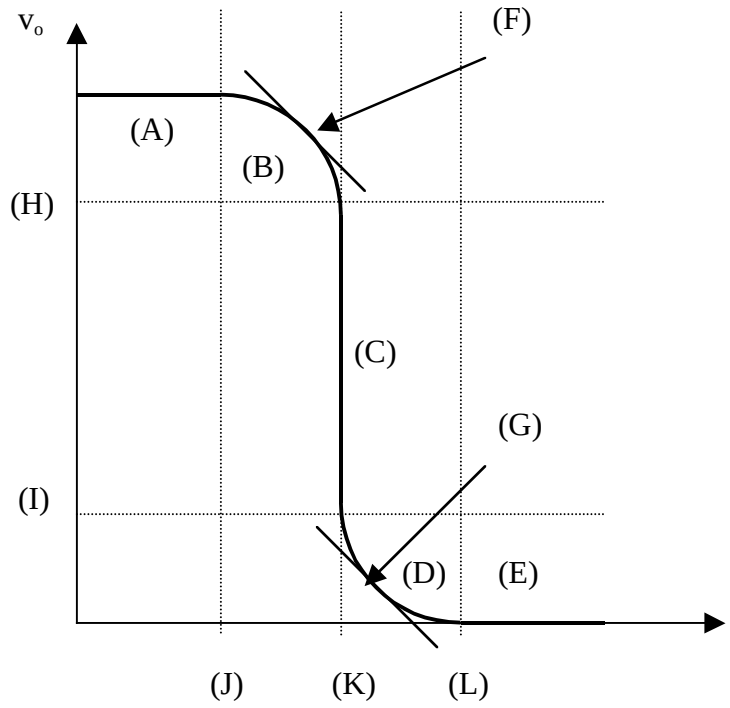
(10 pts) Draw and completely annotate a small-signal model of the above amplifier as would be required to calculate the gain, *including the model for the body effect, and assuming that there is a load resistance R_L to ground connected to the output*:

(5 pts) Assume that, for all devices, I_{ref}=200µA, W=10µm, L=1µm, V_t=1V, $\mu_n C_{ox}$=25µA/V^2, k'$_n$/k'$_p$=2.5, and that V_A=50. Showing your work, calculate the output resistance of the load transistor:

(5 pts) What is the formula for the transconductance of the input transistor that one would use if I_{REF} were an important variable?

(5 pts) Find the formula of the gain of the amplifier assuming that there is a load resistance R_L to ground (but ignore the body effect – in fact, there is none):

The following shows the output transfer characteristic of a CMOS inverter, where the transistors are matched. $|V_t|$ for both transistors is 1V and Vdd=5V. Assume that the regions and lines shown are appropriate for the transitions and/or areas of interest as given in the book and lectures.



Use this graph for the questions on the next page.

(1 pt each) What mode of operation is each transistor in for each region:

	n-channel	**p-channel**
Region (A)	_____	_____
Region (B)	_____	_____
Region (C)	_____	_____
Region (D)	_____	_____
Region (E)	_____	_____

(2 pts each) Find the following voltages:

Voltage (H):_____

Voltage (I):_____

Voltage (J):_____

Voltage (K):_____

Voltage (L):_____

(2 pts) What are points (F) and (G) defined as?

Answer: _____

(5 pts) Suppose that a chip (the Plentium-113B) uses a single 5V power supply, has 1 million transistors, each with 10 fF of load capacitance, and each transistor is clocked at 1 GHz. Showing your work, how much power will the chip use?

(13 pts) Showing your work (it may help to draw a model), derive the formula for the gain of a CMOS inverter in which all values (W,L,k',g_m,r_o, etc.) are equal for both transistors. Assume it is biased so that the input and output voltages are equal:
