UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering
and Computer Sciences

	Homework #3	**EECS 140**
B. E. Boser	Due 09/15/99 before noon in 497 Cory	**Fall 1999**

Note: Use the device parameters given in the class handout "Device Parameters & SPICE Models" and also available on the EECS 140 website, **http://kowloon.eecs.berkeley.edu/~courses/140**.

Grading: Problem 1: 10% Problem 2: 40% Problem 3: 50%

1) Consider the PMOS transistor shown in Fig.1.
   a) Assuming the device is on, what are the signs of the quantities V_{GS}, V_{DS} and I_D ?
   b) Write out the equations for I_D as a function of V_{GS} and V_{DS}, for both the triode and forward active region of the device.
   c) The table below shows three different biasing conditions for a PMOS transistor. For each situation, determine the transistor's region of operation and its drain current. Assume that the device is on, (W/L) = 10 and λ=0.1.

$\lvert V_{GS}\rvert$	$\lvert V_{DS}\rvert$	Region of Operation	I_D
3V	3V		
5V	0V		
1.5V	2.5V		

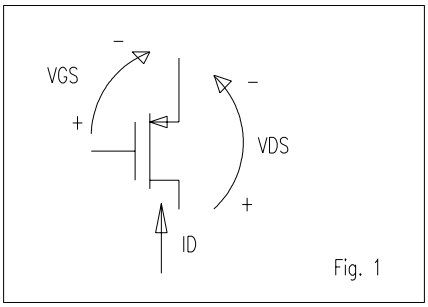

Fig. 1

2) Figure 2 shows a common source amplifier with resistive load. The transistor M1 is biased to operate in the ***triode*** region.
   a) Derive a small signal transistor model for a device operating the triode region, i.e. find expressions for its small signal output resistance and transconductance. Call these parameters r_o' and g_m'.
   b) Verify that M1 operates in the triode region. Calculate r_o' and g_m' for M1 and draw the small signal equivalent circuit for the amplifier circuit. Calculate the low frequency voltage gain $a_{V0}' = v_o/v_i$.
   c) Now assume that V_A is lowered until the device operates in the forward active region. Calculate r_o , g_m and a_{V0} using the expressions established in class. Assume V_{DS}=3V.
   d) Compare the results obtained in (b) and (c). Why are amplifier devices usually operated in the forward active region ?
   e) Derive analytical expressions for $a_{V0} = f(V_{GS}, V_{DS})$ for both regions of operation and compare.

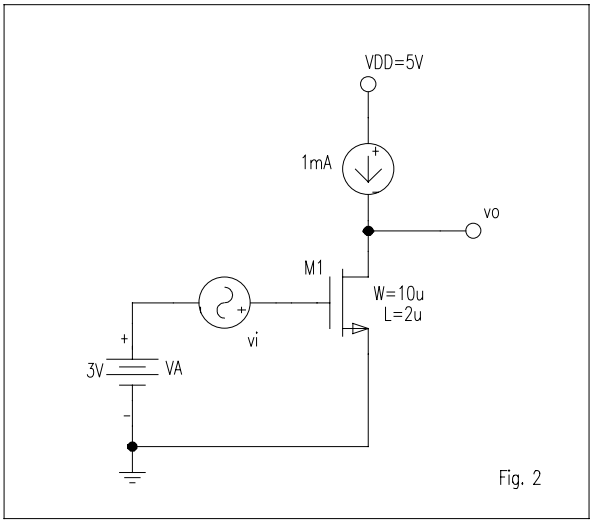

Fig. 2

3) Consider the common source amplifier with capacitive load in Figure 3.

a) Use the parameters given in the schematic to analyze the circuit as follows.

i) Calculate V_A such that the bias point at the output node $V_O = 3V$. Calculate the small signal parameters g_m and r_o for M1. Calculate the low frequency gain a_{V0} , the pole frequency f_0 and the unity gain frequency f_U.

ii) Find the *precise* value for V_A by performing a DC analysis using SPICE. Compare with your result from (i). Use at least 5 significant digits and explain why this is necessary.

iii) Setting VA to the value obtained in (ii), run a .OP analysis. Extract V_{DS}, V_{GS}, g_m and r_o from the SPICE listing file. Verify that the device operates in the forward active region and compare the simulation results for the small signal parameters with (i).

iv) Perform a .AC analysis and printout a Bode plot for the magnitude of the transfer function vo/vi. Mark the results from part (i) in your plot with three circles. Comment on discrepancies

b) Double the device width W and the channel length L. Repeat (i) through (iv).

c) Double the current I and double the device width W. Repeat (i) through (iv).

d) Compare the values for gain and bandwidth obtained in (a) through (c). Create a printout that contains all three Bode plots in one diagram. Explain.

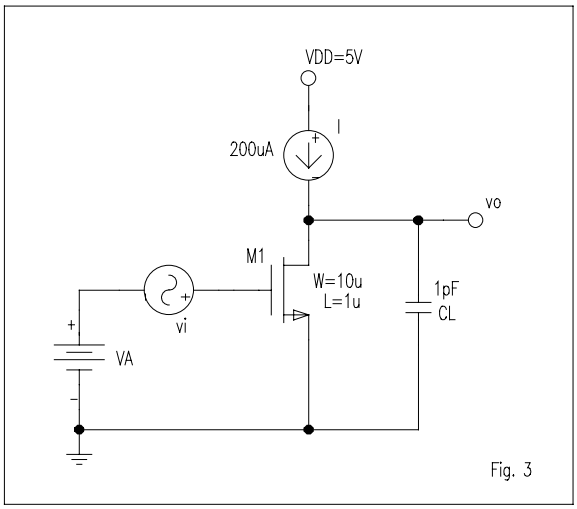

Fig. 3