Consider again the MOSFET amplifier shown in Figure 9.44 (See Notes). Assume as before that the amplifier is operated under the saturation discipline.

a) What is the range of valid input voltages for the amplifier? What is the corresponding range of valid output voltages?

b) Assuming we desire to use voltages of the form $A\sin(\omega t)$ as AC inputs to the amplifier, determine the input bias point $V_I$ for the amplifier which will allow for the maximum input swing under the saturation discipline. What is the corresponding output bias point voltage $V_O$?

c) What is the largest value of $A$ that will allow the saturation region operation for the bias point determined in (b)?

d) What is the small signal gain of the amplifier for the bias point determined in (b)?
Problem 6-2: (Problem 1 from Chapter 9 with part c omitted)

This problem studies the small-signal analysis of the MOSFET amplifier discussed in Problem 3 (Figure 8.40) in the previous chapter.

a) First consider the biasing the amplifier. Determine $V_{IN}$, the bias component of $v_{IN}$, so that $v_{OUT}$ is biased to $V_{OUT}$ where $0 < V_{OUT} < V_S$. Find $V_{MID}$, the bias component of $v_{MID}$ in the process.

b) Next, let $v_{IN} = V_{IN} + v_{in}$ where $v_{in}$ is considered to be a small perturbation of $v_{IN}$ around $V_{IN}$. Make the substitution for $v_{IN}$ and linearize the resulting expression for $v_{OUT}$. Your answer should take the form $v_{OUT} = V_{OUT} + v_{out}$ where $v_{out}$ takes the form $v_{out} = A v_{in}$. Note that $v_{out}$ is the small-signal output and $A$ is the small-signal gain. Derive an expression for $A$.

Problem 6-3: (Problem 2 from Chapter 9 with parts e and f omitted)

Consider again the buffer described in Problem 5 (Figure 8.41) in the previous chapter. Perform a small-signal analysis of this circuit according to the following steps. Assume that the MOSFET operates in its saturation region and continue to use the SCS MOSFET model.

a) Draw the small-signal circuit model of the buffer.

b) Show that the small-signal transconductance $g_m$ of the MOSFET is given by

$$g_m = K(V_{IN} - V_{OUT} - V_T)$$

where $V_{IN}$ and $V_{OUT}$ are the bias, or operating-point, input and output voltages, respectively.

c) Determine the small-signal gain of the buffer. That is, determine the ratio $v_{out}/v_{in}$.

d) Determine the small-signal output resistance of the buffer. That is determine the equivalent resistance of the buffer at the output port of its small-signal model with $v_{in} = 0$. (Hint: This is the Thevenin equivalent resistance of the small-signal circuit looking into the output port.)
e) Determine the small-signal input resistance of the buffer. That is determine the equivalent resistance of the buffer at the input port of its small-signal model. (Hint: This is the Thevenin equivalent resistance of the small-signal circuit looking into the input port.)