All problems are worth 10 points. Unless stated to the contrary, assume all MOS transistors have model parameters $\mu_nC_{OX}=100\mu A/V^2$, $V_{Tn}=1V$, $\mu_n/\mu_p=3$, $V_{Tp}=-1V$ and all BJT transistors have model parameters $J_S A=10^{-12}A$, $\beta_n=100$, and $\beta_p=30$.

**Problem 1**  Assume the capacitors are very large.
   a) Draw the small signal equivalent circuit for the amplifier shown
   b) Determine the quiescent value of $V_C$ and $V_{OUT}$
   c) Obtain the small-signal voltage gain in terms of the small signal model parameters
   d) Obtain a numerical value for the small-signal voltage gain
   e) Determine the small-signal output voltage $\nu_{OUT}$ if $V_M=200\mu V$
   f) What would be the output voltage be if $V_M=200mV$?

![Circuit Diagram]

**Problem 2**
   a) Determine the maximum value of $R_1$ that will keep $M_1$ in saturation. $M_1$ has dimensions $W=18\mu$ and $L=2\mu$ and is in a process with $\mu_nC_{OX}=100\mu A/V^2$, $\mu_pC_{OX}=30\mu A/V^2$, $V_{TNO}=0.5V$, $V_{TPO}=-0.5V$, $C_{OX}=2fF/\mu^2$, $\lambda=0$, $\gamma=0$.
   b) If $R_1$ is $1/3$ of the value determined in Part a), determine the small signal voltage gain of this circuit
   c) With the value of $R_1$ used in part b), determine the total output voltage if $\psi_{IN}(t)=.001\sin(5000t+75^\circ)$.

![Circuit Diagram]
Problem 3  Obtain an expression for the small signal output voltage in terms of the small signal parameters if the input is given by the expression \( V_{\text{IN}}(t) = V_M \cos(\omega t + \theta) \). Assume \( M_1 \) is operating in the saturation region.

Problem 4  Determine the total output voltage for the circuit in Problem 3 if \( V_{\text{DD}} = 5\text{V}, V_{\text{SS}} = -2\text{V}, W_1 = 10\mu\text{m}, L_1 = 2\mu\text{m}, W_2 = 6\mu\text{m} \) and \( L_2 = 1\mu\text{m} \). Assume the devices are from a process with parameters \( \mu_n C_{\text{OX}} = 100\mu\text{A}/\text{v}^2, \mu_p C_{\text{OX}} = 30\mu\text{A}/\text{v}^2, V_{\text{TNO}} = 0.5\text{V}, V_{\text{TPO}} = -0.5\text{V}, C_{\text{OX}} = 2\text{fF}/\mu\text{m}^2, \lambda = 0, \gamma = 0 \).

Problem 5  Obtain the AC equivalent and the DC equivalent circuit for the following network. Assume the transistors are operating in the saturation region and all capacitors are large. You need not solve the circuit.
Problem 6  Assume the capacitors are all very large.
  
g) Draw the small signal equivalent circuit for the amplifier shown
  
h) Determine the quiescent value of $V_C$ and $V_{OUT}$
  
i) Numerically obtain the small-signal voltage gain
  
j) Determine the small-signal output voltage $V_{OUT}$ if $V_M=1\text{mV}$ and $\omega=2000\pi$

![Small Signal Equivalent Circuit](image)

Problem 7  Determine the small signal output voltage if the small signal input voltage is a sinusoidal 1KHz signal with 0-P amplitude of 25mV.

![Small Signal Circuit](image)

Problem 8  Obtain the small signal impedance between the two terminals exiting the box. Assume the MOSFET is operating in the Saturation region and the BJT in the Forward Active region and that the quiescent currents are both 1mA.
Problem 9
Consider a device characterized by the equations
\[
I_1 = V_1 V_2^2
\]
\[
I_2 = 0.1e^{0.2V_1^2V_2}
\]

a. Determine the small signal model for a two-terminal device characterized by the equations given above
b. Determine the numerical values for the small signal model parameters if the quiescent value of the port voltages are \(V_2=1\)V, \(V_1=5\)V.
c. Determine the quiescent currents at the Q-point established in part b.
d. Determine the small signal currents \(i_1\) and \(i_2\) if the small signal voltages \(v_1\) and \(v_2\) were measured to be \(1\)mV\(_{\text{RMS}}\) and \(2\)mV\(_{\text{RMS}}\) respectively. Assume the same Q-point as established in part b.

Problem 10  In the circuit shown the dimensions of the transistor are \(W=8\)u and \(L=12\)u. Assume \(C_1\) is very large.

a) Draw the small signal equivalent circuit for the amplifier
b) Determine the quiescent value of \(V_D\) and \(V_{OUT}\)
c) Obtain the small-signal voltage gain

d) Determine the small-signal output voltage \(V_{OUT}\) if \(V_M=20\)mV
Problem 11  If $R_1 = 20K$, size the device so that the amplifier has a voltage gain of -8. Determine the quiescent value of the output voltage (the voltage on the drain node of $M_1$).

Problem 12  Design an amplifier using only BJT transistors, resistors, capacitors and voltage sources that has a voltage gain of -5 when driving a 2K resistor.

Problem 13  Design an amplifier using only MOS transistors, capacitors, and voltage sources that has a voltage gain of -10 when driving an external 10K resistor.

Problem 14  Use Modelsim to create a 4-bit register, using the D flip-flops from the previous homework. The register should only change its value on a positive clock edge. Include an enable bit and make the register only change its’s value if the enable bit is high during the positive clock edge. Create a test bench to test the correct operation of the register. Include screenshots of your Verilog code, and simulation waveforms.