Use the device parameters from the handout and spice level 1 model

1) For the circuit in figure 1, assume that W/L for all devices is 100um/1um, and \( I_{\text{ref}} \) is 1mA
   a) Calculate the expected output resistance and turn-on voltage.
   b) Use SPICE to plot \( I_{\text{out}} \) vs. \( V_{\text{out}} \), and use expression-builder in awaves to plot the output resistance as a function of output voltage.

2) For the circuit in figure 2, assume that W/L for all devices is 100um/1um, and \( I_{\text{ref}} \) is 1mA
   a) Calculate the minimum value for \( V_{\text{BN}} \) for which all transistors will be in saturation, and calculate the resulting turn-on voltage for the current source and its output resistance.
   b) Use SPICE to plot the output current vs. \( V_{\text{BN}} \) for \( V_{\text{out}} = 2V \). Make another current sink (identical copy of M1 and M2) and bias its output at \( V_{\text{out2}} = 3V \). Use the difference between the two output currents to plot the output resistance as a function of \( V_{\text{BN}} \).
   c) Make a table with the calculated and simulated values for the output resistance and turn-on voltage of each of the current sources in problems 1 and 2. Which current source gives the best performance? Why?

3) Generate \( V_{\text{BN}} \) from part 2a using a diode-connected NMOSFET and another 1mA current. Verify that the bias voltage, turn-on voltage, and output resistance are what you expect.

4) For the circuit in figure 3, assume that the current source has a finite output resistance \( R_L \), and that the MOSFETs are identical.
   a) Write an expression for the four small signal gains: from the two inputs to the two outputs.
   Assume that the current source is 1mA, and the devices are 100um/1um:
   b) Calculate the four small-signal gains assuming that the current source is made with a PMOSFET with an output resistance equal to the NMOS devices.
   c) Calculate the four small-signal gains assuming that the current source is made with a PMOS cascode with an output resistance equal to the NMOS cascode output resistance.

5) Design a telescopic cascode amplifier to pull no more than 1mW of power from a 5V supply with a gain of at least 10,000. Draw a schematic of your amplifier and label all transistors with their sizes, bias conditions, and small-signal parameters. What is the input common mode range of your amplifier? Estimate the pole frequency and unity gain frequency with no load, and with a 10pF load. Use SPICE to calculate the phase margin with no load, and with a 10pF load, and label the plots with your estimated frequencies. Will the amplifier be stable in unity gain feedback in both cases?
Figure 1

Figure 2

Figure 3