Problem 2.3 (4 points) Draw and label the small-signal differential-mode half circuit, and find the differential-mode gain, \( \frac{v_{od}}{v_{id}} \), where \( v_{id} = v_{i1} - v_{i2} \) and \( v_{od} = v_{o1} - v_{o2} \).

\[
g_{m1} = \frac{W}{L} \frac{1}{V} \frac{V_{ov1}}{8} \frac{0.5}{V} = 1200 \mu A/V
\]
\[R_o = R_1 = 3 \, k \Omega\]
\[
\frac{V_{od}}{V_{id}} = -(1200 \mu A/V) (3 \, k \Omega)
\]
\[
\frac{V_{od}}{V_{id}} = -3.6
\]

Problem 2.4 (6 points) Draw and label the small-signal common-mode half circuit, and find the common-mode gain, \( \frac{V_{oc}}{V_{ic}} \), where \( V_{ic} = 0.5(V_{i1} + V_{i2}) \) and \( V_{oc} = 0.5(V_{o1} + V_{o2}) \).

\[
i_1 = g_{m1} \left( V_{ic} - \frac{i_1}{2R_{tail}} \right) \Rightarrow i_1 = \frac{g_{m1} V_{ic}}{1 + 2R_{tail} g_{m1}}
\]
\[
i_2 = \frac{V_{oc}}{R_1 + 2R_2}
\]
\[
i_3 = -g_{m3} \left( \frac{2R_2}{2R_2 + R_1} \right) V_{oc}
\]
\[
i_1 = i_3 - i_2
\]
\[
\frac{V_{oc}}{V_{ic}} = \frac{1.64 \times 10^{-5}}{(0.67 \times 10^{-5} + 8 \times 10^{-14})} \Rightarrow \frac{V_{oc}}{V_{ic}} = 0.019
\]