1. [10 pts total] For the amplifier below, properly bias the circuit, including CMFB, and specify transistor sizes as needed (optimum biasing as always). Find the differential small-signal gain expression and CMFB loop gain expression.

\[
\text{Gain} \approx \frac{g_m}{1 + g_m \cdot \frac{R_1}{2}} \left[ \frac{r_{o2} g_m (R_2 + R_3)}{r_{o1} + r_{o2} g_m \left( \frac{R_1}{2} \right)} \right] \\

\text{CM Loop Gain} \approx -g_m \left[ \frac{r_{o2} g_m (R_2 + R_3)}{r_{o1} g_m R_{o4}} \right] \frac{g_m}{g_m} 
\]
2. [10 pts total] Is this good for anything practical? No. Is this good for an exam to test your understanding? Yes. Specify transistor sizes for M1, M2, and M3, and find all node voltages (in terms of $v_T$ and $\Delta$).
3. [10 pts total] Find the output-referred noise and the input-referred noise.

\[ \frac{V_{0_{in}}^2}{\Delta f} = \frac{\sigma^2}{\Delta f} = \left( \frac{g_{m1} g_{m4} g_{m2}}{g_{m3}} + 1 \right)^2 \]

\[ \frac{V_{0_{in}}^2}{\Delta f} = 4kT \frac{2}{3} \left( g_{m1} \frac{g_{m4}}{g_{m3}} \frac{1}{g_{m2}} \right)^2 + 4kT \frac{2}{3} \frac{1}{g_{m2}} (1)^2 \]

\[ + 4kT \frac{2}{3} \left( \frac{1}{g_{m3}} + \frac{1}{g_{m4}} \right) \left( g_{m4} \frac{1}{g_{m2}} \right)^2 + 4kT \frac{2}{3} \frac{1}{g_{m5}} \left( g_{m5} \frac{1}{g_{m2}} \right)^2 \]
4. [10 pts total] For the amplifier below with constant-gm bias, properly size M1 for approximate unity-gain bandwidth of $1/RC$, properly size M2/M3/M4/M5 for zero systematic offset and RHP zero cancellation.

\[ \text{UBW} = \frac{1}{RC} \]

\[ \rightarrow g_m = \frac{1}{R} \]

\[ I_D = \frac{1}{2} \max \left(\frac{90}{1}\right) \Delta^2 = \frac{2 \Delta}{R} \]

\[ \rightarrow g_m = \max \left(\frac{90}{1}\right) \Delta = \frac{4}{R} \]

\[ \frac{1}{2} \text{current in } \frac{1}{2} \text{ size } \]

\[ M1 \text{ has } \frac{1}{2} \text{ current of } MX \]

\[ \left(\frac{W}{L}\right)_{M1} = \frac{45}{1} \cdot \frac{1}{4} = \frac{45}{4} \]

\[ \text{for } g_m = \frac{1}{R} = \frac{g_m}{4} \]

\[ \frac{1}{4} \text{ size reduces } g_m \text{ by } \frac{1}{4} \]
5. [10 pts total] You’re stranded on a desert island and desperate to get out of there. In your search of your environment, you find an S.O.S. transmitter that requires a 50μA bias. Searching in sandpits you find a 20μA current source and some spare NMOS transistors. Design the needed current mirror with the NMOS devices you have. There are one 5/1 device, two 10/1 devices, and two 30/1 devices. You may use all of them or a subset of them to build a proper current mirror. Find one suitable design for 7 pts, and a second suitable design for 3pts. (Yeah, yeah, there is a battery too and wires/connectors.)