1. [25 points] For the circuit shown below, calculate voltage gains \( \frac{v_{out}}{v_{in}} \) at \( f = 0 \text{Hz} \) and \( f = \infty \text{Hz} \).

Assume M1 can be modeled as an ideal transconductor as shown below.

\( g_m = 20 \text{ mA/V} \)
\( R_D = 1 \text{ k}\Omega \)
\( R_S = 500 \text{ \Omega} \)
\( C_S = 1 \text{ pF} \)
2. [25 points] For the circuit shown below, calculate $v_{OUT+}$ and $v_{OUT-}$. Assume M1 and M2 are biased in saturation region. Assume $I_{BIAS}$ is an ideal current source. Ignore channel length modulation and body effect. Assume $\omega_{in} \ll \omega_{pole}$, where $\omega_{pole}$ is the main pole of the differential amplifier.

\[
\begin{align*}
G_{m1} = G_{m2} &= 10 \text{mA/V} \\
R_D &= 600 \Omega
\end{align*}
\]
3. [25 points] For the circuit shown below, calculate $H(s) = \frac{v_{\text{OUT}}}{v_{\text{IN}}}$. Assume the op-amp is ideal. From the $H(s)$, calculate 3-dB bandwidth.

$$C_1 = 0.5C_2$$
$$R_1 = 2R_2$$
4. [25 points] For the circuit shown below, calculate $v_{OUT}$ as a function of $v_{IN1}$ and $v_{IN2}$ at low frequencies (ignore all parasitic capacitances).

Assume:
- $M1$, $M2$, and $M3$ are biased in saturation
- $g_{m1} = g_{m2} = g_{m3} = g_m$
- $r_{01} = r_{02} = r_{03} = r_0$

```
V_{IN2} ------ M3
          |
          v_{OUT}
V_{BIAS}  ------ M2
            |
V_{IN1}    ------ M1
```

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