1. Assuming that the following circuit is symmetrical and $\gamma = \lambda = 0$:

i) Find the expression for the small-signal differential voltage gain ($\frac{V_{out}}{V_{in1} - V_{in2}}$) of the circuit at very low frequencies.

ii) What is the gain of the circuit at very high frequencies?

iii) Repeat parts (i) and (ii) assuming $\lambda \neq 0$.

**Note:** In this question neglect all other capacitances that are not shown in the circuit.

2. In the following cascode circuit (typically referred to as self-biased cascode circuit) the resistor $R$ is used to maintain a proper voltage to allow both $M_1$ and $M_2$ remain in saturation.
Assume both $M_1$ and $M_2$ have the same size $W/L$. Ignoring the channel length modulation and the body effect, show that for $M_1$ and $M_2$ to remain in the saturation region we should have:

$$\frac{2}{\mu_p C_{ox} \left( \frac{W}{L} \right) R^2} \leq I_{ref} \leq \frac{|V_{tp}|}{R}$$

3. Design a two-stage amplifier based on the topology shown below with the following design specifications:
   - $V_{DD}=1.8V$
   - Total power consumption of 1.8 mW
   - Differential output swing of 2.8V
   - Total gain of 1000
   - $L=0.4\mu m$ for all the device

   Use the following assumptions for your design
   - The circuit is symmetric
   - The bias currents of the first stage and second stage are equal (i.e., $I_6=I_5+I_9$).
   - The magnitude of overdrive voltages of $M_4$, $M_6$, and $M_8$ are equal

   The technology parameters are:
   $\lambda_{(NMOs)}=\lambda_{(PmoS)}=0.1 V^{-1}$, \( \gamma = 0 \), $V_{DD}=1.8V$, $V_{TH(NMOs)}=|V_{TH(PMOs)}|=0.4V$, $\mu_n C_{ox}=0.5 mA/V^2$, $\mu_p C_{ox}=0.25 mA/V^2$.

   **Note:** Use the parameter $\lambda$, only for calculating the $r_o$ of the transistors. **Do not** use $\lambda$ in any other calculation including your bias currents.

   ![Two-stage amplifier diagram](image)

Find $V_{bias1}$, $V_{bias2}$, and all the transistor widths (i.e., $W_0, W_1, W_2, W_3, W_4, W_5, W_6, W_7$, and $W_8$).

4. The unity-gain closed-loop buffer has a phase margin of 50°. What is the percentage of peaking in magnitude frequency response of the closed-loop system in the vicinity of the gain crossover frequency (i.e., the frequency at which the loop-gain is 1)?

**Good luck**