Problem 1 (10 points):

The closed-loop amplifier circuit shown in Fig. 1 uses an op-amp with finite open-loop gain $A$. You can assume that the op-amp input currents are both zero.

(a) If the dc component of $V_{in}$ is 1 V, find the dc component of $V_{out}$.

(b) Assuming that $R_1$ is large enough to be considered an open circuit, find the expression for the closed-loop transfer function $V_{out}(j\omega)/V_{in}(j\omega)$.

(c) From your answer in part (b), show that for sufficiently large $A$ the closed-loop transfer function depends only on the ratio of resistors $C_2/C_1$.

(d) If both $C_1$ and $C_2$ are decreased by 10%, how will the transfer function found in part (c) be affected?

![Fig. 1](image-url)
Problem 2 (10 points):

The circuit shown in Fig. 2 is to be used as a high-quality current source.

(a) Find $I_{OUT}$ assuming that the op-amp is ideal.

(b) What is the lowest dc voltage that can be sustained at the current source output while keeping the transistor in the saturation region? Express your answer in terms of the transistor $(V_{GS} - V_t)$ and other relevant parameters.

(c) Now assuming that the op-amp has a finite gain $A_0$, find the output resistance of this current source in terms of the transistor small-signal parameters and $A_0$.

![Fig. 2](image-url)
Problem 3 (10 points):

The circuit shown in Fig. 3 is a differential amplifier. Assume $\beta = \infty$ and for the BJTs. Consider finite values of $r_o$ for transistors $Q_3$, $Q_{2C}$, and $Q_{2D}$ but ignore the $r_o$ of the other transistors. Assume that transistor $Q_3$ has a dc base voltage so that it conducts dc collector current $I_{EE}$.

(a) Find the approximate dc currents in each of the transistors.

(b) Find the differential-mode gain in terms of transistor small-signal parameters and resistor values.

(c) Find the common-mode gain in terms of transistor small-signal parameters and resistor values.

(d) Find the common-mode rejection ratio.

![Figure 3](image-url)