I. (25 pts) A current amplifier has an input resistance $R_i = 1 \, \text{k}\Omega$, an output resistance $R_o = 10 \, \text{k}\Omega$, and a short-circuit current gain $A_{iC} = 100 \, \text{A/A}$. It is connected between a voltage source $V_s$ of 100 mV with a source resistance of 100 kΩ and a load resistance of 1kΩ.

Calculate the value of $v_0$, $v_0/v_i$, $v_0/v_i$, where $v_i$ is the input voltage to the amplifier.

\[ V_s = 100 \, \text{mV} \]

\[ v_i = \frac{V_s}{1 \, \text{k}\Omega} \]

\[ v_0 = A_{iC} v_i = \frac{10 \, \text{k}\Omega}{1 \, \text{k}\Omega} \times \frac{1 \, \text{k}\Omega}{11 \, \text{k}\Omega} = 0.909 \times v_i \]

\[ \frac{v_0}{v_i} = 0.909 \]

\[ v_o = 90.9 \, \text{mV} \]

\[ v_i = \frac{1}{101} \times 100 \, \text{mV} = 0.990 \, \text{mV} \]

\[ \frac{v_0}{v_s} = \frac{v_0}{v_i} \times \frac{v_i}{v_s} = \frac{90.9}{101} = 0.909 \]
II. (25 pts) Calculate the transfer function $T(s) = v_0 / v_i$ for the filter shown below.

(a) Is it a low-pass or high-pass filter? Discuss qualitatively.

The $T(s)$ of the filter should be of one of the two forms

\[ T(s) = \frac{K}{1 + \frac{s}{\omega_0}} \]  \hspace{1cm} (1)

for a low-pass filter, or

\[ T(s) = \frac{K}{1 + \frac{\omega_0}{s}} \]  \hspace{1cm} (2)

for a high-pass filter.

(b) Find the analytical expressions for $K$ and the $3B$ break angular frequency $\omega_0$.

\[ T(\omega) = \frac{R_2}{R_1 + R_2} \]  \hspace{1cm} \(R_1 / R_2\) = \(\omega_0 = \frac{1}{\omega} \)

\[ \omega_0 = \frac{1}{\sqrt{LC}} \]

\[ T(\omega) = \frac{\frac{R_2}{R_1 + R_2}}{1 + \frac{\omega}{\omega_0}} \]
III. (25 pts) In the circuit shown below,

Calculate the voltage \( v_0 \) in terms \( v_1 \), \( v_2 \) and \( v_3 \). Assume all op-amps are ideal. Work your way from left to right and calculate the intermediate voltages \( v_x \) and \( v_y \).

\[
\begin{align*}
    v_x &= -2v_3 \\
    v_y &= -2v_1 - 4v_2 - 4v_x \\
    &= -2v_1 - 4v_2 + 8v_3 \\
    v_0 &= -3v_y = 6v_1 + 12v_2 - 24v_3
\end{align*}
\]
IV. (25 pts) Calculate the transfer function $T(s) = v_0/v_i$ for the filter shown below. Assume the op-amp is ideal.

(a) Is it a low-pass or high-pass filter? Discuss qualitatively.

(b) Find the analytical expression for $K$ and the 3dB angular frequency $\omega_0$.

\[
\frac{N_T}{N_i} = \frac{1}{1 + \frac{R}{\omega_0}} \quad \omega_0 = \frac{1}{RC}
\]

\[
N_T = N_+ \quad \Rightarrow \quad N_0 = (1 + \frac{R_2}{R_1}) N_+
\]

\[
T(s) = \frac{N_0}{V_i} = \frac{(1 + \frac{R_2}{R_1})}{1 + \frac{\omega}{\omega_0}} \quad \omega_0 = \frac{1}{RC}
\]