PROBLEM 1 (15 points)
An amplifier has two inputs $V_+$ and $V_-$, and one output, $V_0$.

If $V_0 = aV_+ + bV_-$, derive the common mode and differential mode gains as a function of $a$ and $b$.

PROBLEM 2 (15 points)
In the table below, fill in YES or NO in each of the 15 boxes

<table>
<thead>
<tr>
<th></th>
<th>Op Amp</th>
<th>Inverting op-amp circuit amplifier</th>
<th>Non-inverting op-amp circuit amplifier</th>
<th>Differential op-amp circuit amplifier</th>
<th>Instrumentation amplifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>High $Z_{\text{in}}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Differential input</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defined gain over a frequency band</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PROBLEM 3 (35 points)
In the op-amp amplifier circuit shown below, assume the following:
• The op-amp open-loop gain \( A = 10^6 \text{ Hz/f} \).
• Op-amp input currents are zero
• Output offset can be neglected
• The wave generator produces a pure sinewave of frequency \( f \) and has zero output impedance

3a (15 points) Derive expressions for \( V_2 \), \( V_3 \), and \( V_0 \) as a function of input \( V_1 \) at the frequency \( f = 10 \text{ Hz} \). You may neglect small terms that contribute less than a few percent.
3b  (20 points) Derive expressions for \( V_2 \), \( V_3 \), and \( V_0 \) as a function of input \( V_1 \) at the frequency \( f = 10^6 \) Hz. You may neglect small terms that contribute less than a few percent.

PROBLEM 4  (35 points)
Design an analog filter circuit that has the following properties
- Gain between 0.9 and 1.0 for frequencies between 100 Hz and 20 kHz
- Gain less than 0.001 for frequencies above 55 kHz
- Gain less than 0.01 at 60 Hz
- Gain less than 0.001 for frequencies below 2 Hz
4a  (10 points) Sketch the required gain vs. frequency below
4b (25 points) Design a filtering circuit that meets the requirements above with the minimum complexity and cost. For each filtering element, give type, corner frequency, and order number. (Hint: see equation sheet for a table of $f/f_c$ vs. gain and order.) Do not give resistor and capacitor values.