For the circuit above:

- What is the Differential Gain, \( G_d = \frac{V_o}{(V_B - V_A)} \)?

- What is the Common-mode Gain, \( G_{cm} = \frac{V_o}{(\frac{1}{2}(V_B + V_A))} \)?

- What is the Common-mode Rejection Ratio (CMRR)?

All op amps are ideal with \( V_{CC} = 15 \text{ V} \) and \( V_{CC} = -15 \text{ V} \).

- What is the Differential Gain, \( G_d = \frac{V_o}{(V_B - V_A)} \)?

\[
V_o = \left( \frac{R_3 + R_4}{R_1 + R_2} \right) \left( \frac{R_3}{R_2} \right) V_B - \left( \frac{R_1}{R_2} \right) V_B \\
V_o = \left( \frac{30 + 1.9}{30 + 1.901} \right) \left( \frac{30}{1.901} \right) V_B - \left( \frac{30}{1.901} \right) V_B = 15.7890 V_B - 15.7812 V_A
\]

Set \( V_B = -V_A = 1 \text{ V} \), \( V_d = V_B - V_A = 2 \text{ V} \).
\( G_d = \frac{V_o}{V_d} = \frac{(15.7890(1) - 15.7812(-1))}{2} = 15.7851 \)

- What is the Common-mode Gain, \( G_{cm} = \frac{V_o}{(\frac{1}{2}(V_B + V_A))} \)?

Set \( V_B = V_A = 1 \text{ V} \), \( V_{cm} = \frac{1}{2}(V_B + V_A) = 1 \text{ V} \).
\( G_{cm} = \frac{V_o}{V_d} = \frac{|15.7890(1) - 15.7812(1)|}{1} = 0.0078 \)

- What is the Common-mode Rejection Ratio (CMRR)?

\[
\text{CMRR} = 20 \log_{10} \frac{15.7851}{0.0078} = 66.12
\]
For the circuit above:

- Sketch $V_o$ as a function of time.
- What is $V_x - V_y$ at $t = 45$ ms?

All op amps are ideal with $V_{CC} = 15$ V and $V_{CC} = -15$ V.

Thus:

\[
V_o = \left(1 + \frac{2R_A}{R_G}\right) \left(\frac{R_1}{R_2}\right)(V_B - V_A)
\]

\[
V_o = \left(1 + \frac{2 \times 58}{3.7}\right) \left(\frac{58}{2.4}\right)(V_B - V_A) = 781.8 (V_B - V_A)
\]

\[
V_x - V_y = \left(1 + \frac{2R_A}{R_G}\right)(V_B - V_A)
\]

\[
V_x - V_y = 32.35 (V_B - V_A) = 32.35 (4.1 \text{ mV} - 2.2 \text{ mV}) = 0.061 \text{ V}
\]
For the input, $V_i$, below, sketch the output, $V_o$, on the same graph. Indicate voltage levels and the times of any transitions. (The op amp is idea with the indicated $V_{CC}$ and $V_{EE}$ values).

Non-inverting amplifier:
Gain: $G = 1 + R_1/R_2 = 1 + 59/2.9 = 21.34$

Ideally, output would swing from $-42.68 \text{ V}$ (at $t = 0 \text{ ms}$) to $42.68 \text{ V}$ (at $t = 20 \text{ ms}$).
However, output is limited to ±10 V.
Slope is $2 \times 42.68/20 = 2.134 \text{ V/ms}$.
So starting at $V=0$, the limit of 10 V is reached in
$\Delta t = 10 \text{ V} / 2.134 \text{ V/ms} = 4.686 \text{ ms}$

Thus:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$t$ (ms)</th>
<th>$V_o$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 - 4.686$</td>
<td>$5.31$</td>
<td>$-10$</td>
</tr>
<tr>
<td>$10 + 4.686$</td>
<td>$14.69$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 - 4.686$</td>
<td>$25.31$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 + 4.686$</td>
<td>$34.69$</td>
<td>$-10$</td>
</tr>
</tbody>
</table>