For the circuit above:

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

\[
V_o = \left( \frac{R_1 + R_2}{R_3 + R_4} \right) \left( \frac{R_3}{R_2} \right) V_B - \left( \frac{R_1}{R_2} \right) V_B \\
V_o = \left( \frac{29 + 1.401}{29 + 1.4} \right) \left( \frac{29}{1.401} \right) V_B - \left( \frac{29}{1.401} \right) V_B = 20.7150 V_B - 20.6995 V_A
\]

Set \( V_B = -V_A = 1 \text{ V}, \) \( V_d = V_B - V_A = 2 \text{ V} \).

\( G_d = \frac{V_o}{V_d} = \frac{(20.7150(1) - 20.6995(-1))}{2} = 20.7072 \)

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

Set \( V_B = V_A = 1 \text{ V}, \) \( V_{cm} = \frac{1}{2}(V_B + V_A) = 1 \text{ V} \).

\( G_{cm} = \frac{V_o}{V_d} = \frac{|20.7150(1) - 20.6995(1)|}{1} = 0.0155 \)

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

\[
\text{CMRR} = 20 \log_{10} \frac{20.7072}{0.0155} = 62.52
\]
For the circuit above:

- Sketch \( V_o \) as a function of time.

- What is \( V_x - V_y \) at \( t = 45 \text{ ms} \)?

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

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

Thus:

<table>
<thead>
<tr>
<th>( t ) (ms)</th>
<th>( V_A ) (mV)</th>
<th>( V_B ) (mV)</th>
<th>( V_o ) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.2</td>
<td>4.0</td>
<td>0.778</td>
</tr>
<tr>
<td>15</td>
<td>2.6</td>
<td>4.0</td>
<td>0.606</td>
</tr>
<tr>
<td>25</td>
<td>2.2</td>
<td>4.0</td>
<td>0.778</td>
</tr>
<tr>
<td>35</td>
<td>2.2</td>
<td>6.3</td>
<td>1.773</td>
</tr>
<tr>
<td>45</td>
<td>2.2</td>
<td>4.0</td>
<td>0.778</td>
</tr>
</tbody>
</table>

- What is \( V_x - V_y \) at \( t = 45 \text{ ms} \)?

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

\[
V_x - V_y = 26.13 \times (V_B - V_A) = 26.13 \times (4.0 \text{ mV} - 2.2 \text{ mV}) = 0.047 \text{ V}
\]
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 ideal with the indicated $V_{CC}$ and $V_{EE}$ values).

Non-inverting amplifier:
Gain: $G = 1 + R_1/R_2 = 1 + 57/2.4 = 24.75$

Ideally, output would swing from $-49.50$ V (at $t = 0$ ms) to $49.50$ V (at $t = 20$ ms).
However, output is limited to $\pm 10$ V.
Slope is $2 \times 49.50/20 = 4.950$ V/ms.
So starting at $V=0$, the limit of $10$ V is reached in $\Delta t = 10$ V / $4.950$ V/ms = $2.020$ ms

Thus:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$t$ (ms)</th>
<th>$V_o$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 - 2.020$</td>
<td>$7.98$</td>
<td>$-10$</td>
</tr>
<tr>
<td>$10 + 2.020$</td>
<td>$12.02$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 - 2.020$</td>
<td>$27.98$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 + 2.020$</td>
<td>$32.02$</td>
<td>$-10$</td>
</tr>
</tbody>
</table>