For the circuit above:

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

\[
V_o = \left( \frac{R_3 + R_4}{R_1 + R_2} \right) \left( \frac{R_3}{R_2} \right) V_B - \left( \frac{R_1}{R_2} \right) V_B
\]

\[
V_o = \left( \frac{29 + 1.5}{29 + 1.501} \right) \left( \frac{29}{1.501} \right) V_B - \left( \frac{29}{1.501} \right) V_B = 19.3327 V_B - 19.3205 V_A
\]

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

\[ G_d = V_o/V_d = (19.3327(1) - 19.3205(-1))/2 = 19.3266 \]

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

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

\[ G_{cm} = V_o/V_d = |19.3327(1) - 19.3205(1)|/1 = 0.0122 \]

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

\[ \text{CMRR} = 20 \log_{10} \frac{19.3266}{0.0122} = 64.00 \]
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.

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

Thus:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$V_A$ (mV)</th>
<th>$V_B$ (mV)</th>
<th>$V_o$ (V) = 504.2($V_B - V_A$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.2</td>
<td>4.1</td>
<td>0.958</td>
</tr>
<tr>
<td>15</td>
<td>2.7</td>
<td>4.1</td>
<td>0.706</td>
</tr>
<tr>
<td>25</td>
<td>2.2</td>
<td>4.1</td>
<td>0.958</td>
</tr>
<tr>
<td>35</td>
<td>2.2</td>
<td>6.1</td>
<td>1.966</td>
</tr>
<tr>
<td>45</td>
<td>2.2</td>
<td>4.1</td>
<td>0.958</td>
</tr>
</tbody>
</table>

- What is $V_x - V_y$ at $t = 45$ ms?

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

$$V_x - V_y = 35.07 (V_B - V_A) = 35.07 (4.1\text{ mV} - 2.2\text{ mV}) = 0.067\text{ V}$$
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: $G = 1 + R_1/R_2 = 1 + 57/2.5 = 23.80$

Ideally, output would swing from $-47.60 \text{ V} \ (\text{at } t = 0 \text{ ms})$ to $47.60 \text{ V} \ (\text{at } t = 20 \text{ ms})$.
However, output is limited to $\pm 10 \text{ V}$.
Slope is $2 \times 47.60/20 = 2.380 \text{ V/ms}$.
So starting at $V=0$, the limit of $10 \text{ V}$ is reached in $\Delta t = 10 \text{ V} / 2.380 \text{ V/ms} = 4.202 \text{ ms}$

Thus:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$t$ (ms)</th>
<th>$V_o$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 - 4.202$</td>
<td>$5.80$</td>
<td>$-10$</td>
</tr>
<tr>
<td>$10 + 4.202$</td>
<td>$14.20$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 - 4.202$</td>
<td>$25.80$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 + 4.202$</td>
<td>$34.20$</td>
<td>$-10$</td>
</tr>
</tbody>
</table>