The op-amp operates in the linear mode. Using an appropriate model of the op-amp, derive an expression for \( v_o \) in terms of not more than \( i_a, v_a, R_1, R_2, \) and \( R_3 \).

**SOL’N:**

We first remove the op-amp and assume the op-amp output voltage has the value necessary to make the voltage drop across the op-amp inputs equal zero volts. One possible way of labeling the resulting circuit, consistent with the passive sign convention, is shown above (right).

Looking first for components in series that carry the same current, we see that \( R_4 \) and \( R_3 \) have equal but opposite currents:

\[
i_3 = -i_a
\]
Next, we look for voltage loops, making sure we use the 0 V drop across the op-amp inputs at least once. The small voltage loop shown on the diagram above yields the following Equation (using the current through $R_3$ as $i_a$):

$$ +V_a + i_a R_3 - V_o = 0 $$

Solving for $V_o$:

$$ V_o = V_a + i_a R_3 $$