Ex:

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 \( v_s1, v_s2, R_1, \) and \( R_2. \)

Sol’N: a) Because we have negative feedback that causes the op-amp to operate in linear mode, we remove the op-amp and find the value of \( v_o \) that causes the voltage across the inputs of the op-amp to be zero.

We look for v-loops, such as those shown by dashed lines, that pass thru the 0 V drop across the op-amp inputs. These v-loops yield two equations:

\[
-i_1 R_1 + v_{s1} + 0 \, \text{V} - v_{s2} = 0 \, \text{V}
\]  
(1)
and
\[ v_{s2} - 0 \ V - i_2 R_2 - v_o = 0 \ V. \]  \hspace{1cm} (2)

A current summation at the minus input of the op-amp yields a third equation:
\[ i_1 = i_2 \]  \hspace{1cm} (3)

Using this result in equation (2) yields the following result:
\[ v_{s2} - i_1 R_2 - v_o = 0 \ V \]
or
\[ v_o = v_{s2} - i_1 R_2 \]  \hspace{1cm} (4)

Solving equation (1) for \( i_1 \), we have
\[ i_1 = \frac{v_{s1} - v_{s2}}{R_1} \]

Using this expression in equation (4) yields our final answer:
\[ v_o = v_{s2} - \frac{(v_{s1} - v_{s2})}{R_1} R_2 \]
or
\[ v_o = v_{s2} \left(1 + \frac{R_2}{R_1}\right) - v_{s1} \frac{R_2}{R_1} \]