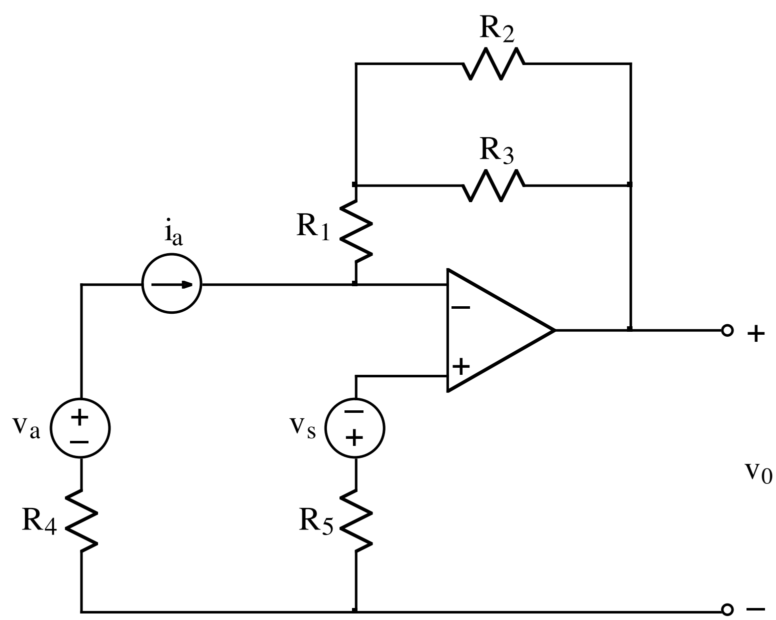
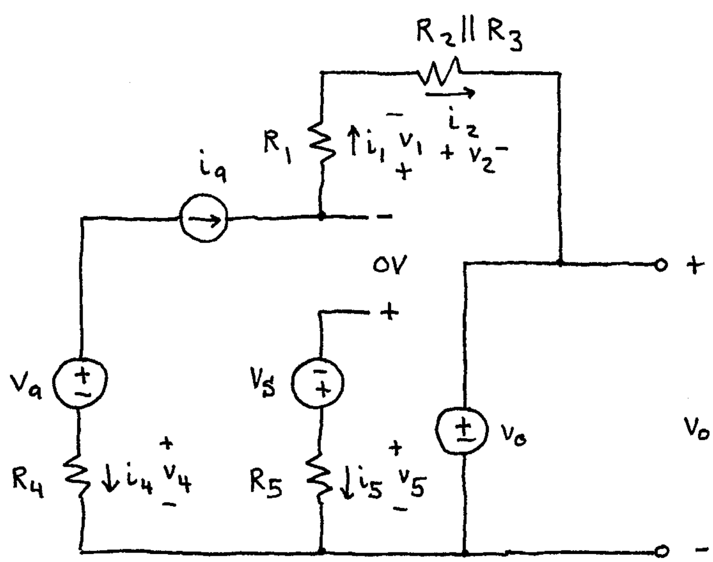
Ex:



The op-amp operates in the linear mode. Using an appropriate model of the op amp, derive an expression for v_0 in terms of not more than v_a, v_s, i_a, R_1, R_2, R_3, R_4 and R_5.

sol'n: Replace op-amp with src called v_0 and assume v-drop across + and − terminals is 0V. We also combine R_2 and R_3.



Write v-loops passing thru 0V across + and − terminals:

$+v_4 + v_q + ?$ Don't use left-side v-loop because of current src.

$+v_5 - v_5 - 0V - v_1 - v_2 - v_o = 0V$

Write current sums at nodes.
The only true node is on the bottom.

$-i_4 - i_5 - i_2 = 0A$

Look for components in series carrying the same current:

$i_4 = -i_q$

$i_1 = i_q$

$i_2 = i_1 = i_q$

$i_5 = 0A$ (since it is in series with an open circuit)

We see that i_q flows all the way around the outer loop.

We need only substitute for v's in v-loop using i_q and Ohm's law for each resistor:

$v_1 = i_1 R_1 = i_q R_1$

$$v_2 = i_2 \cdot R_2 \| R_3 = i_q \cdot R_2 \| R_3$$

$$v_5 = i_5 R_5 = 0 \cdot R_5 = 0V$$

Our v-loop becomes:

$$0V - v_s - 0V - i_q R_1 - i_q \cdot R_2 \| R_3 - v_o = 0V$$

Solving v_o gives the expression we seek:

$$v_o = -v_s - i_q (R_1 + R_2 \| R_3)$$