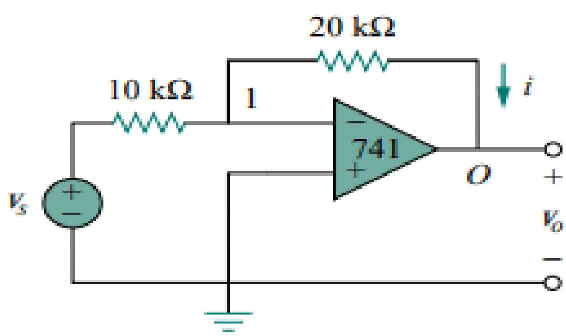
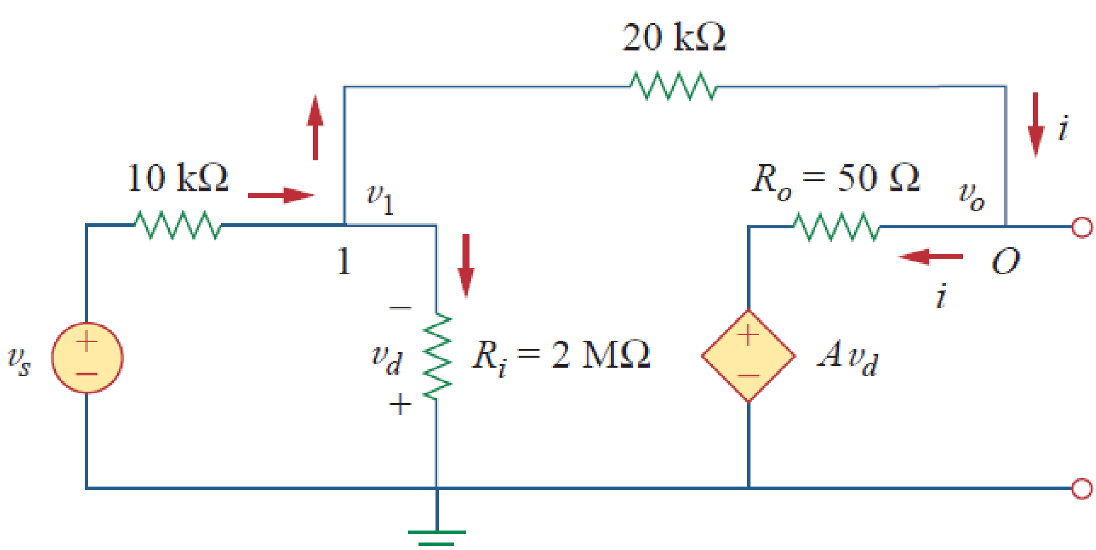
Helwan University
Faculty of Engineering at Helwan
Electronic Circuits
2nd Year Communication Department

Op Amp Sheet

1. For the circuit shown, A 741 op amp has an open-loop voltage gain of 2 × 105, input resistance of 2 MΩ, and output resistance of 50Ω. Find the closed-loop gain Vo/Vs. Determine current i when Vs = 2 V.



Solution:



TA: Abdalla Tawfik

Apply KCL at node 1:

$$\frac{v_s - v_1}{10 \times 10^3} = \frac{v_1}{2 \times 10^6} + \frac{v_1 - v_o}{20 \times 10^3}$$
$$2v_s \simeq 3v_1 - v_o$$

$$v_1 = \frac{2v_s + v_o}{3} \quad \rightarrow Equation\ 1$$

Apply KCL at node 1:

$$\frac{v_1 - v_o}{20 \times 10^3} = \frac{v_o - Av_d}{50}$$

Since:

$$v_d = -v_1 \quad and \quad A = 200000$$

$$v_1 - v_o = 400(v_o + 200000v_1) \quad \rightarrow Equation\ 2$$

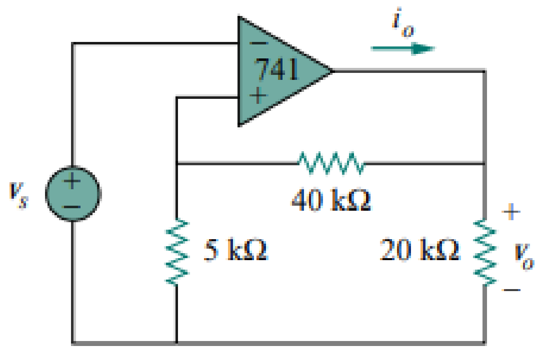
By substituting v_1 **from equation** 1 **into equation** 2**:**

$$\frac{v_o}{v_s} \simeq -2$$

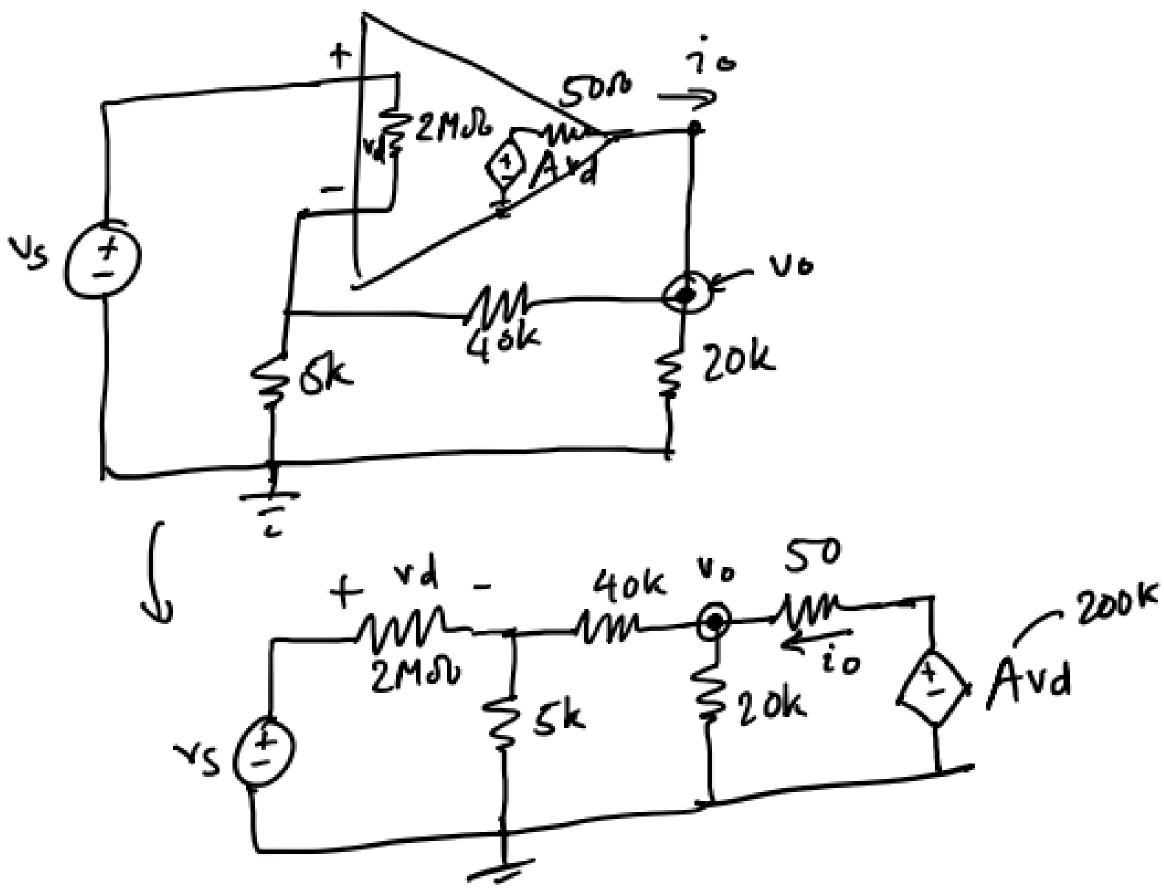
When $v_s = 2V$ **then** $v_o \simeq -4V\ and\ v_1 \simeq 20\ \mu V$

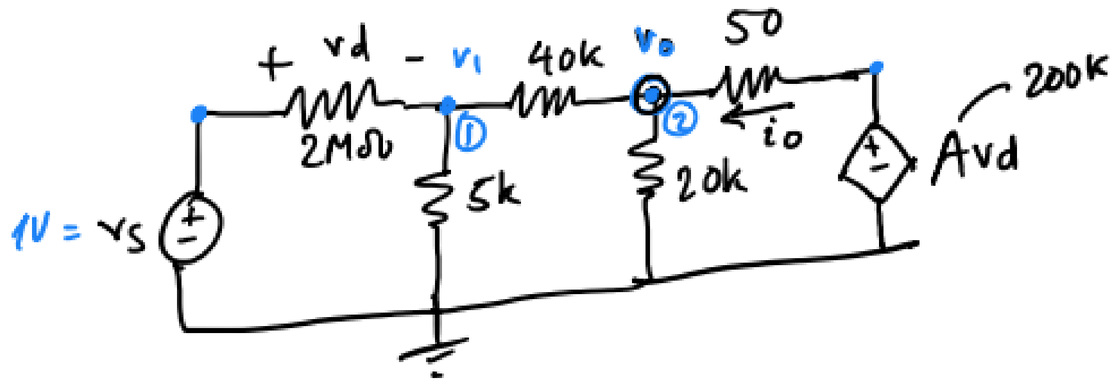
$$i = \frac{v_1 - v_o}{20 \times 10^3} \simeq 0.2\ mA$$

2. If the same 741 op amp in problem1 is used in the following circuit, calculate the closed-loop gain Vo/Vs. Find io when Vs = 1 V.



Solution:





Apply KCL at node 1:

$$\frac{v_o - v_1}{40 \times 10^3} = \frac{v_1}{5 \times 10^3} + \frac{v_1 - v_s}{2 \times 10^6} \quad \rightarrow Equation\ 1$$

Apply KCL at node 2:

$$\frac{Av_d - v_o}{50} = \frac{v_0}{20 \times 10^3} + \frac{v_o - v_1}{40 \times 10^3} \quad \rightarrow Equation\ 2$$

Since:

$$v_d = v_s - v_1 \quad \rightarrow Equation\ 3 \quad and \quad A = 200000$$

By substituting from equation 1 and 3 **into equation** 2:

$$\frac{v_o}{v_s} = 9.00041$$

To find output current

$$i_o = \frac{Av_d - v_o}{50} = 657\ \mu A$$

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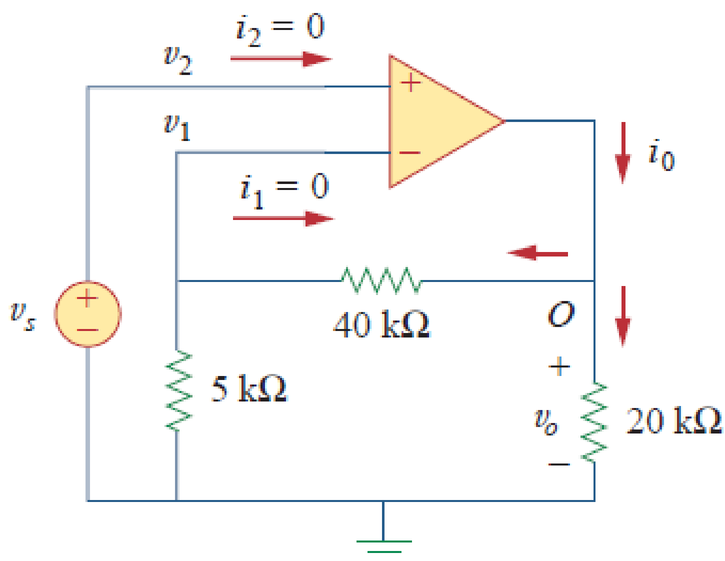
3. Assume an Ideal Op-Amp for problem 2, calculate the closed-loop gain Vo/Vs. Find io when Vs = 1 V. (Compare the results of Problems 2 and 3).

Solution:



$$Since \quad v_2 = v_s \quad then. \quad v_1 = v_2 = v_s$$

Apply KCL at inverting input

$$0 = \frac{v_s}{5} + \frac{v_s - v_o}{40}$$

$$9v_s = v_o$$

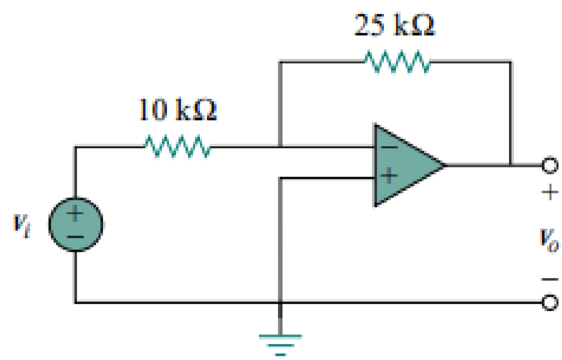
$$\frac{v_o}{v_s} = 9$$

Apply KCL at output

$$i_o = \frac{v_o - v_s}{40 \times 10^3} + \frac{v_o}{20 \times 10^3}$$

When $v_s = 1V$ **then** $v_o = 9V \ and \ i_o = 0.65 \ mA$

4. For the following circuit, assuming Ideal Op-Amp. If Vi = 0.5 V, calculate: (a) the output voltage Vo, and (b) the current in the 10 KΩ resistor.



Solution - a:

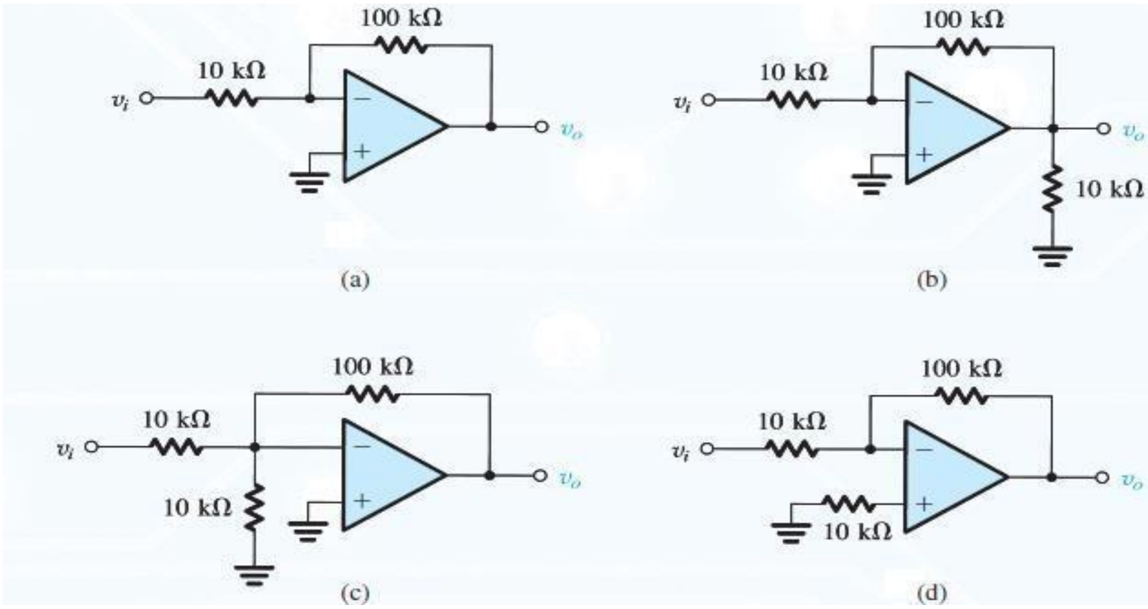
$$\frac{v_o}{v_i} = -\frac{R_f}{R_1} = -\frac{25}{10} = -2.5$$

$$v_o = -2.5v_i = -1.25\ V$$

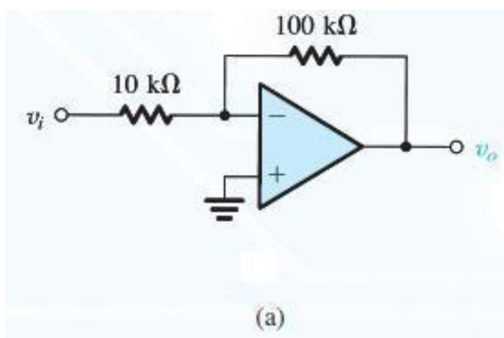
Solution - b:

$$i = \frac{v_i - 0}{R_1} = \frac{0.5 - 0}{10 \times 10^3} = 50\ \mu A$$

5. For the circuit shown, assuming Ideal Op-Amps, Find the voltage gain Av and the input resistance Rin of the following circuits.



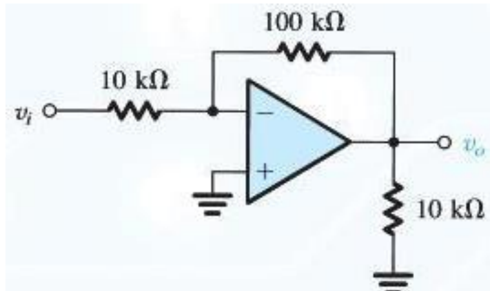
Solution - a:



$$A = -\frac{R_f}{R} = -\frac{100}{10} = -10\ V/V$$

$$R_{in} = 10\ K\Omega$$

Solution - b:



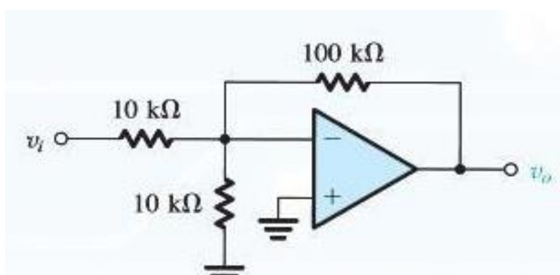
(b)

Load Resistance don't affect Op Amp Gain, then:

$$A = -\frac{R_f}{R} = -\frac{100}{10} = -10\,V/V$$

$$R_{in} = 10\ K\Omega$$

Solution - c:



(c)

The voltage across the new 10 kΩ Resistor will be:

$$V_{10K} = V_2 - 0$$

Since:

$$V_2 = V1 = 0$$

Then:

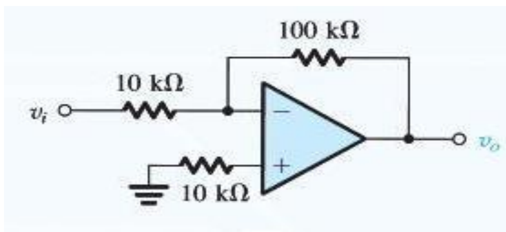
$$V_{10K} = 0$$

Since voltage drop across the new 10 kΩ Resistor is zero volt, then no current will flow in it and it won't affect Op Amp Gain, then:

$$A = -\frac{R_f}{R} = -\frac{100}{10} = -10\ V/V$$

$$R_{in} = 10\ K\Omega$$

Solution - d:



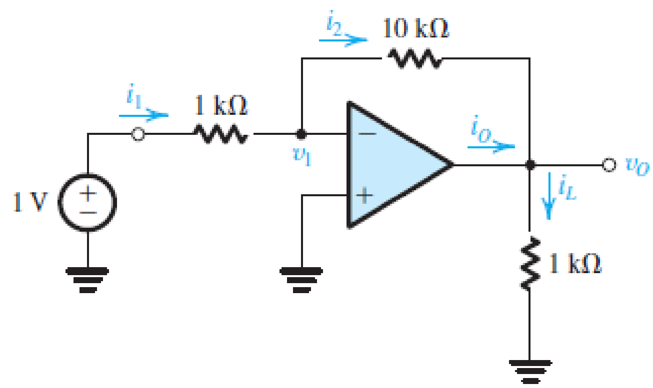
(d)

Since no current flow through Op Amp, then no current will flow in the new 10 kΩ Resistor and it won't affect Op Amp Gain, then:

$$A = -\frac{R_f}{R} = -\frac{100}{10} = -10\ V/V$$

$$R_{in} = 10\ K\Omega$$

6. For the circuit shown, determine the values of V_1, i_1, i_2, V_o, i_L, and i_o. Also determine the voltage gain V_O/V_I, current gain i_L/i_I.



Solution:

$$V_1 = V_2 = 0\ V$$

$$i_1 = \frac{1 - V_1}{1\ K} = 1\ mA$$

$$V_o = -\frac{R_f}{R_{in}} V_{in} = -10\ V$$

$$i_2 = \frac{V_1 - V_o}{10\ K} = \frac{0 - (-10)}{10\ K} = 1\ mA$$

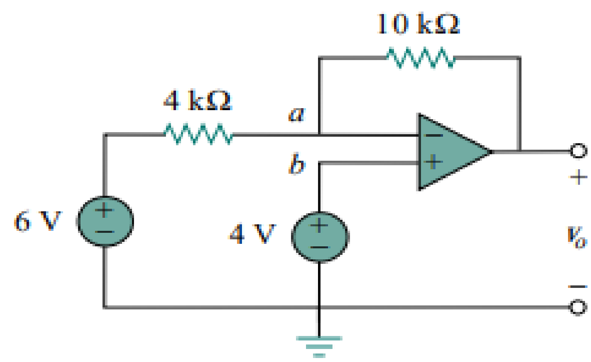
$$i_L = \frac{V_o}{1\ K} = \frac{-10}{1\ K} = -10\ mA$$

$$i_o = i_L - i_2 = -11\ mA$$

$$\frac{V_o}{V_i} = -\frac{R_f}{R_{in}} = -10$$

$$\frac{i_L}{i_i} = -10$$

7. For the op amp in the following circuit, calculate the output voltage V_o using superposition and using nodal analysis.

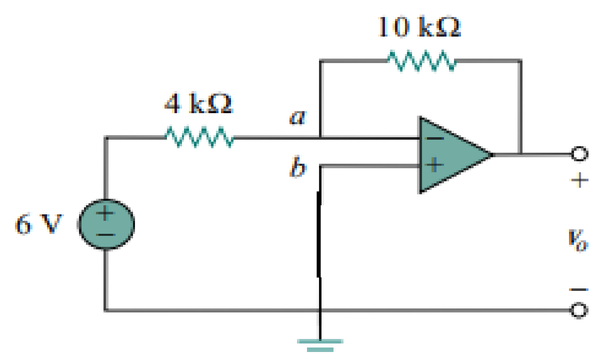


Solution:

For V_{i1}:

$$V_{o1} = -\frac{R_f}{R_{in}} V_{i1}$$

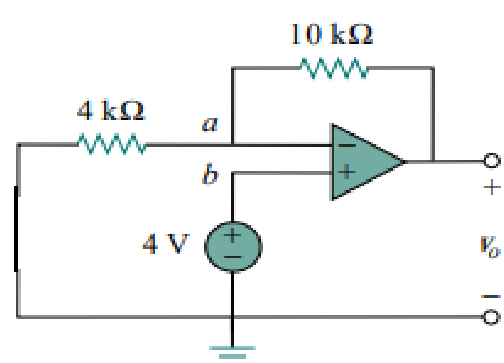
$$V_{o1} = -\frac{10}{4} \times 6 = -15\ V$$



For V_{i2}:

$$V_{o2} = \left(1 + \frac{R_f}{R_{in}}\right) V_{i2}$$

$$V_{o2} = \left(1 + \frac{10}{4}\right) \times 4 = 14\ V$$

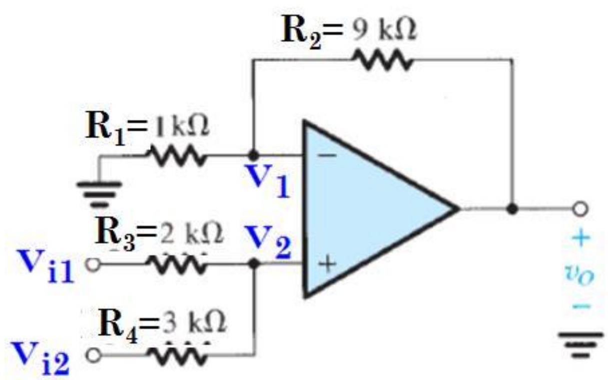


Then the total Vo is:

$$V_o = V_{o1} + V_{o2}$$

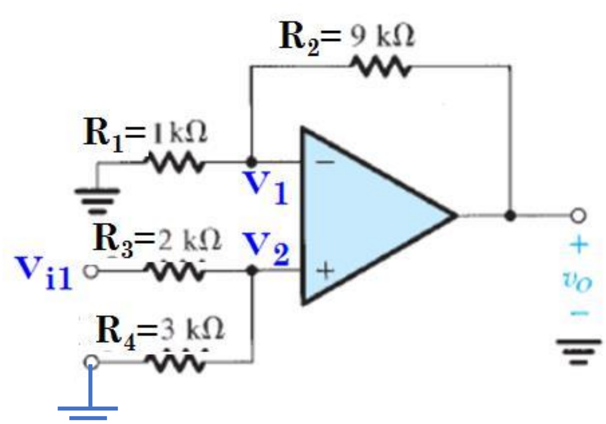
$$V_o = -15 + 14 = -1\ V$$

8. Use the superposition principle to find the output voltage of the circuit shown.
   If 1kΩ resistor is disconnected from ground and connected to a third signal source V_3, determine V_o in terms of V_1, V_2, and V_3.



Solution:

For V_{i1}:



$$V_{o1} = \left(1 + \frac{R_2}{R_1}\right) V_2$$

$$V_{o1} = \left(1 + \frac{9}{1}\right) V_2$$

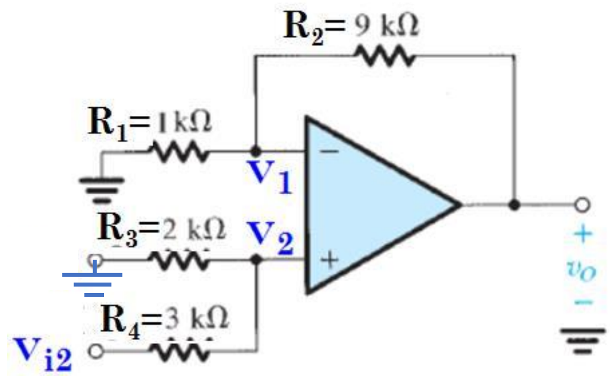
Using voltage divider to calculate V_2:

$$V_2 = V_{i1} \frac{R_4}{R_3 + R_4} = V_{i1} \frac{3}{2+3} = V_{i1} \frac{3}{5}$$

Then:

$$V_{o1} = \left(1 + \frac{9}{1}\right) V_{i1}\frac{3}{5} = 6V_{i1}$$

For V_{i2}:



$$V_{o2} = \left(1 + \frac{R_2}{R_1}\right) V_2$$

$$V_{o2} = \left(1 + \frac{9}{1}\right) V_2$$

Using voltage divider to calculate V_2:

$$V_2 = V_{i2}\frac{R_3}{R_3 + R_4} = V_{i2}\frac{2}{2+3} = V_{i2}\frac{2}{5}$$

Then:

$$V_{o1} = \left(1 + \frac{9}{1}\right) V_{i2}\frac{2}{5} = 4V_{i2}$$

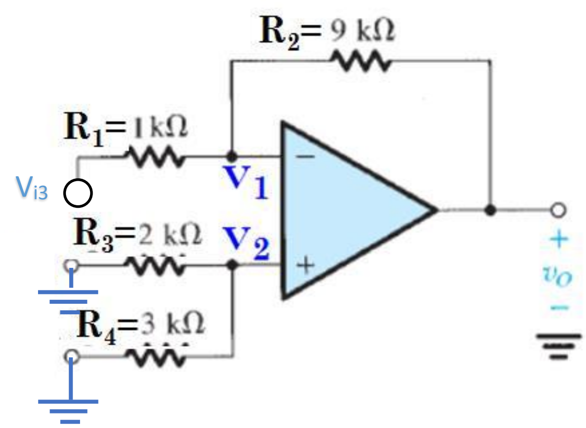
Then the total Vo is:

$$V_o = V_{o2} + V_{o2}$$

$$V_o = 6V_{i2} + 4V_{i2}$$

If 1kΩ resistor is disconnected from ground and connected to a third signal source V3

For V_{i3}:



$$V_{o3} = -\frac{R_2}{R_1} V_{i3}$$

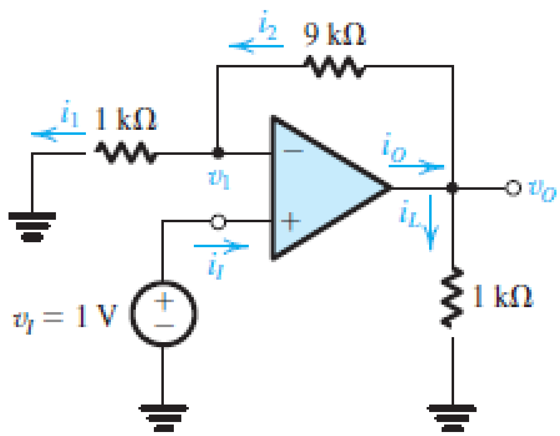
$$V_{o3} = -\frac{9}{1} V_{i3} = -9V_{i3}$$

Then the total Vo is:

$$V_o = V_{o2} + V_{o2} + V_{o3}$$

$$V_o = 6V_{i2} + 4V_{i2} - 9V_{i3}$$

9. For the circuit shown, find the values of V_1, i_1, i_2, V_o, i_L, and i_o. Also find the voltage gain V_O/V_I and the current gain i_L/i_i.



Solution:

$$V_1 = V_2 = 1\,V$$

$$i_1 = \frac{V_1 - 0}{1\,K} = 1\,mA$$

$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_{in} = 10\,V$$

$$i_2 = \frac{V_o - V_1}{9\,K} = \frac{10 - 1}{9\,K} = 1\,mA$$

$$i_L = \frac{V_o}{1\,K} = \frac{10}{1\,K} = 10\,mA$$

$$i_o = i_L + i_2 = 11\,mA$$

$$\frac{V_o}{V_i} = \left(1 + \frac{R_2}{R_1}\right) = 10$$

$$\frac{i_L}{i_i} = \frac{10}{0} = \infty$$